ACCEPTANCE OF INTERNET OF THINGS-APPLICATIONS IN OFFICE BUILDINGS

A Value Sensitive Design study on the acceptance of energy reducing innovations in governmental office buildings.

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Master thesis
Green light report
June 2016

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Abstract

In order to achieve savings on energy consumption within Dutch governmental office buildings, several technical innovations are tested and implemented in the building portfolio of the Central Government Real Estate Agency (Rijksvastgoedbedrijf). One of these innovations is the implementation of Internet of Things (IoT) applications that enhance reductions on energy consumption through the use of tailor-made adjustments for employees regarding climate, lighting and wayfinding.

Although these innovations have proven to be technical feasible, uncertainties remain with regard to their reduction potential and their acceptance by the end-users. A longitudinal research project currently conducted by the TU Delft and The Green Village focusses on this first uncertainty, while this thesis will cover the second uncertainty: the end-user acceptance of IoT applications in office buildings.

Recent history has shown us that user-acceptance is a critical factor for the adoption and large scale diffusion of innovations. For instance, similar to the failed introduction of the smart-energy meters in Dutch dwellings, privacy concerns could hamper the acceptance of these innovations and result in high sunk-costs. Therefore, this research will study the factors that affect the acceptance of IoT applications in office buildings and combines the theory of Responsible Innovation and an adjusted model of the Unified Theory of Acceptance and Use of Technology (UTAUT).

In this research several qualitative and quantitative measurements are conducted among the 494 users of the living lab and resulted in support for the claim for a significant relation between the acceptance of the IoT applications and the factors *Performance Expectancy* and *General Privacy*. After a review by a user-group of the living lab, several recommendations are made regarding the redesign of the current technology-system and implementation-policy in order to increase the acceptation of the IoT applications. The most important recommendations are:

1. All applications should have an opt-in / opt-out option. Users should be able to switch the applications off and work in ‘privacy modus’.
2. The data that is collected with the applications should not be stored for a long period and should only be used for the purpose of the applications.
3. A clear disclaimer and user policy should be included during the launch of the applications.
4. Future-users should be actively involved before, during and after the launch of the applications.

The scientific relevancy of this research can be found in the better understanding of the factors that enhance or hamper the acceptance of certain IoT applications in office buildings and in the fact that support is found for the integration of the research models of Responsible Innovation and Technology Acceptance.
Practically the findings of this research could support the Central Government Real Estate Agency or other organisations that want to invest in IoT applications in office buildings, to enhance the acceptance of these IoT applications and reduce the risk for sunk-costs.

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1 Introduction and problem statement

Residential and commercial buildings are found to be responsible for nearly 40% of the global energy consumption, 25% of the global water consumption and the emission of approximately 1/3 of all greenhouse gasses. Yet, these same buildings offer the greatest potential for achieving significant reductions on energy consumption and greenhouse gas emission, at least cost, in developed and developing countries. Estimations are that energy consumption in buildings can be reduced by 30 to 80% using proven and commercially available technologies. (United Nations Environment Programme, 2016)

In order to meet these reductions on energy consumption, the European Commission has launched the Energy Performance on Building Directive (EPBD) with the main target to reduce CO_2 emissions with 90% compared to the level of 1990. Based on this directive, the Dutch government has set out a plan to implement energy reducing regulation for the coming years: In the nearby future, the Energy Performance Coefficient (EPC) will be lowered for commercial and residential buildings. For instance, in 2020 all newly build buildings have to comply with the regulation of Nearly Zero Energy Building (EPC ≈ 0).

These same energy reducing regulations do not only apply on residential or commercial buildings but also on the building stock of the government itself. Because the government wants to play a leading role in this real estate energy-transition, it committed itself to even more ambitious goals:

- All new real estate, build after 1st of January 2019 has to be a Nearly Zero Energy Building (NZEB);
- A reduction of 25% of the portfolio energy consumption by 2020 (related to the consumption in 2007)
- 14% of the energy production has to come from renewable sources in 2020. In 2050 this has to be 100%;
- After 2020 all the buildings in the portfolio (rented or owned) have to have at least energy label C.
- A reduction of the total amount of office buildings from 130 now to 59 in 2020, reducing the available office space per employee.

The organisation that is responsible for achieving these ambitious goals is called the Central Government Real Estate Agency (Rijksvastgoedbedrijf, RVB). This organisation is a merger of the former Dutch Rijksgebouwendienst, Rijksvastgoed- en ontwikkelingsbedrijf and the Dienst Vastgoed Defensie and manages approximately 13 million square meters of office space and 81.000 hectares of land. The RVB is the largest real estate agent in the Netherlands and employs over 1700 people (Rijksvastgoedbedrijf, 2015).

To meet the ambitious energy reduction goals, the RVB started a programme in 2008 called Programma Groene Technologieën (PGT) in which new energy reducing innovations are assessed, tested and implemented in the current portfolio of the RVB.

One of these innovations is the introduction of the Internet of Things (IoT) applications in office-buildings. This IoT technology enables the building-users to make personalized adjustments regarding climate, lighting and optimizes the building-efficiency with wayfinding applications that support workplace- and colleague finding. These applications contribute to personal comfort and reduce the overall energy-consumption of the building.

The expectations of this IoT techniques are high. Jeremy Rifkin, an important advisor of the European Union on economic trends, refers to the use of IoT as the Third Industrial Revolution (Rifkin, 2015). He states: *By the digitalization of communication, energy, and transport you can manage power and move economic activity across every value chain and create your aggregate energy efficiency. The bottom*

line is that we are embedding sensors in every device, in factories, retail stores, warehouses, distribution centres, smart roads, smart homes, smart vehicles. You can then monitor every device, and importantly, send that data back to the three operating components of the Internet of Things. By 2030 it's going to be ubiquitous—100 trillion sensors we don't really know. This will allow us to bypass all the inefficiencies of traditional vertically integrated organizations of the First and Second Industrial Revolutions and engage directly at near zero marginal cost with an Internet of Things (Hellemans, 2015).
Also the chairman of the Dutch Green Building Counsel supports Rifkin's claim and stresses that the use of IoT is inevitable in order to make (Dutch) buildings more sustainable and less energy consuming (Vliet, 2016).

In the recent plans of the RVB a lot of attention is given to the technical feasibility of the IoT applications. For instance, the RVB launched a large research project in close coordination with The Green Village of the TU Delft in order to test the technology behind these applications. This research is conducted in a living lab, an office building in Rijswijk (NL), where they measure the payoff of the applications in terms of energy reduction over time.

However, not only the technical feasibility was regarded to be important by the RVB. Also the socio-technical interaction between technology and users was found to be crucial for user-acceptance and large scale adoption and diffusion of these IoT applications. Lack of support by the users can result in rejection of the innovation and can lead to high sunk-costs.
An example of this lack of user support is for instance the roll-out of smart electricity meters by energy-companies in all Dutch dwellings. This cost-reducing technique was introduced to enable energy-firms to remotely collect data about the electricity and gas-use of customers. However, the disregarding of privacy issues was the trigger for social- and consumer-organisations to take action against the large scale application of this technique, framing it as a governmental spying device (Wisman & Lodder, 2013); (Alabdulkarim, Fens, & Lukszo, 2012)

In order to investigate this socio-technical interaction this research will deal with questions like: Which values are dominant for the future users in the acceptance of the IoT techniques? Which stakeholders have influence on the system and the implementation-process? What technical or policy adjustments can be made to create alignment between the dominant values of the future users and the IoT applications?

Literature review, interviews- and survey techniques are used in order to pinpoint the factors that affect the acceptance of the IoT applications in the living lab. Eventually these findings will result in a better insight in the factors that affect the acceptance of IoT applications in office buildings and to recommendations towards the developers of the IoT applications to improve their innovations and to make them more aligned with the preferences of the (future) users.

1.1 Research objective

The objective of this research is to further develop the understanding of the relevant factors that affect the acceptance of IoT applications in an office environment. If these factors are better understood, then possible recommendations can be prescribed for the redesign of the applications or perhaps policy-adjustments that could support and stimulate user acceptance and large scale diffusion of this IoT applications within office buildings.

1.2 Research questions

In order to achieve the research objective, the following main research question is formulated:

Which factors are important for the acceptance of IoT applications within office buildings?

The following sub questions will lead to the answering of the main research question:

1. *Based on current theories, what factors could be relevant regarding the acceptance of IoT applications in office buildings?*
   This analysis of current theories makes this thesis more rigor and enables the exploration of the current knowledge-level of the related concepts.
2. *Which stakeholders influence the acceptance of IoT applications in office buildings?*
   It is important to know which groups influence the acceptance of IoT applications, because then the focus of this research can be set on these groups. Therefore, this research specifically zooms in into the situation of the living lab.
3. *What factors are perceived relevant by the (future) users regarding the acceptance of IoT applications in office buildings?*
   Field research has to point out what the perceived relevant factors are within a user group in the living lab. These findings could potentially complement the findings of sub question one and will enhance the purposiveness, precision and confidence of this research.
4. *To what extent is the acceptance of IoT-applications affected by the perceived relevant factors?*
   This sub-question will address the extension of effect of each relevant factor.
5. *What recommendations can be made to mitigate concerns regarding the acceptance of IoT-applications in office buildings*?
   This last sub question will have a normative character and could include potential policy implications for future projects that incorporate IoT techniques or recommendations of the redesign of the IoT-applications.

1.3 Research strategy

This thesis uses the approach of Value Sensitive Design(VSD) in order to answer the upper research questions (Friedman & Kahn, 2002). This means that this thesis is divided in three stages that are aligned with this VSD approach: the conceptual investigation stage, the empirical investigation stage and the technical investigation stage.

In the first stage a conceptual investigation on the most important topics of this study will answer the first and second sub-question of this research. This theoretical study covers the concepts of: IoT, Responsible Innovation and the theory of the Technology Acceptance. Also a stakeholder analysis is conducted in order to identify the most important groups that affect the acceptance of innovations. Also this stakeholder analysis gives direction to which groups this research should focus on.

In the second stage of this research an empirical investigation is conducted. This stage has a more explorative nature and will answer sub questions three and four. In this stage interviews with a user group are executed in order to preselect potential factors that affect the acceptance of the innovations among the users of the living lab. Also in this stage hypotheses are developed and tested with survey questionnaire among all the users of the living lab.

Finally, the gathered data is analysed in stage three and discussed during a second round of interviews with a user group of the living lab. During this last stage, the technical investigation takes place. This stage will result in the answer to sub-question five and lead to conclusions and recommendations regarding the innovations.

Figure 1 visualizes the research strategy and the stages of the VSD approach:

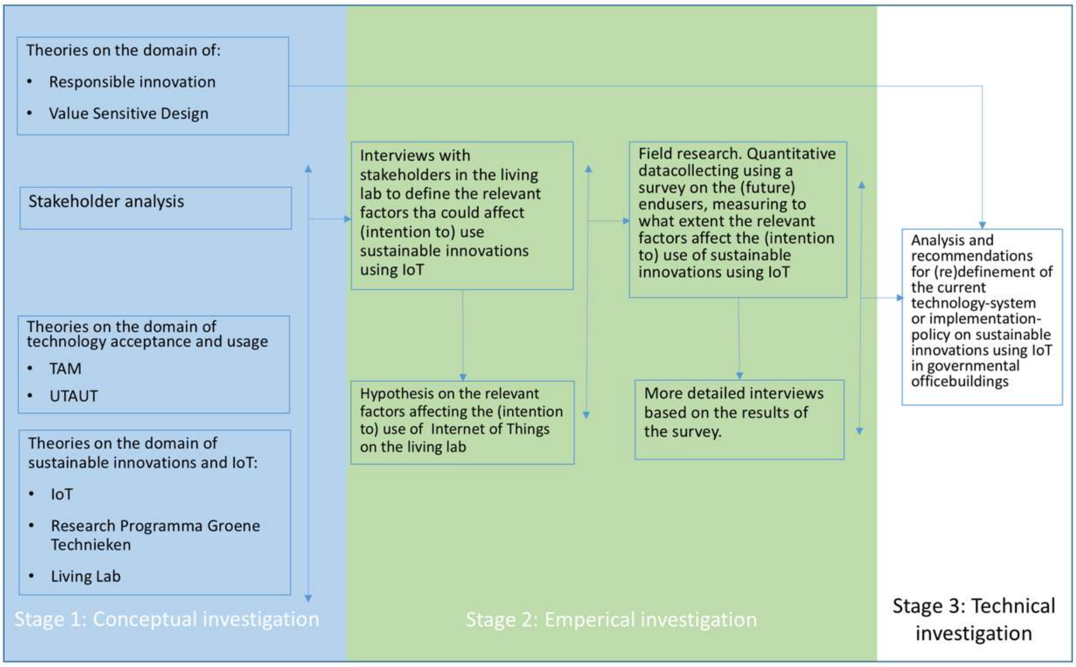


Figure 1: Research strategy of this thesis

1.4 Research object

This study is conducted on a living lab of the RVB. A living lab is a research concept which brings together interdisciplinary experts to develop, deploy, and test new technologies and strategies in actual living environments (MIT Living Labs, 2015). This living lab approach makes it possible to execute the research in a non-contrived setting with minimal interference of the research-group (Sekaran & Bougie, 2009).

This living lab is a building called *Noordzee* and is located at Lange Kleiweg 34 in Rijswijk (NL). The building is constructed in 2004 and contains eight floors with a total gross floor area of 7.318 m^2. The building was designed for the Division Noordzee of the Dutch Department of transportation (Rijkswaterstaat) by VMX Architecten. Special feature of the design of this object is the large amount of glass used in the façade (Rijksvastgoedbedrijf, 2015).

Figure 2: Picture of the living lab

The use of this building as a research object can be seen as a form of convenience sampling however the characteristics of the building are representative for the complete RVB building portfolio. Also the nature of the activities is very similar to the activities done in offices with other corporate services like lawyer firms, banks, insurance companies etc.

2 Internet of Things

One of the main concepts in this thesis is Internet of Things. This concept is closely identified with wireless communication but is also used regarding other sensor technologies like Radio Frequency Identification (RFID), QR-codes etc. The '*thing*' in IoT is not clearly formulated. It could be a person with a heart-rate monitor implant, a farm animal with a biochip transponder, an automobile that has built in sensors that alerts the driver when the tyre-pressure is too low, or any other natural or man-made device that can be assigned an IP-address in order to transfer data over a network (Shin, 2014).

The IoT concept is not new; It was first proposed in 1999 by Ashton (2009) however, no uniform definition is developed yet. Atzori et al describe the IoT-concept as: '*the pervasive presence around us of a variety of things or objects – such as RFID tags, sensors, actuators, mobile phones, etc. – which, through unique addressing schemes, are able to interact with each other and cooperate with their neighbours to reach common goals*' (2010, p. 2787).

The definition used by the European Union is more generic: *The IoT is composed of many interacting, federated devices that communicate over many different communication networks* (Bassi & Horn, 2008, pp. 6-7).

The most recent definition is stated the United Nations ITU telecom standardisation organisation which describes IoT as *'the network of physical objects or 'things' embedded with electronics, software, sensors, and network connectivity, which enables these objects to collect and exchange data'.* (www.itu.int, 2015, p. 2)

Research done by Atzori et al (2010) divides the concept of IoT in three view angles: a 'things'-orientated vision, an 'internet'-orientated vision and a 'sematic' orientated vision. In figure 3 these three view angles are visualized. The centre of this figure is what Atzori et al. defines as IoT.

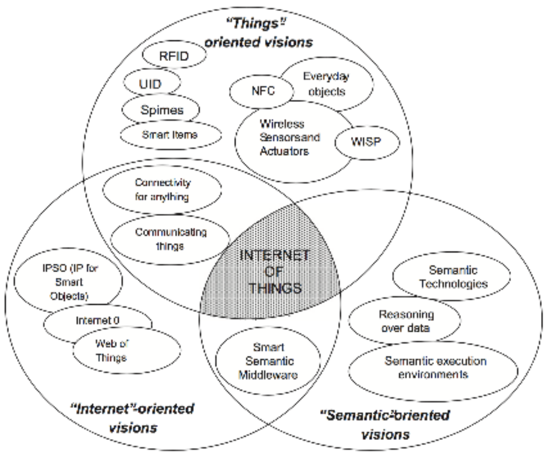


Figure 3: Concept of IoT according Atzori et al.(2010)

2.1 Internet of things in this thesis

Even after the upper elaboration on the concept, IoT remains a fuzzy concept and tends to become an all-purpose word, embracing even the slightest connotation of the concept in it. Therefore, in this paper the IoT-concept will be limitedly used and will only regard to the IoT applications that are part of the Smart Building™ concept. Within the Programma Groene Technologieën several applications of the SmartBuilding™ concept regarding climate, lighting and wayfinding are applied. In the next section the Smart Building ™ Concept is explained in more detail.

2.1.1 Smart Building™ concept

The concept of Smart Building™ is developed by a Dutch engineering consultancy firm Deerns. This firm operates worldwide in the engineering consultancy market and employed in 2015 approximately 600 staff members in 24 national offices around the world and had a revenue of €70 million in 2014 (Deerns.com, 2016).
One of the focal markets of Deerns is engineering consultancy regarding the development of sustainable buildings and reduction of energy consumption in the building environment. It is therefore member of The Green Grid, National Green Building Council and the European Green Building Council and executed over 100 LEED or BREEAM certified building projects.

The rapid developments in wireless IoT techniques in combination with the rise of home automation (Markets, 2015) and the increasing demand for sustainable buildings let to the development of the Smart Building™ concept. This concept is an IT application that is responsive to its users and their environment and enables a more integrated connection between building, user and environment.

It consists of two hardware networks that connect the different building functionalities. These two hardware networks are called the bGrid and the bOs. The bGrid is the backbone of the system and is a fine meshed sensor network that can communicate with the user through portable devices like smartphones, tablets or beacons, and is able to measure temperature, light, humidity, CO_2, noise and movement of devices with an accuracy of 50 cm. The bGrid sensors use the low-power Bluetooth 4.0 communication protocol and can be integrated into the buildings infrastructure or placed after the construction phase in new or existing buildings as shown in figure 4.

Figure 4: Bluetooth 4.0 Low energy sensors on the ceiling

These Bluetooth sensors cover an area of 6 m^2 and can be wireless connected through a gateway to the bOs and the internet. This bOs is usually the existing IP network that is available in a building and forms the hub between the sensors in the building and the devices that are connected to the bOs like indoor climate-systems (HVAC), automatic solar blinds, printers, beamers etc.

The functionalities that allow the more integrated connection between building and user are clustered in seven categories:

- Wayfinding
- Personal climate and lighting
- Individual footprint monitoring
- Personal safety and security
- Building usage optimization
- Asset finder
- Smart sustainable grid

Table 1 describes the applications of these seven categories.

Table 1: Seven categories of the Smart Building Concept(tm)

Category in Smart Building™ concept	**Examples of application**
Wayfinding	Workplace finder Room and catering booking service Parking place finder Colleague finder Find my services like catering or facility services Find my devices like printers, beamers etc.
Personal climate and lighting	Individual adjustment of climate Individual adjustment of lighting.
Individual footprint monitoring	CO_2 footprint monitor per employee Paper or energy consumption monitor per employee Benchmarking
Personal safety and security	Access control on personal level also with use of fingerprint or iris scan on the device Evacuation support Locker access also with use of fingerprint or iris scan on the device.
Building usage optimization	Support of facility management like cleaning services Flexible usage of building spaces
Asset finder	Asset finder application that shows the location of important assets in buildings like drip pumps in hospitals.
Smart sustainable grid	Smart distribution of (renewable) energy in the building, like the possibility for electrical cars to be charged when solar power is available.

2.1.2 Smart building™ concept in the living lab

In the living lab of this study only applications for the category Wayfinding and Personal climate and lighting are applied. For the Wayfinding category these applications are the Workplace finder and Colleague finder developed by the Yesdelft! start-up Mapiq (Mapiq, 2016). These applications support a more efficient use of the building by enabling the user to find colleagues and free workplaces and by for instance closing unused floors in the building on less occupied days and by doing so reducing the need of heated, cooled and lighted office spaces.

For the personal climate category a commercial application called Comfy is used (www.gocomfy.com, 2016). This application enables the users to create a microclimate zone around a single workplace and therefore reduces the need for heating or cooling the complete office space. For instance when using a heated chair the comfort ambient temperature can be as low as 15°C (Wyon, Fang, Melikov, & Zhang, 2007) which eventually reduces the overall building energy consumption.

Finally for the personal lighting category the commercial Connected Lighting System of Philips is used (philips.nl, 2013). This last application enables the user to individually adjust the lighting-preferences at their workstation. Just like the climate application, only the occupied workstations have to be lighted completely. The ambient lighting in the office can therefore be reduced which results in a reduction of the overall building energy consumption.

Figure 5: Visuals of the Mapiq Colleague Finder, the Mapiq Workplace Finder, The Comfy climate-application and Philips Connected Lighting application

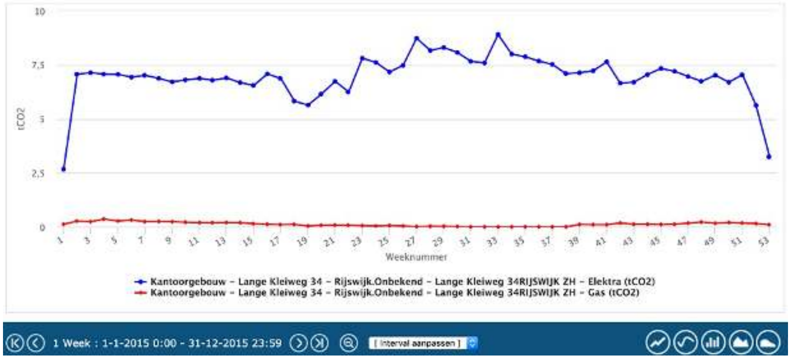
2.2 Potential system yields

On top of the research supported by The Green Village that, several other studies have investigated the potential yields in terms of energy savings of the use of IoT applications in buildings (Vesely & Zeiler, 2014); (Moreno, Ubeda, Skarmeta, & Zamora, 2014); (Brad & Murar, 2014). These studies, along with several commercial whitepapers were used to calculate an estimation of the total yield of all applications regarding the energy reduction in the building. Although great care is taken during these calculations, we have to bear in mind that the outcomes are just rough estimations. This is because all performance calculations of the IoT applications depend greatly on the building-specific details and the nature of the work that is executed in the buildings. Also several side-effects that potentially could influence the actual outcome like for instance the outdoor climate, are not taken in account during the calculations.

2.2.1 Current energy consumption in the living lab

Before the potential yields of the applications are calculated, it is useful to first measure the current energy consumption in the living lab. This consumption is measured with a software tool eSight (eSight, 2016) which enables to monitor the energy consumption of a building and access the data in an online database. In order to be able to compare the different yields of the applications the building energy consumption is measured in CO_2 equivalent. In figure 6 you can see the 2015 energy use of the building calculated in tCO_2 for electricity and tCO_2 for gas. The total amount of tCO_2 per year is 370 + 7 = 377 tCO_2.

These figures correspond with a current energy use of 89,2 kWh/m^2 and Gas 2,0 m^3/m^2. This consumption is close to the average consumption for the complete RVB portfolio. (85,6 kWh/m^2 Gas 2,2 m^3/m^2); (RVB, 2015).



Datum/tijd	Kantoorgebouw - Lange Kleiweg 34 - Rijswijk.Onbekend - Lange Kleiweg 34 RIJSWIJK ZH - Elektra (tCO2)	Kantoorgebouw - Lange Kleiweg 34 - Rijswijk.Onbekend - Lange Kleiweg 34 RIJSWIJK ZH - Gas (tCO2)
29-12-2014 0:00:00	2,6665	0,1232
5-1-2015 0:00:00	7,0654	0,2663
12-1-2015 0:00:00	7,1391	0,2442
19-1-2015 0:00:00	7,0696	0,3594
26-1-2015 0:00:00	7,0631	0,2726
2-2-2015 0:00:00	6,9332	0,3177
9-2-2015 0:00:00	7,0173	0,2430
16-2-2015 0:00:00	6,8747	0,2522
23-2-2015 0:00:00	6,7129	0,2393
2-3-2015 0:00:00	6,8061	0,2119
9-3-2015 0:00:00	6,8729	0,1967
16-3-2015 0:00:00	6,7877	0,1906
23-3-2015 0:00:00	6,8962	0,2009
30-3-2015 0:00:00	6,6794	0,1932
6-4-2015 0:00:00	6,5463	0,1466
	369,6458	**6,5117**

Figure 6: Output-sheet of the eSight tool, regarding the energy consumption in the living lab in 2015

2.2.2 Colleague Finder and Workplace Finder

No studies with accurate measurements related to energy reduction for the Colleague Finder and Workplace Finder applications are knows yet, however in one of the pilot buildings in which these applications are applied (the Edge in Amsterdam) the reduction in needed office space was over 25 % (OVG, 2016). This building was originally designed to house 6000 employees, but two years after completion it now houses work spots for 8000 employees. After an interview with the installation manager of this building, this increase of housing potential was mainly due to the Colleague Finder and Workplace finder applications. The use of these applications enhanced a more efficient use of the building and enabled the housing of more employees in the building with equal energy-consumption, meaning a reduction in energy consumption per employee. If this reduction of 25% is projected to the situation of the living lab, a reduction of energy consumption of 94 tCO_2/year is possible.

2.2.3 Personal climate application

In recent history several studies are conducted on energy use in buildings. In the Netherlands it is measured that on average the Heating, Ventilation and Air-Conditioning systems (HVAC) make up 20-40% of the energy usage in commercial buildings. (Pérez-Lombard, Ortiz, & Pout, 2008). In the United States this figure is more specified to 39% (Frost & Sullivan, 2015). For this calculation on the energy consumption of the HVAC, the assumption of 30% is used.
Based on the product information of the Comfy application(www.gocomfy.com, 2016) a reduction of 15% on the total HVAC energy consumption is possible. This figure is supported by Dutch scientific research on User Centred Energy Reduction Systems (Zeelen, 2015).
Combining both figures gives a potential reduction of 30% * 15% = 4,5% of the total energy consumption of 376,16 tCO_2 in the living lab. This results in a potential reduction of 17 tCO_2.

2.2.4 Personal lighting application

The last application that could contribute to an energy reduction is the Connected Lighting application of Philips. On average lighting is responsible for 31% of the total energy consumption of office buildings in the US (Frost & Sullivan, 2015) and it is assumed that this figure corresponds with the Dutch situation. In the product specifications of Philips it is stated that 'application of the Connected Lighting System could give a reduction of 80% towards traditional TL lighting systems' (Philips, 2016, p. 1) (lighting, 2016). If these two figures are combined the total energy reduction potential of this system is 31% * 80% = 24,8% of the total energy consumption of 377 tCO_2 in the living lab. This results in a potential reduction of 93 tCO_2.

2.2.5 Overview of potential yields

In table 2 an overview is given from all calculations of this chapter:

Table 2: Overview of potential yield per application

Smart Building™ Category	**Application**	**Potential energy reduction (%)**	**Potential energy reduction in living lab (tCO_2)**
Wayfinding	Mapiq Colleague Finder and Workplace Finder	25%	94
Personal climate and lighting	Philips Lighting application	24,8%	93
	Comfy Climate application	4,5 %	17
Total potential yield		**54,3%**	**204**

2.2.6 Potential risks involving the use of the applications

Even though the use of the Smart Building™ Concept offers some promising perspectives, there also could be disadvantages or risks to the use of these techniques. The first potential disadvantage refers to the perceived energy reducing potential of this technique and is called the rebound- or Jevons effect. This effect is best described as an increase of consumption of a resource, as a result of the increased efficiency with which a resource is used (Bauer & Papp, 2009). So instead of a reduction of energy consumption, the energy use could increase. An example of this rebound effect is the increase of the burning time of energy efficient LED bulbs in relation to the traditional lighting systems (Schleich, Mills, & Dütschke, 2014) or the increase of the use of more energy efficient heating systems in buildings with equal ambient temperature related to buildings with less efficient heating systems (Galvin, 2015).

A second potential pitfall is the security of the applications. Because the applications make use of an internet-based infrastructure, there is always the potential risk of security breaches like hacks or theft of data. Especially IoT applications with an 'always on' network connectivity are enabling new types of attacks that have not been seen in the past; these applications represent a new set of targets for potential data exposure and crime (Isaca, 2015). For example, IoT-connected medical devices are assumed to be the next targets for hackers (GRC, 2016) as well as internet connected refrigerators (Tapellini, 2015). These kind of crimes require more focus on data confidentiality, authentication, and access control (Sicari, Rizzardi, Grieco, & Coen-Porisini, 2014).

A third risk related to the use of IoT applications is the misuse of data. This regards to the person or entity who collects and processes your personal data. This data controller is only allowed to use the data for a legitimate reasons and must also respect certain obligations like privacy laws. If these obligations have not been respected, the data is misused and this could be harmful for the IoT user (European Commission, 2016).

An example of this misuse is the collection of location based data by smartphone applications. Not many users realise that some app providers and developers sell their users' location data to marketing companies, allowing profiles to be built for targeted advertising and other purposes not necessarily apparent from use of the original app (Clark, 2011).

3 Literature review

This chapter is part of the conceptual stage of the VSD- approach and covers the findings in literature regarding the most important topics of this research. It also provides an answer to the first sub question of this thesis: *Based on current theories, what factors could be relevant regarding the Acceptance of IoT applications in office buildings?*
At first an elaboration of the topics of Responsible Innovation and Technology Acceptance is presented. Then the theories of Responsible Innovation and Technology Acceptance are more closely examined on overlap between both theories. This overlap is important for the use of these theories in the second empirical investigation stage and the third technical investigation stage.

3.1 Responsible Innovation

The concept of endorsing relevant public values in the innovation process is called Responsible Innovation (Teabi, Correljé, Cuppen, Dignum, & Pesch, 2014). Many definitions are given to this concept, of which three are described below.

"*Responsible Research and Innovation is a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view on the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products"* (Schomberg, 2011, p. 11)

"RI is an activity or process which may give rise to previously unknown design pertaining either to the physical world the conceptual world, the institutional world or combinations of these which – when implemented- expand the set of relevant feasible options regarding solving a set of moral problems'. (Hoven, Responsible Innovation: Managing the Responsible Emergence of Science and Innovation in Society, 2013, p. 80)

"RI means taking care of the future through collective stewardship of science and innovation in the present" (Stilgoe, Owen, & Macnaghten, 2013, p. 1570).

In order to create clarity around the concept of RI the latter researchers developed a framework of RI in which the concept is put in a framework that consists of four dimensions: Anticipation, Inclusion, Reflexivity and Responsiveness. Although this framework should not be considered as a *'…off- the-shelf quick fix for responsible governance'* it can ' *... allow scientists and decision makers to build on past lessons rather than reinventing responsibilities for each particular emerging technology*' (Stilgoe, Owen, & Macnaghten, 2013, p. 1577).

The four dimensions of RI are:

- Anticipation: This describes and analyses the intended and potential unintended impacts of an innovation that might rise.
- Inclusion: This dimension opens up visions purposes, questions and dilemmas to broad collective deliberation through processes of dialogue, engagement and debate inviting and listening to a wider perspective from publics and diverse stakeholders.
- Reflexivity is the dimension that regards reflecting on the underlying purposes motivations and potential impacts, what is known and what is not known.
- Responsiveness regards the use of the collective process of reflexivity to both set the direction and influence the subsequent trajectory and pace of innovation through effective mechanisms of participatory and anticipatory governance.

The concept of RI can be seen as a key-concept of this study because it supports Elkington's People, Planet and Profit approach as adopted in the mission statement of the Rijksvastgoedbedrijf (Elkington, 1997); (Rijksvastgoedbedrijf, 2015). This 3P approach is all about finding the balance between social impact of organisational actions, taking responsibility for the environment and the pursue of an economic sound policy. This means that for instance in certain situations social values could be in conflict with economical values and have to be balanced off against each other.

This line of reasoning can also be applied to the innovations that are planned to be applied in the living lab. Here the main motive to install these innovations is to create environmental gains, but on the other side there are potential conflicts with social values like privacy or economical values like a low return-on-investment ratio.

In order to deal with these potential value-conflicts the concept of Responsible Innovation can give guidance. For many years technology and innovations were considered to be value neutral, however research has shown that technologies can be strongly value laden by incorporating certain dominant values in artefacts or by failing to represent other values (Winner, 1980) (Ligtvoet, et al., 2015). An example of this a value laden innovation is the design of a web browser that collects cookies of its users, without the properly informed consent notifications. And while doing so violating its user's privacy.

Incorporating values in the design and application of new technology is necessary but not easily executed. This is partly due to the Collongridge control dilemma: When a technology is young enough to influence its future trajectory, you can't know where it will lead but when a technology is mature enough for you to have a good idea of its consequences, it's too late to change it (Collongridge, 1980).

3.1.1 Methods to integrate societal values in technological design

As the upper section described the 'what' of RI, this section will cover the 'how' of this concept. In recent history several attempts are made to come up with a method to include the relevant public values in the design and application of technological innovations. The most important methods are Real-Time Technology Assessment, Anticipatory Governance, Socio-technical Integration, Upstream Public Engagement, Constructive Technology Assessment (CTA) and Values-Sensitive Design (VSD). (Stilgoe, Owen, & Macnaghten, 2013) Because the most recent scientific publications are found on VSD, this method is chosen to elaborate further on.

The inclusion of values, norms and design requirements for new product development was first described in 2002 by Friedman and Kahn in their research on Value Sensitive Design (VSD);(Friedman & Kahn, 2002). In this paper they describe Value Sensitive Design as '*a theoretically grounded approach to the design of technology that accounts for human values in a principled and comprehensive manner throughout the design process'* (p. 1)

VSD is a methodology that deals with questions like:
'*How do stakeholders apprehend individual values in the interactive context*?' '*How do they prioritize competing values in design trade-offs*?' or '*How do they prioritize individual values and usability considerations*? (Friedman, Kahn, & Borning, 2008, p. 73).

The VSD approach can be seen as a method that proactively influences the design of a new technology in an early stage of its design process. It is a comprehensive approach that consists of conceptual, empirical, and technical investigations (Poel & Rooyakkers, 2011);(Friedman, Kahn, & Borning, 2008):

- Conceptual investigations focus on the clarification of the values at stake, and on the trade-offs between the various values.
- Empirical investigations regard to the social scientific research on the context, understanding and experiences of the future users of the technical artefact.
- Technical investigations zoom in the artefact and describe the technical mechanisms of an artefact and the identification and development of technical mechanisms and designs that could support certain values.

As described in the research strategy the three steps of the VSD approach are used to structure this thesis, as projected in figure 7:

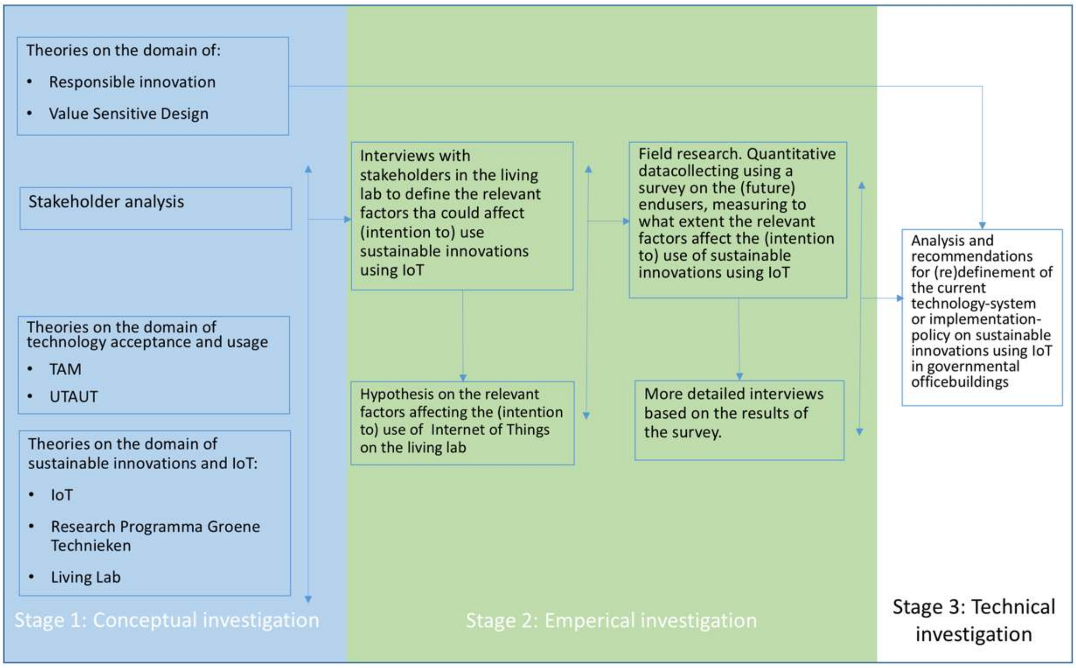


Figure 7: Projection of the VSD steps on the research strategy

3.2 Technology Acceptance

The second key concept in this research is Technology Acceptance (TA). This concept deals with acceptance, adoption and diffusion of technical innovations and has been subject for a large amount of studies during the last three decades. This section will elaborate on the scientific progress that is made during these last 30 years and will describe the latest theoretical insights on the concept of TA.

But before the models and theories are described, there first has to be understanding about the terms technology and acceptance. In human society today, technology is a result of science and engineering. A specific definition for the word technology is difficult to determine, because technology can refer to material objects of use to humanity, such as specific machines, hardware or utensils, but it can also refer to systems, methods of organization, and techniques. Oye et al. describe technology as an enabler to disseminate knowledge. *'Technology can be seen as a broad concept that refers to use and knowledge of tools and crafts, and how these tools and crafts affect our ability to control and adapt to the environment'* (2012, p. 252-254).

The second term in TA is acceptance. This construct is often seen in combination with the terms adoption and diffusion. In fact, in most scientific research the terms acceptance and adoption are used in the same meaning. In this paper the term *Acceptance* is used to describe the *Behavioural intention to use an innovation*. This line of reasoning is also supported by the definition of *behaviour intention to use*: *The feelings of the employee towards the Acceptance of the system* (Venkatesh, Davis, Morris, & Davis, 2003, p. 161).
The term *adoption* is used in a more active connotation and refers to the actual *use of a system*. Finally, the term diffusion is used when adoption spreads throughout a large population. (Rogers, 1976); (Hall & Kahn, 2002, p. 2).

3.2.1 Technology acceptance model

Over the years many models of technology acceptance have been developed. The most important are: Theory of Reasoned Action (TRA), Technology Acceptance Model (TAM), Motivational Model (MM), Theory of Planned Behaviour (TPB), Combined Theory of Planned Behaviour/Technology Acceptance Model (C- TPB-TAM), Model of PC Utilization (MPCU), Innovation Diffusion Theory (IDT), and the Social Cognitive Theory (SCT); (Oye, Iahad, & Rahim, 2012). The key dependent variable in all of these models is *Behavioural intention to use* (here: *Acceptance*) and actual *Usage* (here: *adoption*) The Theory of Reasoned Action (TRA) is regarded as '*one of the most fundamental and influential theories of human behaviour*' (Venkatesch, Morris, Davis, & Davis, 2003, p. 428) and can be seen as the basis of all other described predictive models.

The Technology Acceptance Model (TAM) is an extension of the TRA (Ajzen & Fishbein, 1980) and is developed by Davis et al. (1989) as a model to predict the (intentional) use of information systems. It covers the following attributes:

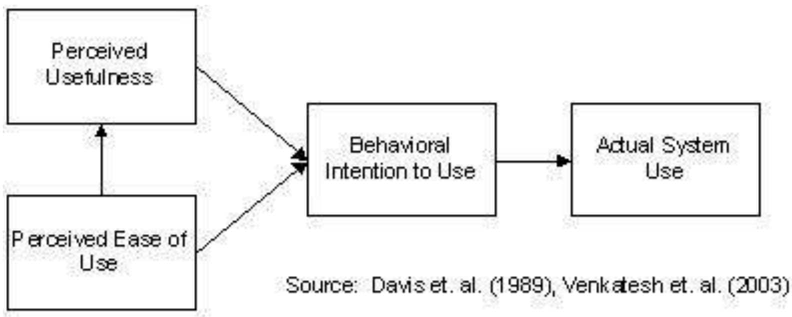


Figure 8: Basic Technology Acceptance Model

TAM uses two factors that influence the depended variable of *Behavioural Intention to use*. The first is *perceived usefulness* and the second is *perceived ease of use*. Davis et al. defines *perceived usefulness* as '*the degree to which a person believes that using a particular system would enhance his or her job performance.*' *Perceived ease of use* is defined as '*the degree to which a person believes that using a particular system would be free of effort'* (1989, p. 985).
Although the TAM was originally developed to predict behaviour regarding the acceptance of information systems, it has been proven to be applicable in a wide variety of other technical domains (Taylor & Todd, 1995), like health care (Hu, Chau, Liu Seng, & Yan Tam, 1999), decision making support systems (Lee, li, Yen, & Huang, 2010) or innovations in the automobile industry (Meschtscherjakov, Willfinger, Scherndl, & Tscheligi, 2009).

The TAM model, and its derivations, gradually became the accepted models for research regarding information systems acceptance. The advantage of TAM is that it is specifically designed to address the acceptance of technology. In more recent publications about technology acceptance, the TAM is often extended with additional predictive factors like subjective norm, voluntariness, job relevance, output quality, result demonstrability, demographics, managerial knowledge, social factors, environmental characteristics, and task-related characteristics (Mathieson, 1991) (Pijpers, Van Montfoort, & Heemstra, 2002).
A recognized limitation of TAM is, that it is only capable of successfully predicting technology acceptance for 30% to 40% of the cases (Compeau & Meister, 2002);(Venkatesh & Davis, 2000). As a result of this, researchers have searched for better technology acceptance models that can deliver a higher successful prediction. This led to the development of an extended TAM (TAM2) and eventually the *Unified Theory of Acceptance and Use of Technology* (UTAUT) model. The following section will elaborate more on this UTAUT model.

3.2.2 Unified Theory of Acceptance and Use of Technology model

In 2003, Venkatesh, Morris, Davis and Davis developed the Unified Theory of Acceptance and Use of Technology (UTAUT). This theory is based on a compilation of the eight prominent technology acceptance theories and several models that originate from different research areas such as information systems, sociology, and psychology. In 2005 this UTAUT theory resulted in the publication of a widely used model and validated measurement tool (Sundaravej, 2005).

The four determinants of acceptance that are part of UTAUT are *Performance expectancy, Effort expectancy, Social influence and Facilitating conditions*. The major advantage of the use of the UTAUT model is its predictive efficiency: There where TAM was only capable of predicting technology acceptance success of 30% to 40%, UTAUT has a predictive efficiency up to 70%. (Oye, Iahad, & Rahim, 2012); (Venkatesch, Morris, Davis, & Davis, 2003).

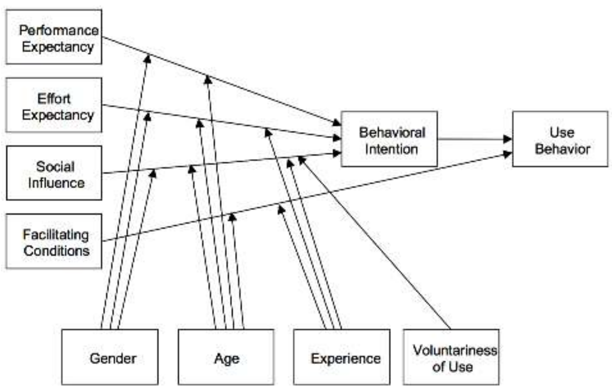


Figure 9: : Basic model of the Unified Theory of Acceptance and Use of Technology

UTAUT is widely applied in research in technology acceptance regarding several (wireless) IT applications like mobile banking (Wang & Wang, 2010); (AbuShanab & Pearson, 2007); (Cheng, Song, & Qian, 2008), the use of mobile paying methods public transport (De Hoog, 2014) or the usage of Radiofrequency ID-technology in E-health applications (Spil & Schuring, 2006).

Between 2005 and 2012 several extensions to the basic UTAUT model were made on order to enhance the models predictive capacity and to make it specific for certain markets and innovations. This resulted in the publication of an enhanced UTAUT2 model which was especially designed for the consumer acceptance of ICT innovations. (Venkatesh, Thong, & Xu, 2012). This UTAUT2 model contains three extra factors on top of the original UTAUT model: *Habit, Hedonic motivations* and *Price value*.

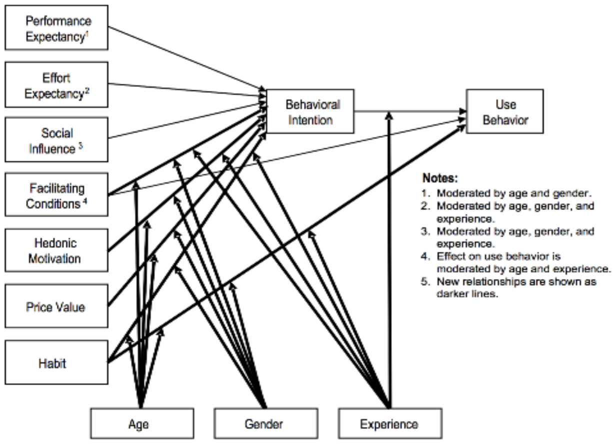


Figure 10: The UTAUT 2 framework (Venkatesh, Thong, & Xu, 2012)

Also other researchers extended the original UTAUT model with potential predictive factors. Examples of these factors are: Trust (Gefen, Karahanna, & Straub, 2003), Privacy (Min, Ji, & Qu, 2008), Concerns for the natural environment (Letiklane, 2015) etc.

In table 3 and 4 the most commonly used extensions of the UTAUT model are presented, first there a table with the definitions of the UTAUT2 model factors, then a table with other known extensions.

Table 3: Original UTAUT2 factors

UTAUT 2 Factor	**Description (Venkatesh, Thong, & Xu, 2012)**
Performance Expectancy (PE)	The degree to which an individual believes that using the system will help him to attain gain in job performance
Effort Expectancy (EE)	The degree of ease associated with the use of the system
Social Influence (SI)	The degree to which an individual perceives that important others believe he should use the new system
Facilitating Conditions (FC)	The degree to which an individual believes that an organizational and technical infrastructure exists to support [the] use of the system
Habit (H)	The extent to which people tend to perform behaviours automatically because of learning
Hedonic Motivations (HM)	The fun or pleasure derived from using a technology, and it has been shown to play an important role in determining technology acceptance and use.
Price Value (PV)	Consumers' cognitive trade-off between the perceived benefits of the applications and the monetary cost for using them
Intention to adopt/behaviour (IB)	The feelings of the employee towards the acceptance of the system
Usage (U)	The usage of a technology system

Table 4: Extensions of UTAUT model found in previous research

Extension Factor	Description
Personality	Individual differences among people in behaviour patterns, cognition and emotion (based on the big 5 theory, which incorporates the dimensions neuroticism, conscientiousness, openness to experience, agreeableness and extraversion); (Mishel, Shoda, & Smith, 2004)
Trust	A willingness to be in vulnerability based on the positive expectation toward another party's future behaviour (Mayer, Davis, & Schoormans, 1995, p. 712)
Privacy concern	User concern on personal information disclosure (Li, 2011, p. 465)
(Perceived) Playfulness	The degree of cognitive spontaneity in microcomputer interactions, with a high level of cognitive spontaneity indicating a high degree of playfulness, and a low level of cognitive spontaneity indicating a low degree of playfulness. While the trait-based approach focuses on playfulness as the individual's characteristic, the state-based approach emphasises playfulness as the individual's subjective experience of human-computer interaction (Wang, Wu , & Wang, 2009, p. 109)
National Culture	Hofstede (2001) defines culture as patterns of thinking, feeling and potential acting, which have been learned throughout a lifetime, and which are likely to be used repeatedly and unlikely (or difficult) to be changed by the individual. (Nistor, Lerche, Weinberger, Ceobanu, & Heymann, 2014, p. 38)
Profession culture	Individual education and professional practice in a given domain. STEM (science, technology, engineering or mathematic) vs non-STEM (Nistor, Lerche, Weinberger, Ceobanu, & Heymann, 2014, p. 39)
Perceived Security	The consumers' perceptions that a certain system is secure to conduct transactions (Morosan & DeFranco, 2016, p. 21)
Concern for the natural environment	The general attitude and obligation towards the environment. (Wiese, Sauer, & Ruttinger, 2004, p. 1182)
Biophilic tendencies	An individual's affiliations with nature or biophilia (Letiklane, 2015, p. 36)
General Privacy	Privacy reflects the individuals' rights to be left alone (Morosan & DeFranco, 2016, pp. 21-22)
System privacy	The consumers believe that a given IS is not appropriate to safeguard their privacy (Morosan & DeFranco, 2016, pp. 21-22)
Self-Efficacy	The belief that someone has the capability to perform a particular behaviour. (Compeau & Higgins, 1995, p. 189).
Personal innovativeness	Innovativeness reflects a person's desire to seek out the new and different (Hirschman, 1980). (Tan, Ooi, Chong, & Hew, 2014)
Anxiety	Evoking anxious or emotional reactions when it comes to using the system (Heerik, Kröse, Evers, & Wielinga, 2010, p. 364)

3.3 Merging of the theories of Responsible Innovation and Technology Acceptance

In this section theory of Responsible Innovation and Technology Acceptance are investigated in more detail in order to find overlap between the two concepts. This overlap is useful in order to combine both concepts in the empirical and technological investigation stage of this research. Put differently, when both theories overlap, we can use the UTAUT model as a blueprint in the empirical investigation stage to generate the relevant factors or values that then later used as input for the technical investigation stage.

For RI the focus will be on VSD and the concepts of values, norms, design requirements. For TA the focus will be on the meaning of the UTAUT-factors. The first part of this chapter starts to define and describe the concepts of values, norms, design requirements and (UTAUT) factors. In the second part the definitions and descriptions of the used concepts and values are given. Finally, this second part will conclude with a table and a visualisation of a value tree which connects the relevant values and (UTAUT) factors to each other.

3.3.1 Values

Within several scientific disciplines there are different definitions of the construct of values. For instance, in philosophy, values are seen as relatively stable principles that help people make decisions based on their preferences and on they consider good. In the economics branch, the construct of values is usually used in discussions of (social) choice, where a social value is placed in balance with other alternatives and in which the selection is guided by the best choice under a utilitarian ethic (the greatest good for the greatest number). However, in this thesis the focus of the construct of values is set on its sociological explanation. In this avenue of research, values are defined as '*lasting convictions or matters that people feel should be strived for in general and not just for themselves to be able to lead a good life or to realize a just society*' (Poel & Rooyakkers, 2011, p. 86).

Value can be categorized in different ways. For instance, a distinction can be made between intrinsic and instrumental values. An intrinsic value is an objective in and of itself. An instrumental value is a means to realizing an intrinsic value (for instance healthy life can be a means to the end of a happy life). A second distinction in values is made by Schwartz which classified universal values and 'lower level' or derivative values (Schwartz, 2012, p. 4). Universal values are seen as overarching constructs that incorporate several lower level values. For instance, the value freedom, can be seen as a derivative value under the universal value of self-direction.

Schwartz described his ten basic values as universal values because: '*they are grounded in one or more of three universal requirements of human existence. These requirements are needs of individuals as biological organisms, requisites of coordinated social interaction, and survival and welfare needs of groups.*'(Schwartz, 2012, p. 4). In table 5 an overview of these ten universal/ basic values is presented.

Table 5: Schwartz' Theory of Basic Values (2012)

Basic Value	**Description**
Self-Direction	Independent thought and action--choosing, creating, exploring
Stimulation	Excitement, novelty, and challenge in life
Hedonism	Pleasure or sensuous gratification for oneself.
Achievement	Personal success through demonstrating competence according to social standards
Power	Social status and prestige, control or dominance over people and resources
Security	Safety, harmony, and stability of society, of relationships, and of self.
Conformity	Restraint of actions, inclinations, and impulses likely to upset or harm others and violate social expectations or norms.
Tradition	Respect, commitment, and acceptance of the customs and ideas that one's culture or religion provides.
Benevolence	Preserving and enhancing the welfare of those with whom one is in frequent personal contact (the 'in-group')
Universalism	Understanding, appreciation, tolerance, and protection for the welfare of *all* people and for nature.

When assessing these basic values, we have to bear in mind that the pursuit of any value can have consequences that may conflict with some other values within this value-structure. On the other hand, several values can also be taken as congruent with one another.
Therefore, these basic values are not to be seen as self-contained but can be classified in interrelated value clusters.

Schwartz presented these interdependencies in a circular framework with four dimensions or value-clusters: Self-transcendence, Conservation, Self-Enhancement and Openness to change. Each cluster contains congruent basic values and has a potential value conflict with an opponent value cluster. For example, '*pursuing achievement values typically conflicts with pursuing benevolence values. Seeking success for oneself tends to obstruct actions aimed at enhancing the welfare of others who need one's help. But pursuing both achievement and power values is usually compatible*' (Schwartz, 2012, p. 8).

Figure 11: Schwartz' theoretical model of relations among his 10 motivational types of values (Schwartz, 2012)

3.3.2 Derivative Values

Based on the Schwartz' Theory of Basic Values, Dietz et al described 56 derivative values that are most common in social science. These 56 values and their description are listed in the appendix of this thesis and can be seen as 'lower level' values that originate from the higher basic or universal values from the Theory of Basic Values (Dietz, Shwom, & Fitzgerald, 2005, pp. 348-349).
Clearly this extensive list of is too comprehensive if you want to apply these factors in for example a VSD approach. Therefore, Friedman et al. narrowed down this enumeration to a shortlist of several frequently used values in the VSD-approach for new product innovations. (Friedman, Kahn, & Borning, 2008).

Ligtvoet et al extended the list later to an overall of 23 values that are frequently used in new technology. This list is copied in table 6. These 23 values are clustered in three sections of functional values (accountability, correctness, efficiency, environmental sustainability, legitimacy, reliability, safety, tractability), social values (cooperation, courtesy, democracy, freedom from bias, identity, participation, privacy, trust) and individual values (autonomy, calmness, economic development, informed consent, ownership, universal usability, welfare); (Ligtvoet, et al., 2015, pp. 169, 170).
Functional values relate to the artefact itself, social values to the interaction with other users/ society and individual values to the personal preferences regarding the technology.

Table 6: List of 23 derivative values often used in VSD (Ligtvoet, et al., 2015)

Value	**Description**
Accountability	The system allows for tracing the activities of individuals or institutions
Autonomy	The system allows for its users to make their own choices and choose their own goals
Calmness	The system promotes a peaceful and quiet state
Cooperation	The systems allows for its users to work together with others
Correctness	The systems processes the right information and performs the right actions
Courtesy	The system promotes treating people with politeness and consideration
Democracy	The system promotes the input of stakeholders
Economic development	The system is beneficial to the economic status/finances of its users
Efficiency	The system is effective given the inputs
Environmental sustainability	The system does not burden ecosystems, so that the needs of current generations do not hinder future generations
Freedom from bias	The system does not promote a select group of users at the cost of others
Identity	The system allows its users to maintain their identity, shape it, or change it if required
Informed consent	The systems allows its users to voluntarily make choices, based on arguments
Legitimacy	The system is deployed on a legal basis or has broad support
Ownership	The system facilitates ownership of an object or of information and allows its owner to derive income from it
Participation	The system promotes active participation of its users
Privacy	The system allows people to determine which information about the is used and communicated
Reliability	The system fulfils its purpose without the need to control or maintain it
Safety and health	The system does not harm people
Tracability	The functioning of the system can be traced
Trust	The system promotes trust in itself and in its users
Universal usability	The system can be easily used by all (foreseen) users

3.3.3 Norms

In social science, norms are defined as '*rules that prescribe what concrete actions are required, permitted or forbidden* ' (Poel & Rooyakkers, 2011, p. 87). These are rules and agreements about how people are supposed to treat each other. For instance, the value of safety can be translated into a norm that traffic coming from the right should always be given way.
Schwarz describes norms as '*standards or rules that tell members of a group or society how they should behave*.' (Schwartz, 2012, p. 16).
Norms vary on a scale of how much we agree or disagree that people should act in a specific way. Our values affect whether we accept or reject particular norms. More generally, because norms are social expectations, we are more or less inclined to accept them depending on how important conformity vs. self-direction values are to us. (Schwartz, 2012)

3.3.4 Design requirements

Design requirements are '*requirements that a good or acceptable design has to meet*.' (Poel & Rooyakkers, 2011, p. 186). The assessment of good or acceptable refers to the norms which are applied in a certain situation. In order to comply with the latter norm of giving way to traffic that comes from the right, a design requirement could be that all road should be provided with stripes and signs in order to make clear to the traffic who has stop to and give way.

3.3.5 Value hierarchy

A common approach to link the values, norms and design requirements is the value hierarchy. In figure 11 a visualization of the Value Hierarchy is given. This approach enables the translation of values into norms, into design requirements. In VSD this approach is often used as an analytical tool in order to gain insight in values, norms and design requirements that can be identified in the technological and institutional design. It also could create insight in the way that the interaction between stakeholders and their expectations. (Correljé, Cuppen, Dignum, Pesch, & Teabi, 2015)

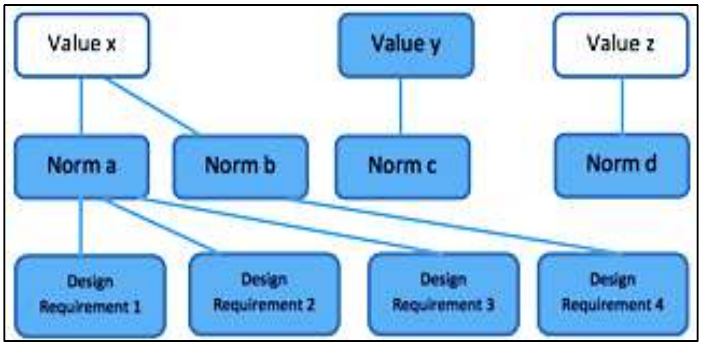


Figure 12: Value hierarchy (Vd Poel, 2013)

3.3.6 Value hierarchy and UTAUT factors

The factors in the UTAUT model seem to have a strong relation with values or norms, however there is no research known that theoretically connects the UTAUT factors with values or norms. This connection is important because in the next stage of this research both factors and values are used regarding their influence on acceptance of the IoT applications.

In this section the connection between values, norms and design requirements and UTAUT factors is established through the use of a value hierarchy instrument called the value tree. In table 7 such a value tree is presented. This tree contains a classification of values based on the 4 value-clusters and 10 universal or basic values of the Schwartz' Theory of Basic Values (Schwartz, 2012, pp. 4,5) and Ligtvoets' list of 23 values most frequently applied in the VSD (Ligtvoet, et al., 2015).

On the rightest column of the table the basic and extend UTAUT factors are placed.
Based on the definition and description of each factor in literature they are placed in the row of the table that corresponds with the basic or derivative values of Schwartz or Ligtvoet. The code behind the UTAUT-factor (ie. (h,2,3)) corresponds with the specific value

In figure 13 the interrelationships between values, norms design requirements and UTAUT factors is summarized.

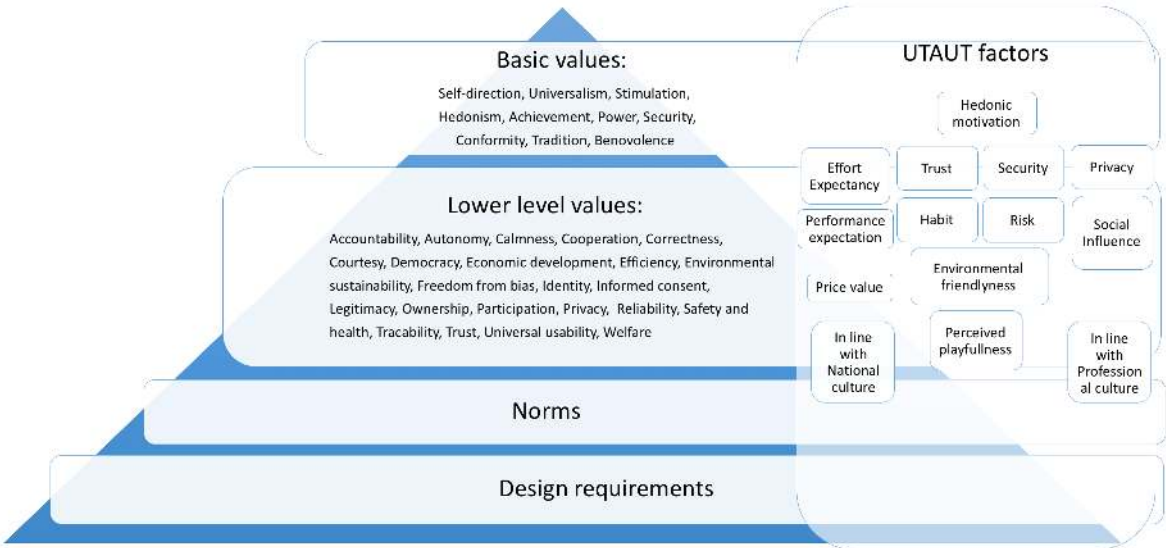


Figure 13: Summary of the interrelationships between values, norms, design requirements and UTAUT factors

Value cluster	Basic Values according to Schwartz including defining goals	Derivative values according Schwartz (2012)	Derivative values according Friedman (2008)/ Ligtvoet (2015)	Related factors of extended UTAUT2 model (Venkatesh, Thong, & Xu, 2012)
Openness to change	**Self-Direction**: Independent thought and action--choosing, creating, exploring	a. Creativity b. Freedom c. Choosing own goals d. Curious e. Independent f. Self-respect g. Intelligent h. Privacy	1. Autonomy 2. Informed consent 3. Privacy	• General privacy (h, 2, 3) • System privacy (h, 3)
	Stimulation: Excitement, novelty, and challenge in life	i. A varied life j. An exciting life k. Daring		
	Hedonism: Pleasure or sensuous gratification for oneself.	l. Pleasure m. Enjoying life n. Self-indulgent	4. Calmness 5. Welfare	• Hedonic motivations (l, m, 5) • Anxiety(negative l, 4)
Self-enhancement	**Achievement:** Personal success through demonstrating competence according to social standards.	o. Ambitious p. Successful q. Capable r. Influential s. Intelligent t. Self-respect u. Social recognition	6. Correctness 7. Efficiency 8. Reliability 9. Universal usability 10. Welfare	• Performance expectancy (p, q, 7, 10), • Effort expectancy (q, 8,9) • Facilitating conditions (q, 9) • Self-Efficacy (q,s,9)
	Power: Social status and prestige, control or dominance over people and resources.	v. Authority w. Wealth x. Social power y. Preserving my public image z. Social recognition	11. Accountability 12. Economic development 13. Identity 14. Ownership	• Performance expectancy (x, z, 12) • Social influence (y, 13) • General privacy (y, 13) • System privacy (11) • Security (11)
Conservation	**Security:** Safety, harmony, and stability of society, of relationships, and of self.	aa. Social order bb. Family security cc. National security dd. Clean ee. Reciprocation of favours ff. Healthy gg. Moderate hh. Sense of belonging	15. Democracy 16. Legitimacy 17. Ownership 18. Safety and health 19. Tracability	• Environmental concerns (18) • General privacy (hh, 16) • System privacy (aa, 19) • Security (bb, cc, 19)
	Conformity: Restraint of actions, inclinations, and impulses likely to upset or harm others and violate social expectations or norms.	ii. Obedient jj. Self-discipline kk. Politeness ll. Honouring parents and elders mm. Loyal nn. Responsible	20. Cooperation 21. Participation	• Social influence (mm, nn, 20, 21)
	Tradition: Respect, commitment, and acceptance of the customs and ideas that one's culture or religion provides.	oo. Respect for tradition pp. Humble qq. Devout rr. Accepting my portion in life ss. Moderate tt. Spiritual life	22. Courtesy	• Social influence (oo) • Habit (oo)
Self-Transcendence	**Benevolence:** Preserving and enhancing the welfare of those with whom one is in frequent personal contact (the 'in-group')	uu. Helpful vv. Honest ww. Forgiving xx. Responsible yy. Loyal zz. True friendship aaa. Mature love bbb. Sense of belonging ccc. Meaning in life ddd. Spiritual life.	23. Cooperation 24. Participation 25. Trust	• Social influence (yy, xx, 23, 24) • System Privacy (xx, 25) • Security (xx, 25)
	Universalism: Understanding, appreciation, tolerance, and protection for the welfare of *all* people and for nature.	eee. Broadminded fff. Social justice ggg. Equality hhh. World at peace iii. World of beauty jjj. Unity with nature kkk. Wisdom lll. Protecting the environment mmm. Inner harmony nnn. Spiritual life	26. Democracy 27. Environmental sustainability 28. Freedom of bias	• Environmental concerns (jjj, lll, 27)

Table 7: Value tree with interrelationships between values and UTAUT factors

4 Stakeholder analysis

One part of the conceptual investigation stage is the stakeholder analysis. This method is used to give a description of the actors and their context related to the innovations that are implemented and gives an answer to the second sub question of this research: *Which stakeholders influence the acceptance of IoT applications in (governmental) office buildings?* This stakeholder analysis is important because it determines to which groups the research should focus. This stakeholder analysis is based on the framework described by Cuppen (2012) and consists of five steps:

1. Determine the purpose of the stakeholder analysis
2. Define the limits of the stakeholder analysis
3. Stakeholder identification
4. Analysis of the stakeholder characteristics
5. Conclusion

4.1 Purpose of the stakeholder analysis

This first step of the stakeholder analysis is the determination of its purpose. In this study the stakeholder analysis can be seen as instrumental (Cuppen, 2012) and is made in order to create an overview of all the relevant groups that affect the acceptance of an innovation. Put differently it is used to create a better understanding of all relevant actors. Also the stakeholder analysis is an important step in the conceptual investigation stage of the Value Sensitive Design (VSD) method that is used in this research (Friedman, Kahn, & Borning, 2008).

4.2 Limits of the stakeholder analysis

Setting the limits for a stakeholder analysis is useful because it brings focus to this exercise. Setting the limits can be done in several ways for instance geographically (local, regional, national, global) or per branch or work field. In this study the limits are set geographically because of the use of the living lab, which can be seen as a geographical entity (MIT Living Labs, 2015). This means that only the direct and indirect stakeholders that are in some way connected to the living lab building are included in this stakeholder analysis.

4.3 Stakeholder identification

In this section of stakeholder identification, several heuristics are used to come up with a list of relevant stakeholders. A key issue here is diversity, meaning that the stakeholders have to sufficiently differ regarding variety, disparity and balance. Variety refers to the number of categories into which the elements can be divided. Balance refers to how the elements are distributed among the categories. Disparity refers to the degree and nature to which the categories themselves are different from each other (Cuppen, 2012, p. 28). For the identification of the stakeholder's heuristics are used like the division between regime / niche-player, affiliation and involvement in the innovation process. A regime player has a large impact on the system, the influence of the niche-player is relatively small.

Table 8: Stakeholder identification

Stakeholder	Regime / Niche	Size	Affiliation
End-users	Regime	Medium	Government
Facility management workers	Niche	Small	Commercial
Maintenance workers	Niche	Small	Commercial
Central Government Real Estate Agency	Regime	Large	Government
Dutch Department of transportation	Regime	Large	Government
Energy suppliers	Niche	Large	Commercial
Facility management	Niche	Small	Commercial
Technical installation firms	Niche	Small	Commercial

4.4 Stakeholder features

In this fourth step an analysis of the features of each stakeholder is made. This analysis is focussed on the features regarding the future implementation and use of the innovations and will contain an analysis of power and interests and an analysis of the potential benefits and harms per stakeholder. The analysis of power and interests is made using a power-interests matrix (figure 9); (Eden & Ackermann, 1998) in which the X-axis represents the power of the stakeholder regarding the implementation and use of the innovations, and the Y-axis the interests per stakeholder.

Table 9: Power-interest matrix for stakeholders

		Power	
		High	Low
Interests	High	End-users Central Government Real Estate Agency	Dutch Department of transportation Maintenance workers Facility management
	Low		Energy suppliers Technical installation firms.

In another division of stakeholders is the division between direct and indirect stakeholders. Direct stakeholders are those individuals who interact directly with the technology or with the technology's output. Indirect stakeholders are those individuals who are also impacted by the implementation or use of the system, though they never interact directly with it (Friedman, Kahn, & Borning, 2008). In table 10 the stakeholders for this research are mapped and their potential benefits and harms regarding the use of the system are described. In the last column the corresponding value related to the benefits and harms is given.

4.5 Conclusion of stakeholder analysis

Although this research focusses on the acceptance of innovation by the end-users of the (governmental) office building, it is good to understand and describe all other relevant stakeholders that could have an effect on this acceptance-process. The exercise of the stakeholder analysis gives a comprehensive overview of these relevant groups and forms an essential part of the conceptual investigation stage in the VSD approach that is used in this study.

A real conclusion is hard to make because of the fact that this analysis is just an intermediate step in the process. The most important 'conclusions' of this analysis are the tables of in the sections of the 'stakeholder identification' and 'stakeholder features'.

Stakeholder description		Potential benefits	Potential harms	Corresponding values
Direct	End-users	• More comfort that results in higher productivity • Efficiency in searching and finding colleagues. • Responsibility towards the environment.	• Privacy concerns, sense of freedom at the office. • More dependent on IT-systems • Extra effort towards learning and using the system	• Privacy • Freedom • Welfare • Environmental sustainability • Efficiency
	Facility management workers	• Efficiency cleaning the offices	• Potential loss of jobs due to higher efficiency	• Efficiency • Participation
	Maintenance workers	• Efficiency in the maintaining the installations	• Potential loss of jobs due to higher efficiency • More knowledge of complex systems needed	• Efficiency • Participation
Indirect	Central Government Real Estate Agency	• More efficient use of the buildings in terms of energy-use and facility-use • Less costs per employee • Less pollution of the environment	• Implementation and maintenance costs of the system	• Efficiency • Economic development • Environmental sustainability
	Dutch Department of transportation	• Higher productivity per employee yields to less employees needed for their tasks. • More efficient use of the buildings, leads to less building costs. • More comfort leads to happier employees.		• Economic development • Welfare
	Energy suppliers	• More insights in the use of electrical appliances.	• Less production leads to less profit.	• Economic development
	Facility management	• Higher efficiency yields to lower cleaning and maintenance costs.	• More knowledge of complex systems needed.	• Economic development
	Technical installation firms	• More installations leads to more revenues.	• More knowledge of complex systems needed.	• Economic development

Table 10: Stakeholders and their benefits, harms and corresponding values

5 Research methods in the empirical- and technical investigation stages

In this chapter the methods used in the empirical investigation and the technical investigation stage of this thesis are described.
The empirical investigation is done in two steps: First an interview with a user group of the living lab is conducted in order to identify the most relevant factors that affect the acceptance of the IoT applications. The outcome of these explorative interviews will gives an answer to the third sub question of this thesis *What factors are perceived relevant by the (future) users regarding the Acceptance of IoT applications in office buildings?* Also this outcome is used to develop a research framework and hypotheses.
In the second step the hypotheses are tested with a quantitative survey among all users of the living lab. The data of this survey is statistically analysed and eventually will answer the fourth sub question of this thesis: *To what extent is the acceptance of IoT-applications affected by the perceived relevant factors?*

Finally, the output of the empirical investigation stage is the input for the technical investigation stage. The final stage has a more normative character and is used to review the outcomes of the survey with a user group of the living lab and to formulate concrete recommendations for the technical redesign of the applications and/or adjustments for the implementation policy. This technical investigation stage will eventually answer the last sub question of this research *What recommendations can be made to mitigate concerns regarding the acceptance of IoT-applications in office buildings*?

5.1 Explorative interviews with users about relevant factors

In order to pinpoint the factors that are perceived to be most relevant for the end-users to accept the IoT applications, several exploratory qualitative interviews are executed among a sample of the current population in the living lab. During these interviews a semi-structured technique called repertory grid technique (RGT); (Kelly, 1955) is used to identify these relevant factors. This technique is chosen because it allows the examination of a person's unique pattern of preferred values or the relationship between certain values and if you want to order them in a hierarchical way (Burr, 2012).

5.1.1 The Repertory Grid Technique (RGT)

The method of RGT consists of four steps: Element elicitation, construct elicitation, rating and analysis. In the first step of element elicitation, the most commonly used control mechanisms regarding light, climate and wayfinding in office buildings were printed on small reference cards. Each of these control mechanisms had their own specific mix of functionalities and these functionalities were explained during the interview. To give an example three reference cards that were used for the control mechanisms for lighting are presented in figure 14: 1. A time-controlled switched, 2. A manually operated desk light and 3. A location controlled personalized desk light IoT-application. All the other reference cards of the other control mechanisms are listed in the appendix of this thesis

Figure 14: RGT Cards used during the interview: A time-controlled light switch, 2. A manually operated desk light and 3.A location controlled personalized desk light IoT-application

During the second step of the RGT, the construct elicitation, the interviewee is asked to elaborate on the different control mechanisms that were presented: '*How are two of these elements similar, and thereby different from a third element?"* and then '*How is the third element different from the other two*?' In this way the interviewer can retrieve the individual perceptions of the interviewees regarding the values or factors of the control mechanisms. These values or factors are then written down in a bipolar way, like for instance: manually vs automatic, or innovative and old-fashioned. During this step the reference cards are shuffled several times in order to come up with as much values or factors as possible.

During the third step of the RGT, all the listed values or factors regarding the different control mechanisms are ordered in a hierarchical way. The interviewee is asked to list the founded values of factors in such a way that his most important one is on top and his least important one at the bottom of the list. This is step is done in order to detect the personal preferences of the interviewee.

In the final step of the RGT method, all the preference lists of all interviewees are placed in a long list of values or factors. Frequency tables are then developed in order to rank the factors and an analysis of the interviewee's meaning behind the factor is made to find out whether some factors could be merged to one or not.
Eventually the end stage of this final step is a list of merged factors of values or factors that are found most relevant by the interviewees regarding the use of the different applications. This shortlist is then used as input for the development of hypotheses and a questionnaire.

5.1.2 Sample of the interviews

In total six interviews are conducted among a user group that is currently working in the living lab. In order to establish diversity among the interviewees a sample is selected that consisted of four female- and two male end-users, with an age ranging from 27 to 58 years and a work experience ranging from 3 months to 15 years.

5.1.3 Interview analysis

The interview analysis is done in four steps. First all recordings of the interviews are transcribed into Dutch and are included in the appendix of this thesis.

Secondly the quotes of the interviewees are analysed, filtered and the frequency of the mentioned factors is counted. This step is results in a table with a long list of preferred factors that are mentioned by the interviewees during the interviews.

The third step of the analysis of the interviews is the merging of the long list of factors to a more usable list of merged factors. This merging is based on the actual meaning, for instance the merger of the factor *individually* and *individually adjustable.* If you take a closer look at the meaning of both factors you will find that both refer to enhancing job performance by adjusting temperature or light to the preferences of the user. Both factors conceptually mean the same so can be merged and counted twice in the frequency table. The end stage of step three is a list of merged factors that is completely based on the input of the interviews.

The last step of the analysis is comparing the merged factors of step three to the theoretical insights of the UTAUT2 factors and its extensions. Goal of this last step is to find relations between the theory and the findings of the interviews. Put differently, is there an overlap in the factors that are described in the theory and the factors found in the interviews? If so than this validates the inclusion of these factors in the research framework and the development of hypotheses with these factors.

5.2 Questionnaire

Goal of this step is to quantitatively test the hypotheses that are made at the end of step one of the empirical investigation stage. In this thesis the method of a survey is chosen to test the hypotheses because of the combination of high internal validity and relatively high external validity. Because the findings of this research should be also applicable on other building in the RVB portfolio, this generalizability is necessary. A second reason to pick this survey method is because it is suitable to study the perceived beliefs, norms and values of the respondents and it enables the researcher to statistically compare the outcomes of large quantities of respondents (Sekaran & Bougie, 2009). Due to the limited time available for this research only one (cross-sectional) survey could be conducted.

The development of a questionnaire is done in five steps: First step is the development of a draft list of items. Second step is the translations of these items into Dutch, followed by the testing of the questionnaire by a small test panel in step three. In the fourth step the output of the test phase is processed in the final version of the questionnaire. Then in the last step the items are issued to the respondents. Due to the large population and the limited time available an electronic tool is used to issue the questionnaire. Therefore, the items have to be transposed into a software tool that is suitable to execute and process the items and the collected data. In this thesis, the tool Collector (Survalyzer.com, 2016) is used because a licence of this tool was available at the TU Delft and this tools was found to be well equipped for this research. This internet based tool enables the researcher to reach a relatively large group of respondents by e-mail and process their input, without the use of time-consuming paper questionnaires or face-to-face interviews. Disadvantage of this tool is its potential ow respond-rate.

5.2.1 Items

Besides the items that are part of the research framework, it is also useful to issue descriptive items like age, gender, experience, educational level, floor that the respondent usually works and amount of days that it works in this building. These descriptive items give a good image of the composition of the sample and could be used in a later stage of this research as moderating factors.

5.2.2 Sample of the questionnaire

In this research a form of cluster sampling is used in order to create a representative group of respondents. Cluster sampling are samples gathered in groups that are similar in some way, this could be geographical, cultural or any other typology. Because we make use of a living lab the sample can be seen as a geographical cluster of respondents that represent the governmental employee in general (MIT Living Labs, 2015). More specific this way of sampling is called area sampling. One of the main advantages of this way of sampling is the practical ease of addressing the population. The main disadvantage is its generizability, which is assumed to be less than for instance probability sampling or stratified sampling methods (Sekaran & Bougie, 2009, pp. 250-251).

Based on the current population of the building of approximately 450 users, the minimum amount of respondents needed to get a representative sample is n= 132. This calculation is based the following formula:

$$Sample\ Size = \frac{Z^2 * (p) * (1-p)}{c^2}$$

Where *Z* represents the margin of error, meaning the probability of rejecting the null hypothesis when it is actually true (also known as a type I error). For the calculations of a representative sample a confidence level of 95% is used.

Then *c* represents the confidence level. This is the amount of uncertainty you can tolerate. For instance, if there are 20 yes-no questions in a survey, then with a confidence level of 95%, you would expect that for one of the questions (1 in 20).

Finally, the *p* relates to the response distribution and is set on 14,2%. This value represents the skewness of the answers in the research. For instance, if the sample is skewed highly one way or the other, then the population is probably skewed too. The value of response distribution is calculated by 100% divided by the number of answering option. When a 7-point Likert scale which is used in this study corresponds with a value of 100/7 = 14,2% (Steekproefcalculator.com, 2016). When all the users of the living lab receive an invitation, this sample size of n=132 corresponds with a response rate of 30,4%. A higher response rate gives a higher reliability; a lower response rate gives a lower reliability.

5.2.3 Analysis

To execute the calculations, the Statistics Package for Social Science (SPSS) software package is used to analyse the data on normal distribution, reliability, correlation, and regression.
First the normal distribution of the data has to be established. This is a condition in order to continue the analysis with parametric tests and analyses. Secondly the reliability analysis is executed in order to define the degree to which the measurements are free from error and therefore yield to consistent results. The correlation analysis is a measure of the degree to which a change in the independent variable will result in a change in the dependent variable. And finally the regression analysis is conducted in order to analyse the variables, with a focus on the relationship between a dependent variable and one or more independent variables.

5.3 Explorative interviews with users about recommendations

The output of the empirical investigation stage is the input for the technical investigation stage. The final stage has a more normative character and is used to review the outcomes of the survey with a user group of the living lab. These reviews are done during a second round of interviews and the purpose of these interviews is to formulate concrete recommendations for the technical redesign of the applications and/or adjustments for the implementation policy in order to increase the acceptancy of the applications. These interviews are a form of qualitative research and are conducted in a semi-structure way, using partially the same technique as in the first round of interviews, the repertory grid technique (RGT); (Kelly, 1955).

In total three interviews are conducted among a group of employees that is currently working in the living lab. The interviews were recorded and transcribed in Dutch. Similar to the first interview round, reference cards are used to support the interviews. All the used reference cards are included in the appendix of this thesis.

6 Explorative interviews with users about relevant factors that affect acceptance

In order to develop a list of merged factors that will be of influence on the acceptance of the IoT applications, the interviews with a user group in the living lab are conducted and analysed as described in the Method chapter. The analysis consists of four steps: the transcription of the interviews, the development of a long list of factors, the merging of factors and the comparison of the list of merged factors with the existing theory on Technology Acceptance. Eventually this chapter will result in an answer to the second sub-question of this research: *What factors are perceived relevant by the (future) users regarding the acceptance of IoT applications in office buildings?*

6.1 Step 1: Transcriptions of the interviews

The transcriptions of the interviews are included in the appendix of this thesis. In order to cover the content and the meaning of the interviews, the transcriptions are as literally as possible.

6.2 Step 2: The long list of factors mentioned in the interviews

The analysis of the transcriptions of the interviews results in a long list of factors that are potentially of influence on the acceptance of IoT applications in the living lab. The description of these factors is done a bipolar way (preferred factor vs opposite factor), for instance, the factor *automatic* and its opposite *manual*. This long list of factors and values that is listed in table 11 and is weighted by the frequency of the factors mentioned during the interviews. The complete table of this analysis is included in the appendix of this thesis.

Table 11: Step 2 of the interview analysis: Making a long list of bipolar factors

Preferred factor	**Frequency**	**Opposite factor**
Know where your colleagues are precisely and real time	1 (A)	Don't know where your colleagues are
Rough position	2 (B, F)	Accurate position
Adaptability during the day	1 (A)	Not adaptive during the day
Adapting to weather changes	1 (C)	Not adaptive with its environment
Individually	2 (D, B)	Collective
Convection heat	1 (E)	Contact heat
Physical comfort	1 (D)	Pain
Comfort	1 (C)	Frustration
Automatic	3 (A, D, B)	Manual
Ease of use	2 (E, D)	Hard to use
Saving money on electricity	1 (D)	Wasting money
Saving of energy / Better for environment	3 (F, C, B)	Wasting energy/ bad for environment
Enhanced productivity of labour	3 (A, F, C)	Reduces productivity of labour
Adjustability in lux	3 (A, F C)	Binair. On or off
Individually adjustable	5 (E, D, F, C, B)	Adjustable for all users or the complete building
High price	1 (F)	Free
Matches with an specific user	1 (A)	Is anonymous
Privacy	4 (E, F, C, B)	No privacy
Reliability	1 (A)	unreliable
Fun	1 (B)	Annoying
New	3 (F, C, B)	Old fashioned, Old school
Social supervision	1 (A)	No social supervision
Quick respond	2 (A, C)	Slow respond

6.3 Step 3: The merging of factors

In this step the long list of factors is merged in order to come up with a shorter list of merged factors. This merging is done based on the meaning-description of the factor: During the interviews some participants were using different words to give meaning to the same factor.

The first factors to merge are described as: *Know where your colleagues are precisely and real time*, *Reliability* and *Accurate position*. All these descriptions mention that a real-time and pinpointed location could affect the acceptance of the (Wayfinding) application. However, the interviewees do not agree on whether this is influence is positive or negative. The merged factor is now called *Accuracy*. One remark is that this factor of *Accuracy* only refers to the Wayfinding applications, and not to the applications controlling the lighting and climate.

The second merging is done with the factors of *Adjustability in lux, Adaptability during the day, Adapting to weather changes, Individually adjustable* and *Individually*. All these descriptions refer to the preference for the Climate- and lighting application to be able to adjust to changing. Therefore, these factors are merged to the factor of *Adaptability*. This factor of *Adaptability* only refers to the use of the Climate- and lighting applications and not to the Wayfinding applications.

A third combination of factors can be found in *Convection heat, Physical comfort, Enhanced labour productivity* and *Comfort*. These factors can be merged to the factor of *Enhanced productivity of labour,* because in all situations the interviewees refer to the level of physical or psychological comfort that eventually is perceived to have a positive effect on the productivity of labour, like working more efficient and being less distracted.

Then the factors of *Automatic, Quick respond* and *Ease of use* can be merged. In their description of the meaning, all the interviewees agree that the applications have to be easy to operate, and not to be too slow, or complex to use. Therefore, this factor is merged to the factor of *Ease of use.*

The next pair of factors of *Saving money on electricity* and *Saving of energy / Better for environment* refer to the same meaning. They both refer to the importance of the saving energy in order to contribute to a better environment. At a first glance saving money appears only an economical factor, however during the interviews the underlying construct is for money saving was not economical but environmental driven. Therefore, these two factors are merged to *Environment.*

Also a merger that can be made from the long list of factors in the merger of *Matches with a specific user*, *Social supervision* and *Privacy*. All these factors refer to the desire of the interviewees to have a certain form of privacy in their working environment. Most of the interviewees prefer the right to be left alone when they choose to. The merged factor is now called *Privacy.*

Table 12: Overview of the merged factors

Preferred factor	Merged factor
Know where your colleagues are precisely and real time	Accuracy
Reliability	
Accurate position	
Adjustability in lux	Adaptability
Adaptability during the day	
Adapting to weather changes	
Individually adjustable	
Individually	
Convection heat	Enhanced productivity of labour
Physical comfort	
Enhanced productivity of labour	
Comfort	
Automatic	Ease of use
Quick respond	
Ease of use	
Saving money on electricity	Environment
Saving of energy / Better for environment	
Matches with an specific user	Privacy
Social supervision	
Privacy	
High price	Facilitating conditions
Fun	Fun
New	New

Finally, the last merger is a reinterpretation of the factor of *High Price*. Most likely this factor is about the price value of a product, however in this situation the employer pays for the installation of the applications, so price value can't be an issue. Therefore, the meaning of the factor is based on the perception of the interviewee that the employer will not install these applications because they are too expensive. After a closer look, you could relate this factor to the meaning of *Facilitating conditions*. So in this research the description of high price is therefore changed to *Facilitating conditions.*

Eventually two factors remain that cannot be combined or merged with another one. These factors are *Fun* and *New.* These factors will be copied without any adjustments to the list of merged factors.
So conclusion of the exercise in step three is a list of nine factors that are perceived by the interviewees as factors that potentially affect the acceptance of IoT applications in (governmental) office buildings. These factors are: *Accuracy, Adaptability, Well-being, Ease of use, Environment, Privacy, Facilitating Conditions, Fun* and *New.*

6.4 Step 4: Relate the list of merged factors to the actual UTAUT2 model

In this last step a relation is drawn between the list of merged factors of step three and the theoretical insights of the UTAUT2 factors. Goal of this last step is to find relations between the perceptions of the interviewees and the existing theory of Technology Acceptance. Put differently, is there an overlap in the factors that are described in the theory and the factors found in the interviews?
In order to refresh the UTAUT2 factors and their extensions, a list of the most commonly used factors and extensions is presented in table 13:

Table 13: UTAUT 2 factors and extensions. (Venkatesh, Davis, Morris, & Davis, 2003)

Original UTAUT2 Factor	**Extensions of the UTAUT2 model found in previous studies**
Performance Expectancy	Personality
Effort Expectancy	Trust
Social Influence	Privacy concern
Facilitating Conditions	(Perceived) Playfulness
Habit	National Culture
Hedonic Motivations	Profession culture
Price Value	Perceived Security
Intention to adopt/behaviour	Concern for the natural environment
Usage	Biophilic tendencies
	General Privacy
	System privacy
	Self-Efficacy
	Personal Innovativeness
	Anxiety

If you take a closer look to the factors of the UTAUT 2 model and its extensions, several factors of the list of merged factors overlap with this theory:

The first factor that overlaps with an UTAUT factor is *Enhanced productivity of labour* and *Performance Expectancy.* Both factors are about the being able to execute your work in a more efficient and effective way and that the technology should contribute to a better job performance.

The second overlap is found in the factor *Ease of use* and *Effort Expectancy*. Both describe the way the applications should operate. This should be easy and not to complex, difficult or time consuming.

The third overlap is found in the factor of *Hedonic motivations* and *Fun*. Both factors describe that the technology has to be fun and enjoyable and should have some degree of playfulness.

Then the fourth overlap is the factor *Privacy* and the factor *General Privacy*. Both refer to the right to be left alone (in the working environment). Although other factors are found in previous studies that mention the factor of *Privacy*, ie. *System privacy* or *Privacy concern*, but if you take a closer look then these factors are more related to the protection of data, or informed consent. Only the factor *General Privacy* specifically refers to the right to be left alone and that is exactly what the interviewees meant in their description of the factor of *Privacy*.

The fifth overlap on a factor and factor is *Environment* with *Concern for the natural environment*. Both factors refer to the effects of one's actions on the natural environment.

The sixth overlap is the factor of *High Price* and *Facilitating Conditions.* In the UTAUT2 factor *Price value* refers to the consumer technology, in which the usage of a technology by actual buyer is influenced by the price value of the factor, which is in this situation not the case. Here the technology is not bought by the actual end-user, but by its employer. However, during the interviews one interviewee didn't expect a technology to be viable because of its high (initial) price. This line of reasoning does not relate to the meaning of *Price Value* as meant in the UTAUT2 model, but more to the factor of *Facilitating Conditions*. Therefore, we can claim that there is no overlap between the factor of *High Price* and *Price value,* but there is an overlap between *High Price* and *Facilitating Conditions.*

Finally, the last overlap is found in the factor of *New* and the factor of *Personal Innovativeness.* Both factors refer to the same desire to embrace innovations and new things.

A more thorough substantiation on this chapter can be found in chapter 4 of the appendix.

6.5 Conclusions of the first round of interviews

Based on the first round of interviews we can conclude that the model that fits best for the research to acceptancy of IoT application in the living lab should contain the factors*: Performance Expectancy, Effort Expectancy, Hedonic Motivations, General Privacy, Concern for the natural environment, Facilitating conditions, Personal Innovativeness, Adaptability* and *Accuracy.* With this statement an answer is also given to the third sub research question:
What factors are perceived relevant by the (future) users regarding the acceptance of IoT applications in office buildings?

One important remark that has to made is that based on efficiency-principles the actual research model will not contain all these factors. This is due to the fact that the actual research framework has to be as lean as possible in order to be workable. This implies that only the most important predictors of *Acceptance* are used in the next stage for the development of hypothesis and a research framework. Based on the frequency of the factors in the interviews, only the most important predictive factors are included in a shortlist. These are *Performance Expectancy, Effort Expectancy, General Privacy, Concern for the natural environment* and *Personal Innovativeness.*

7 Hypotheses development and research framework.

Now that the first round of interviews is conducted and analysed, we can conclude that based on these interviews the following factors are most likely to be of influence on the acceptance of the IoT applications: *Performance Expectancy, Effort Expectancy, General Privacy, Concern for the natural environment* and *Personal Innovativeness.* These factors are used in this chapter for the development of hypotheses, but first this chapter starts with a closer look to the factor *Acceptance*.

7.1 Factors

7.1.1 Acceptance

Before relations between factors can be drawn and hypotheses are developed, it is necessary to have a clear understanding about the (meaning of the) factor of *Acceptance*. The original TAM framework describes this depending variable as *User Acceptance* and in the UTAUT theory this factor is called *Behavioural Intention*. From this UTAUT theory *Behavioural Intention* is defined as '*the feelings of the employee towards the acceptance of the system'* (Venkatesh, Davis, Morris, & Davis, 2003, p. 161) and can be seen as an indication of an individual's readiness to perform a given behaviour (Ajzen, 2002).
In the dictionary the meaning of the word *Acceptance* is defined as *An express act or implication by conduct that manifests assent to the terms of an offer* (Merriam-webster.com, 2016). Because there is a large conceptual overlap between the definitions of Venkatesh, Ajzen and Merriam-Webster, we decided to use the term *Acceptance* to cover the constructs Behavioural *Intention* and *User Acceptance.*
Because we focus in this study on two application clusters, the applications for Wayfinding and the control of Climate- and lighting - systems, there should also be two variables for acceptance. One for the acceptance of the Wayfinding applications and one for the Climate- and lighting applications. Therefore, in this research the factor *Acceptance* is split in these two application clusters, each cluster with its own dependent variable for *Acceptance*: These clusters are *Acceptance to use the Climate- and lighting applications* and *Acceptance to use the Wayfinding applications*. These two factors are hypothesised separately. This means in the end that two separate models and frameworks are made, both based on their own application cluster.

7.1.2 Performance Expectancy

The factor *Performance Expectancy* is part of the original UTAUT model and relates to the job performance of the user of a system. It is described as *the extent of belief of an individual on the utilisation of a system to gain a required result from a job* (Venkatesh, Davis, Morris, & Davis, 2003, p. 447) and refers to the degree to which using a technology will provide benefits to the user in performing certain activities. In several studies support is found that when (future) users attribute a higher *Performance Expectancy* to a system, the *Acceptance* of a system will be higher (Xu & Gupta, 2009);(Oye, Iahad, & Rahim, 2014);(Venkatesh, 2012). Also based on the findings of the interview analysis it is likely that *Performance Expectancy* positively influences the degree of *Acceptance* of the applications. Therefore, this relation is also adopted in this research for both application clusters and leads to the following hypotheses:

HL1: A higher perceived performance expectancy positively influences the acceptance of the Climate- and lighting applications.

HP1: A higher perceived performance expectancy positively influences the acceptance of the Wayfinding applications.

7.1.3 Effort Expectancy

Also the factor of *Effort Expectancy* is part of the original UTAUT model and relates to an individual's perception on the degree of ease that a system is to use. Venkatesh et al define this factor as '*the degree of ease associated with consumers' use of technology'* (Venkatesh, 2012, p. 159) and since the first development of the UTAUT model in 2003 a large amount of studies has shown that *Effort Expectancy* has a positive influence on the *Acceptance* (Xu & Gupta, 2009); (Yun, Han, & Lee, 2011); (Tan, Ooi, Chong, & Hew, 2014). Also based on the interview analysis we can assume a positive relationship between the factor *Effort Expectancy* and *Acceptance* on both application clusters. Therefore, this relation is adopted in this research for both application clusters in the following hypotheses:

HL2: A higher perceived effort expectancy positively influences the acceptance of the Climate- and lighting applications.

HP2: A higher perceived effort expectancy positively influences the acceptance of the Wayfinding applications.

7.1.4 Privacy

Until now only factors of the original UTAUT model are described. However, based on the findings of the interview analysis, it is found likely that also other non-UTAUT factors could be of influence on the *Acceptance of both application clusters*. One of this non-UTAUT factors is *Privacy*.

Privacy is a construct that is hard to define. Regarding the concept of *Privacy*, a variety of definitions can be found, however the concept lacks of one overall accepted interpretation due to its plurality and inconsistency. Or as Finn and Friedewald describe it: '*The notion of privacy remains out of the grasp of every academic chasing it*' (Finn & Friedewald, 2013, p. 2). Colin Bennett notes that attempts to define the concept of *Privacy* have generally not met with any success (Bennett, 1992). Although a widely accepted definition of *Privacy* remains unattainable, there has been more consensus on a recognition that privacy comprises multiple dimensions. For instance, some regard to *Privacy* as a need, some as a value and others as a right, a condition or an aspect of human dignity (Hoven, 2008).
In this research we distinguish three factors regarding to *Privacy*. All these three factors are found to have an effect on *Acceptance* in previous studies. These Privacy factors are described as *General privacy, System Related privacy* and *Privacy Risks*.

General privacy reflects the '*individuals' rights to be left alone, and is regulated by the desire of individuals to participate, or not to, in the public society, including with information, thus balancing the public vs. private aspects of their lives'* (Morosan & DeFranco, 2016, pp. 21-22); (Min, Ji, & Qu, 2008). Finn et al described this factor as Privacy of space and location: '*The right of individuals to move about in public or semi-public space without being identified, tracked or monitored. This conception of privacy also includes a right to solitude and a right to privacy in spaces such as the home, the car or the office*' (Finn & Friedewald, 2013, p. 5)

The second privacy related factor that could have an effect on *Acceptance* is *System Related Privacy*. Morosan & DeFranco described this factor as '*the consumers believe that a given IS is not appropriate to safeguard their privacy'* (Morosan & DeFranco, 2016, pp. 21-22) and refers more to the protection of data.

The last privacy related factor is described by Li. et al as *Privacy Risks*. This factor is defined as '*the concern of a person that his/her personal information may not be properly handled by an organization and would anticipate certain risks and uncertainties regarding that information'* (Li, 2011, p. 470).

Based on the analysis of the interviews it became clear that the interviewees referred to *Privacy*, solely to the right to be left alone, as described in the factor of *General Privacy*. Therefore, only this factor is adopted and included into this research. This is done by the following hypotheses:

HL3: A higher perceived general privacy positively influences the acceptance of the Climate- and lighting applications.

HP3: A higher perceived general privacy positively influences the acceptance the Wayfinding applications.

7.1.5 Concern for the natural environment

A second non-UTAUT factor that is likely to have an effect on the *Acceptance* of the application clusters of this study is the *Concern for the natural environment*. This factor has a potential positive relation to the *Acceptance* of the application clusters, based on two lines of reasoning. The first one is theoretical: Based on previous research on environmental friendly products, a positive relationship was found between *Concerns for the natural environment* and the *Behavioural Intention* (Acceptance) to use environment friendly products (Lekitlane, 2015).

The second line of reasoning is based on the interview analysis. The outcome of this analysis also clearly indicated that the interviewees value the IoT-applications because of their perceived capability to reduce the impact on the environment. Therefore, this study includes the factor of *Environmental Concerns* as an independent variable that could positively affect the *Acceptance* of the IoT applications. The hypotheses are:

HL4: A higher perceived concern for the natural environment positively influences the acceptance of the Climate- and lighting applications.

HP4: A higher perceived concern for the natural environment positively influences the acceptance of the Wayfinding applications.

7.1.6 Personal innovativeness

The next factor in this study is *Personal Innovativeness*. Also this factor has not been incorporated in the original UTAUT or UTAUT2 studies, however several studies support a positive relationship of *Personal Innovativeness* towards the *Behavioural Intention* (Acceptance) to use a system. The factor of *Personal Innovativeness* is defined as '*a person's desire to seek out the new and different*' (Hirschman, 1980, p. 285);(Tan, Ooi, Chong, & Hew, 2014). Xu et al describe it as '*an individual's willingness to try out a certain system'* (Xu & Gupta, 2009, p. 139).

Besides this theoretical support of a potential positive relationship between *Personal Innovativeness* and *Behavioural Intention* to use a system, there is also support found for this relationship in the analysis of the interviews. The interviewees mention the '*embracing of innovations and new things*'. *Personal innovativeness* is therefore included in this research by the following hypotheses:

HL5: A higher perceived personal innovativeness positively influences the acceptance of the Climate- and lighting applications.

HP5: A higher perceived personal innovativeness positively influences the acceptance of the Wayfinding applications.

7.1.7 Moderating variables

In this last section some variables are introduced that have been found to have a moderating effect on the relations between the dependent and independent factors in the UTAUT model (Venkatesh, 2012). For instance, it was found that *age, gender*, and *experience* moderate the effect on *Hedonic Motivations*, such that it will be stronger among younger men in early stages of experience.

This finding in the research of Venkatesh is supported by several other studies (Wang, Wu, & Wang, 2009); (Li, 2011); (Tan, Ooi, Chong, & Hew, 2014); (Harsono & Suryana, 2014). Therefore, these moderating variables are adopted in this research in order to investigate their potential effect on these relations that are described in the hypotheses.

7.2 Frameworks

The hypotheses of the former section result in a research model that is specifically tailored for the study on the acceptance of Climate- and lighting applications and the acceptance of Wayfinding applications in the living lab. In order to include all hypotheses in a conceptual model, two frameworks are presented in figure 15 and 16. One for each application cluster.

7.2.1 Acceptance of the Climate- and lighting applications

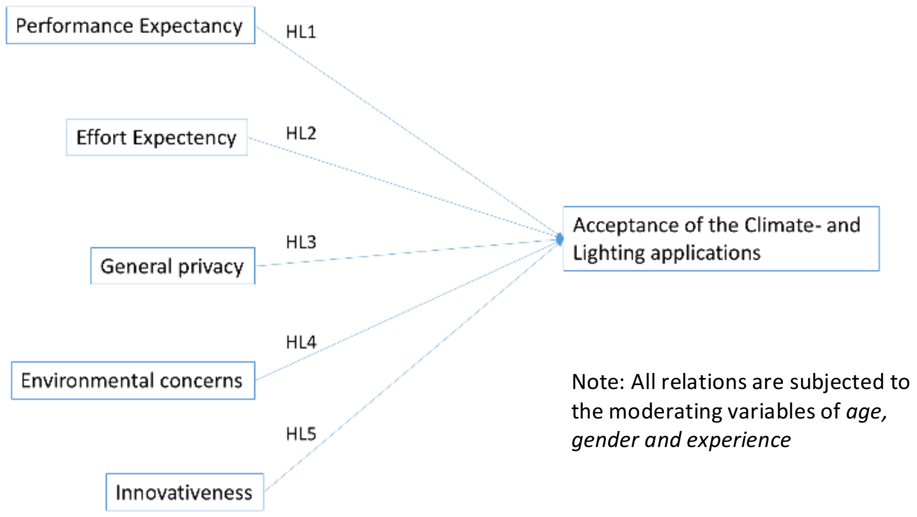


Figure 15: Conceptual framework of the Climate- and lighting applications

7.2.2 Acceptance of the Wayfinding applications

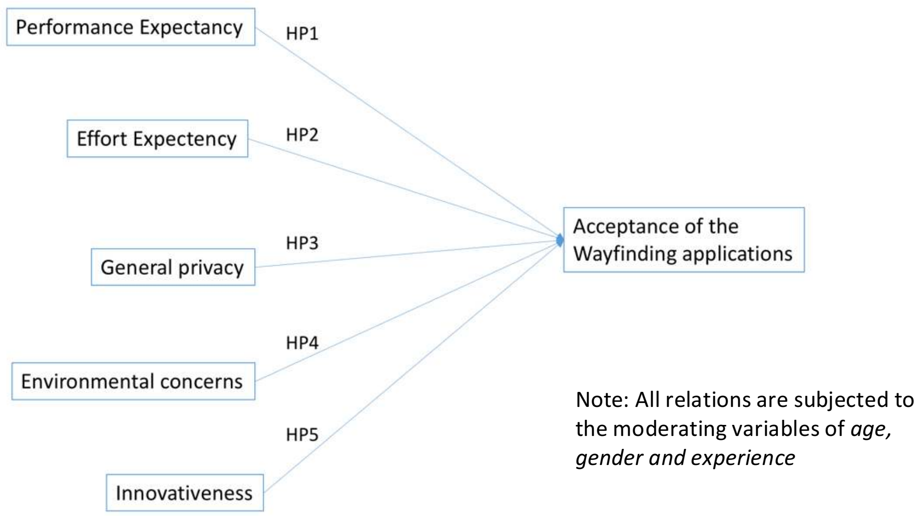


Figure 16: Conceptual framework of the Wayfinding applications

8 Questionnaire survey among the users of the living lab

This chapter covers the method of quantitative data collection and analysis. This survey forms the second step in the empirical investigation stage and is executed with the use of a questionnaire. The development of this instrument, the operationalization of the factors, the sampling and the data analysis are discussed in the following sections.

8.1 Questionnaire development

The development of a questionnaire is done in four steps. First the factors of the former chapter are operationalised in order to be measurable with a questionnaire. This step is supported by the literature review and the content of previous research. This means that when certain factors have been operationalised before in earlier studies, then these findings will be adopted in the new questionnaire.

The seconds step is the construction on of new items or adjusting existing items in order to make them aligned with the subject of this thesis.

The third step is translating the items to Dutch. Also this step relies on the findings of previous studies. Some studies have already developed a validated translation of the questions from English to Dutch (Sjeban, 2014) (Kleine Schaars, 2009), so these items are copied.
When a validated translation was not available, then a simple translation is not sufficient because of potential language and cultural differences. Therefore, the procedure of multiple forward and backward translations is executed (Beaton, Bombardier, Guillemin, & Ferraz, 1976). This means that items are first translated from English to Dutch by a person that is familiar with the conceptual meaning of the item. Secondly a different person, re-translates this item back into English. This person is not (necessary) known with the conceptual meaning of the item. Eventually this re-translation is examined by the first person and assessed on its conceptual validity. If so then this translation is copied to the questionnaire.

The last step is the testing of the questionnaire. This is done using a small test-panel that fills in the questionnaire and thoroughly investigates each question. Feedback of this test panel is then used to optimize the questionnaire.

8.2 Operationalization of the factors

As described before the factors that are mentioned in the hypotheses of this research have to be made measurable. Therefore, the factors are transformed into items that conceptually match with the factor. This process is called operationalization and is executed in table 14.

8.2.1 Scale

Because most of the factors that are adopted from former research use a 7-point Likert scale, all the other items in this questionnaire are also aligned with this scale. This scale corresponds with 1 – Strongly disagree, 2 – Disagree, 3 – Somewhat disagree, 4 – Neither agree or disagree, 5 – Somewhat agree, 6 – Agree, 7 – Strongly agree.

8.2.2 Coding

In order to create some variety in the questionnaire and to keep the respondents alert, some items are reversed coded. This means that the question is negatively formulated and that the scale should be reversely used. For instance, the question *I think that the application is easy to use*, will be reversely coded to *I think that the application is difficult to use.*

Table 14: Items operationalised factors adopted from former studies

#	Factor	Items	Adopted from
1	Performance Expectancy	PE1. Using the System would be useful in my daily life.	(Venkatesh, UTAUT 2 , 2012)
2		PE3. Using System would help me accomplish things more quickly.	
3		PE4. Using System would increase my productivity.	
4	Effort Expectancy	EE1. Learning how to use the System looks easy to me.	(Venkatesh, UTAUT 2 , 2012)
5		EE2. I think that the System is easy to use.	
6		EE3. It is easy for me to become skilful at using the System.	
9	General privacy	SP1: Using the System makes me concerned about my personal privacy	(Morosan & DeFranco, 2016, pp. 21-22)
10		SP2: Using the System would make me personally uncomfortable	
11		SP3: Using the System would make me have privacy concerns	
12	Environ-mental concerns	ENV1: In general, I am concerned about the environment	(Letiklane, 2015)
13		ENV2: It does matter to me whether materials of a product can be reduced, reused or recycled	
14		ENV6: I can make a difference in reducing the degradation of the environment	
15	Personal Innovative-ness	IN1: If I heard about a new technology, I would look for ways to experiment with it.	Thakur and Srivastava, 2014; Yang et al., 2012 and Slade 2015)
16		IN2: Among my peers, I am usually the first to explore new technologies.	
17		IN3: I like to experiment with new technologies.	
18	Acceptance	BI1. I intend to continue using the System in the future.	(Venkatesh, UTAUT 2 , 2012)
19		BI3. I plan to continue to use the System frequently.	
20		BI4 The use of the System is a good idea	

8.2.3 Moderating variables

As described in the former chapter several variables were included as moderating variables. Based on the scales of the research of Venkatesh (Venkatesh, UTAUT 2 , 2012) these variables are measures by:

1. *Age*: younger then 30, between 30 and 45, and older then 45
2. *Gender*: Male, female
3. *Experience*: less than 5 years, between 5 and 10 years, more than 10 years.

8.2.4 Descriptive variables

Descriptive variables are those variables that which will be reported on, without relating them to anything in particular (Sekaran & Bougie, 2009). They are used to give a description of the respondents that participated in the research. In this research the following variables are included:

1. *Average hours per week working in the living lab*
2. *Which floor does the respondent usually works*
3. *The use of flexible work places*
4. *I make use of a smart phone*
5. *Level of education*

Variable 1 is included in order to describe the amount of days a person works in the building. The more often the respondents uses the building, the more they probably are involved in this research.
Variable 2 describes which floor a respondent usually uses. In this research some floors are excluded from the test, so it could be interesting to find out if people of different floors have different perceptions of the innovations.
Variable 3 is conditional to the use of the applications. It could be that people with fixed work spots fill out the questionnaire for innovations that are specifically introduced for people with flexible work places. Therefore, the inclusion of this variable enables the exclusion of the 'wrong' respondents.
The fourth variable gives descriptive data about the ability of the use of the applications. Although the applications are able to be used with a tablet or computer, the technical infrastructure of the innovations is specifically designed for the use with a smartphone. If people don't have such a device, or are not used to work with it, then they are not likely to be future users of the applications.

8.3 Sample

The area sample that is used during the quantitative research is based on the employee-information in the corporate e-mail program 'Outlook'. In total 494 employees were found to be working (at least one day of the week) in the living lab on the Lange Kleiweg 34 in Rijswijk. The invitation to participate in the research was send to these 494 persons. A number of 25 invitation e-mails bounced due to an automatic out-of-office reply, which brings the sample size down to 469. Participation was voluntary, so no incentives were given and only the fully completed questionnaires are included in this data analysis.

A total of 217 (46,3%) respondents completed the full questionnaire; 132 males (60,8%) and 85 females (39,2%). This number of respondents exceeds the threshold of 157 respondents that is needed to have a representative sample. All the other descriptives are included in table 15.

Table 15: Descriptives of the respondents

Sample description	**Summary**	**N (Total = 217)**	**%**
Age	<30 years	6	2,8
	30-45 years	82	37,8
	45-60 years	110	50,7
	>60 years	19	8,8
Experience at this organisation	>5 years	58	26,7
	5-10 years	44	20,3
	>10 years	115	53,0
Educational level	Lower professional education (LBO / VMBO / MAVO)	2	0,9
	Medium professional education (MBO / HAVO)	22	1,8
	Higher professional education (HBO / VWO)	75	34,5
	University (WO)	114	52,5
Flexible work spot	Has a flex workplace but always uses the same desk	14	6,5
	Swaps desk several times a week, but never during the day	134	61,8
	Swaps desk several times a day	51	23,5
	Has a fixed assigned desk	18	8,3
Average hours working at the RWS building in Rijswijk	<10 hours a week	29	13,4
	10-20 hours a week	69	31,8
	20-30 hours a week	76	35,0
	30-40 hours a week	39	18,0
	>40 hours a week	4	1,8
Usually works on floor	1	12	5,5
	2	16	7,4
	3	19	8,8
	4	12	5,5
	5	28	12,9
	6	54	24,9
	7	32	14,7
	8	42	19,4
	No specific	2	0,9
Uses a smartphone	No	9	4,1
	Yes, it's my personal device	8	3,7
	Yes, it's in loan of my employer	83	38,2
	Yes , I have one for private use and one in loan of my employer	117	53,9

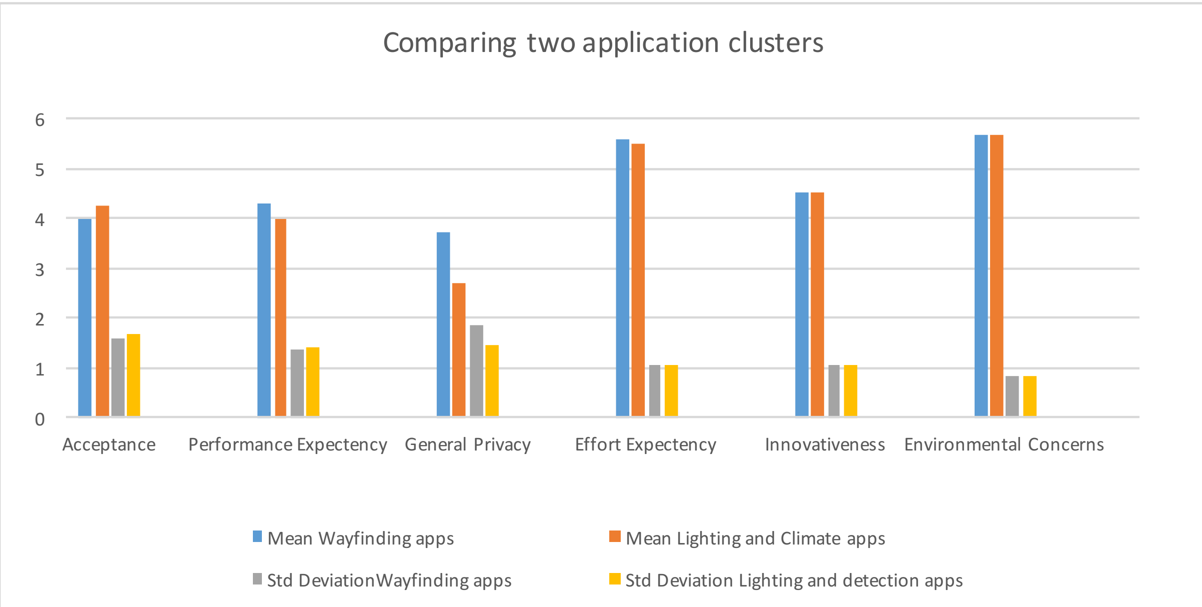
8.4 Data Analysis

The analysis of the data is covered in this section, based on the information gathered in the survey. For this analysis the software tool SPSS is used and all original data-outputs of this software tool are included in the appendix chapter 6.
There are several steps executed in order to test the hypotheses of this study. These steps are: recoding of the raw data, a factor analysis, analysis of the goodness of the data (reliability and validity), normal distribution test, transformation of the non-normally distributed data, making of scatterplots and executing a correlation and regression analysis. Finally, the data-set is split using the moderating variables age, gender and experience. However, chapter starts with a simple histogram for the frequency distribution in order to get more feeling for the data.

8.4.1 Frequency distribution

In this first section the scores of the Wayfinding applications and the scores of the Climate- and lighting applications are presented. Each mean score and standard deviation of each factor is visualised in table 16. Most of the factors show comparable scores on both mean as standard deviation. Only the factor *General Privacy* shows a remarkable difference in scores between both application clusters. Obviously the respondents perceive more privacy concerns using the Wayfinding applications then for the Climate- and lighting applications.

Table 16: Comparison table for both application clusters



A second observation from table 16 is that the overall scores of *Effort Expectancy* and *Environmental concerns* are relatively high with a score of approximately 5,5 on a scale of 7. This means that the perception of the respondents on the easiness to use the applications (*Effort Expectancy*) and their concerns regarding the environment are high, hence no much room for improvement is left on these factors. However, the scores of Performance *Acceptance, Expectancy* and *Innovativeness* are relatively mediocre (4-5) and *General Privacy* scores lowest (3-4). From this point of view *General Privacy* has the most room for improvement.

8.4.2 Validity

Before the data can be used in more complex calculations, it first has to be recoded and analysed on communality. Recoding is done based on the recoding scheme that is included in the appendix chapter 6.1. The communality is assessed by calculating the KMO-value. The KMO-value here is 0,81 which exceeds the communality threshold of 0,7. This means that there is a degree of communality in the items. Based on the scree-plot (threshold set on eigenvalue = 1,0) an amount of 7 communalities is found in the data. This finding validates a later merge of the items into factors.

After a closer look to the communalities, the claim can be made that the communalities between the items are aligned with the theory of the factors of *Performance Expectancy* (PE), *Effort Expectancy* (EE*), General Privacy* (GP), I*nnovativeness* (IN) and *Environmental Concerns* (EC) for both of the application clusters: the Wayfinding applications and the Climate- and lighting applications. This observation also supports the claim of sufficient content validity of the factors.

A second form of validity is convergent validity, a measure that indicates whether the different items that measure the same factor, correlate with one another. The threshold for the convergent validity is a factor loading value higher then 0,5 for a positive correlation, of lower than -0,5 for a negative correlation. For all factors these thresholds are exceeded, meaning that there is enough support for sufficient convergent validity.

The third form of validity is discriminant validity. This means that the items are distinct enough and do not overlap with the data of other factors. Support for this form of validity is not quite robust. For instance, an item on *General Privacy*, correlates positively with other items of this factor, but also correlates negatively with items on *Performance Expectancy*. This observation could lead to a certain degree of multi-collinearity later on the analysis of the data.

8.4.3 Reliability

In order to assess the reliability within the communality of the items, a reliability analysis is executed. This analysis is a measure for the interrelationship between the items and whether can be aggregated in one factor. This is done by computing the Cronbach Alpha, which has to exceed 0,7 in order to make the aggregation of items reliable. In table 17 an overview of all aggregated factors is given. All the values of Cronbach's Alpha exceed 0,7, which means that all proposed aggregated factors are found reliable.

Table 17: Summary reliability analysis

	Factor	Items analysed	Cronbach Alpha
Wayfinding applications	Performance Expectancy	PE5a, PE3a, PE4a, PE1a_RC	0,84
	Effort Expectancy	EE2a, EE1a_RC	0,83
	General Privacy	GP1a, GP2a	0,90
	Acceptance	BI1a, BI4a	0,77
Climate- and lighting applications	Performance Expectancy	PE1-RC, PE4, PE3	0,82
	Effort Expectancy	EE1, EE2_RC	0,82
	General Privacy	GP1, GP2	0,78
	Acceptance	BI1, BI4	0,88
	Environmental Concerns	EC1, EC2_RC, EC6, EC7	0,82
	Innovativeness	IN1, IN3_RC, IN2	0,73

8.4.4 Normal distribution

Normal distribution of the data is met when the skewness-score of all factors is between -1 and 1 and the total skewness is less than triple the standard error of the data. In table 18 the skewness-scores and standard errors are given:

Table 18: Summary normal distribution analysis.

	Factor	Skewness	Standard error	Normal distributed
Wayfinding applications	Performance Expectancy (PEa)	-0,40	0,17	Yes
	Effort Expectancy (EEa)	-0,65	0,17	No, skewness is more triple the standard error
	General Privacy (GPa)	0,24	0,17	Yes
	Acceptance (BIa)	-0,14	0,17	Yes
Climate- and lighting applications	Performance Expectancy (PE)	-0,36	0,17	Yes
	Effort Expectancy (EE)	-0,38	0,17	Yes
	General Privacy (GP)	0,84	0,17	No, skewness is more triple the standard error
	Acceptance (BI)	-0,37	0,17	Yes
	Environmental concerns (EC)	-0,80	0,17	No, skewness is more triple the standard error
	Innovativeness (IN)	-0,25	0,17	Yes

In this observation some factors are not normally distributed. These factors are *Effort Expectancy* (Wayfinding applications), *General Privacy* (Climate- and lighting applications) and *Environmental Concerns*. Primarily this finding excludes these factors from the use of parametric analysis tools like the correlation or regression analysis. However, several options are now applicable in order to make them normally distributed. These options are called data-transformations.

The first option is to use a log10-transformation (for negative skewness-values the Reflected log10 transformation is used). After this transformation the values for the factors of *Effort Expectancy* (Wayfinding applications), *General Privacy* (Climate- and lighting applications) and *Environmental Concerns* are:

Table 19: Summary of normal distribution after log10-transformation

Factor	Skewness	Standard error	Normal distributed
Effort Expectancy (Wayfinding)	-0,14	0,17	Yes
General Privacy (Climate- and lighting)	0,08	0,17	Yes
Environmental Concerns	0,06	0,17	Yes

Conclusion: the log10-transformation works and gives a normally distributed pattern. This means no other transformation method is necessary and the analysis can continue with the parametric tests of the correlation and regression analysis.

8.4.5 Correlations

Now that normal distribution is realised, all preconditions are met to execute the parametric analyses of correlation and regression. Before these analyses are executed, several scatterplots (see appendices chapter 6.6) are drawn in order to visualize the relations between the dependent and independent variables. All correlations were found to be linear. In table 20 the output of the correlation analysis is given.

Climate- and lighting applications

Table 20: Correlation matrix Climate- and lighting applications

		1	2	3	4	5	6
1	**Acceptance of the Climate- and lighting applications**	-					
2	**Performance Expectancy**	0,86**	-				
3	**Effort Expectancy**	0,36**	0,32**	-			
4	**General Privacy**	-0,31**	-0,22**	-0,22**	-		
5	**Environmental Concerns**	-0,07	-0,07	-0,25**	0,23**	-	
6	**Innovativeness**	0,11	0,07	0,16*	-0,08	-0,18**	-

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

The upper table presents the correlations of all the factors regarding the Climate- and lighting applications. The dependent variable *Acceptance* significantly positively correlates with the factors *Performance Expectancy* and *Effort Expectancy*. It significantly negatively correlates with *General Privacy*. There is no support found for the correlation between *Environmental Concern* and *Innovativeness*. In relation to the hypotheses the figure 17 puts these figures in an overview.

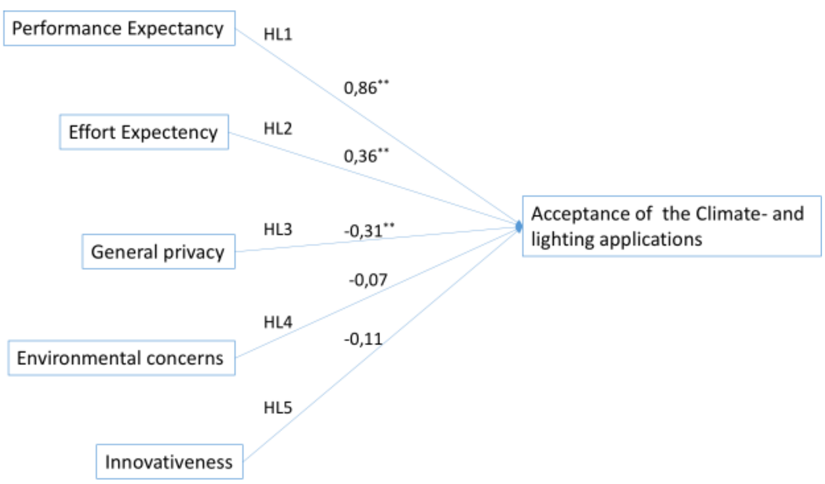


Figure 17: Correlation Climate- and lighting applications

Wayfinding applications

For the Wayfinding applications the correlation matrix is given in table 21:

Table 21: Correlation matrix Wayfinding applications

	1	2	3	4	5	6
1 Acceptance of the Wayfinding applications	-					
2 Performance Expectancy	0,75**	-				
3 General Privacy	-0,58**	-0,30**	-			
4 Effort Expectancy	-0,24**	-0,23**	-0,15*	-		
5 Environmental Concerns	-0,13	-0,14*	-0,15*	0,23**	-	
6 Innovativeness	0,15*	0,014*	-0,05	-0,16*	-0,18**	-

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

This upper table presents the correlations of all the factors regarding the Wayfinding applications. The dependent variable *Acceptance* significantly positively correlates with the factors *Performance Expectancy, Effort Expectancy* and *Innovativeness*. It significantly negatively correlates with *General Privacy*. There is no support found for the correlation between *Environmental Concern*. In relation to the hypotheses figure 18 puts these figures in an overview.

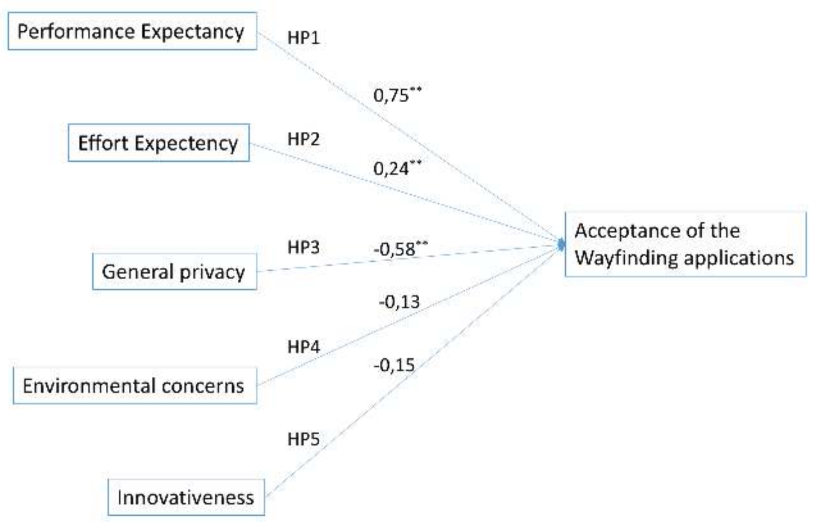


Figure 18: Correlation and hypotheses Wayfinding applications

8.4.6 Regression

In order to gain insight how strong the influence of certain variables is on the dependent variable, a regression analysis is made. In this analysis the R^2 value represents the amount of change of the dependent variable regarding to the change of the significant independent variables.

Climate- and lighting applications

In this multiple linear regression, the dependent variable is *Acceptance of the Climate- and lighting applications* and the independent variables are *Performance Expectancy, Effort Expectancy, General Privacy, Environmental Concerns* and *Innovativeness*. A significant regression coefficient was found (F(5,211)= 131,58, p < 0,01) with a R^2 of 0,76. The analysis showed significant main effects of *Performance Expectancy* (β= 0,96 t(211) =22,21, p< 0,001) and *General Privacy* (β= -0,83, t(211) =-3.30, p= 0,001). No significant main effect of *Innovativeness* (β= 0,05, t(211) =0,983, p =0,323), *Environmental Concerns* (β= 0,38, t(211) =0,99, p =0,32), and *Effort Expectancy* (β= 0,11, t(211) =1.93, p =-0,06) was found.

So with the upper scores of the regression analysis, support is found for the significant influence of *Performance Expectancy* and *General Privacy* of the dependent variable *Acceptance*. The R^2 is 0,76 meaning that 76 % of the change in *Acceptance* is explained by *Performance Expectancy* and *General Privacy*. This outcome supports the hypothesis HL1: *A higher perceived performance expectancy positively influences the acceptance of the Climate- and lighting applications* and HL3: *A higher perceived general privacy positively influences the acceptance of the Climate- and lighting applications*. For all the other hypotheses no significant report was found.
Second remarkable observation is the difference between the β-values for *Performance Expectancy* and *General Privacy*. These β-values represent the slope in the linear relation between these factors and the factor *Acceptance*. Put differently, when the β-value is higher, the slope of the correlation is steeper and the effect of a change in the factor (PE or GP) on the change on *Acceptancy* is higher. Here we see that the β-value for *Performance Expectancy* is higher than for *General Privacy*: 0,96 (PE) against -0,83 (GP). Hence if we want to improve the *Acceptance* it is more efficient to focus on changing the *Performance Expectancy* then the *General Privacy.*

Wayfinding applications

In this multiple linear regression, the dependent variable is *Acceptance of the Wayfinding applications* and the independent variables *Performance Expectancy, Effort Expectancy, General Privacy, Environmental Concerns* and *Innovativeness*. A significant regression coefficient was found (F(5,211)= 97,83, p < 0,01) with a R^2 of 0,70. The analysis showed significant main effects of *Performance Expectancy* (β= 0,73 t(211) =15,19, p<.001) and *General Privacy* (β= -0,34, t(211) =-9.71, p<0,01). No significant main effect of *Innovativeness* (β= 0,06, t(211) =1.000, p =0,32), *Environmental Concerns* (β=-0,05, t(211) =-0,64, p =0,52), and *Effort Expectancy* (β= 0,34, t(211) =1.05, p =0,30) was found.

So with the upper scores of the regression analysis, support is found for the significant influence of *Performance Expectancy* and *General Privacy* of the dependent variable *Acceptance*. The R^2 here is 0,7 meaning that 70% of the change in *Acceptance* is explained by *Performance Expectancy* and *General Privacy*. This outcome supports the hypothesis HP1: *A higher perceived performance expectancy positively influences the acceptance of the Wayfinding applications* and HP3*: A higher perceived general privacy positively influences the acceptance the Wayfinding applications.* For all the other hypotheses no significant report was found.
Also for this regression a higher β-value for *Performance Expectancy* is found then for *General Privacy*, hence also for the Wayfinding applications it is more efficient to improve the perceived *Performance Expectancy* then the *General Privacy* in order to enhance the *Acceptance* of these applications.

8.4.7 Moderation table

In this section the effect of the moderating variables on the correlations and regressions are presented. As described earlier, several studies on the UTAUT2 model found significant moderation for the variables *gender, age* and *experience*. These factors are also investigated in this section, but on top of that other descriptive data is also used in order to find support for any moderating effect. These descriptive factors are *education, hours per week working in the living lab* and *floor of the living lab*. When there is a moderating effect of these descriptive factors then profiles of users can be made in relation to *Acceptance of IoT applications.*

In order to investigate the moderation of *gender, age* and *experience*, the data file was split into subsection related to the moderations. This means *gender* is split in male/female, *age* is split into <30y, 30-45y, 45-60y and >60y. Finally, *experience* was split into <5y, 5-10y and >10y.

In order to investigate the potential descriptive moderators, the data file is split in subsections related to these factors: For *education* this is VMBO, MAVO, MBO, HAVO, HBO, VWO, WO. For *hours per week in the living lab*, these subsections are 0<10, 10<20, 20<30, 30<40 and >40. Finally, for *floor in the building*, subsections are made based on the top4 floors (5-8) and the bottom floors (0-4). This division is made because on the top floors, the infrastructure of the Smart Building™ concept is already visible, On the lower floors it isn't.

Table 22 shows only the scores of the significant correlations (all with a value of p< 0,01) between the factors *Performance Expectancy* (PE) *General Privacy* (GP), *Effort Expectancy* (EE), *Innovativeness* (IN) and *Environmental Concerns* (EC). This is done for both application clusters, the Wayfinding applications and the Climate- and lighting applications. Also the R^2 of the regression is adopted in this table, in order to get insights in the magnitude of the influence of the independent and dependent variables.

Table 22: Summary of moderations on gender, age, experience, education, hours per week working in the living lab and floor.

	Gender		**Age**				**Experience**		
	Male (N=132)	Female (N=85)	<30y (N=6)	30-45y (N=82)	45-60y (N=110)	>60y (N=19)	<5y (N=58)	5-10y (N=44)	>10y (N=115)
Correlation with Acceptance for the Wayfinding applications	PE (0,70) GP (-0,52) R^2= 0,66	PE (0,82) GP (-0,69) R^2= 0,80	.. .. .. No valid score	PE (0,76) GP (-0,54) R^2= 0,70	PE (0,75) GP (-0,64) R^2= 0,75	PE (0,58) R^2= 0,8	PE (0,79) GP (-0,53) R^2= 0,72	PE (0,74) GP (-0,62) R^2= 0,74	PE (0,71) GP (-0,57) R^2= 0,69
Correlation with Acceptance for the Climate- and lighting applications	PE (0,86) GP (-0,29) EE (0,39) R^2= 0,78	PE (0,84) R^2= 0,73	.. .. .. No valid score	PE (0,83) R^2= 0,73	PE (0,88) GP (-0,41) R^2= 0,8	PE (0,77) EE (0,73) R^2= 0,85	PE (0,86) R^2= 0,79	PE (0,81) R^2= 0,70	PE (0,86) R^2= 0,78

All correlations are significant at the 0,01 level (2 tailed)

	Education						Hours per week working in living lab					Usually works on floor	
	VMBO/ MAVO (N=2)	HAVO (N=4)	MBO (N=22)	VWO (N=4)	HBO (N=71)	WO (N=114)	0<10	10<20	20<30	30<40	>40	0-4	4-8
Correlation with Acceptance for the Wayfinding applications	.. .. .. No valid score	.. .. .. No valid score	PE (0,85)) GP (-0,62 R^2= 0,81	.. .. .. No valid score	PE (0,73) GP (-0,51) R^2= 0,72	PE (0,72) GP (-0,55) R^2= 0,69	PE (0,78) GP (-070) R^2= 0,81	PE (0,80) GP (-0,59) R^2= 0,77	PE (0,67) GP (-0,41) R^2= 0,57	PE (0,75) GP (-0,82) R^2= 0,82	.. .. .. No valid score	PE (0,91) GP (-0,31) R^2= 0,84	PE (0,85) R^2= 0,74
Correlation with Acceptance for the Climate- and lighting applications	.. .. .. No valid score	.. .. .. No valid score	PE (0,88), GP (-0,75) R^2= 0,88	.. .. .. No valid score	PE (0,87) R^2= 0,75	PE (0,84) GP (0,27) R^2= 0,72	PE (0,84) R^2= 0,73	PE (0,86) GP (-0,31) R^2= 0,76	PE (0,84) GP (-0,30) R^2= 0,73	PE (0,88) GP (-0,47) R^2= 0,85	.. .. .. No valid score	PE (0,70) GP (-0,46) R^2= 0,62	PE (0,74) GP (-0,27) R^2= 0,71

All correlations are significant at the 0,01 level (2 tailed)

The outcome presented in table 22, supports the moderation of *age* regarding the relation between *General Privacy* and *Acceptance* of an IoT application: No statistical significant support is found for the respondents group with an *age* >60 years. For all other potential moderating variable like *gender* and *experience*, no support is found.

An explanation for the moderation of *age* regarding the relation between *General Privacy* and *Acceptance* could probably be found in the fact that elderly people are less protective towards their personal data on the internet then younger people (Walsh, 2014). An explanation of this lack of support for *experience* could lay in the fact that other studies only found a moderation-effect for *Experience* on the factors *Habit* and *Effort Expectancy* and *Acceptance* (Venkatesh, UTAUT 2 , 2012). In this situation *Habit* is not included in the research framework and *Effort Expectancy* does not has a significant effect on *Acceptancy* so logically this moderating effect is also not found significant. This same line of reasoning goes for the lack of moderation for *gender*. This moderator was only found of effect of the relation between the factor *Hedonic Motivation* and *Acceptance* (Venkatesh, Thong, & Xu, 2008), however because *Hedonic Motivations* is not included in the framework it is logical that there is no moderating effect for other factors.

Also the descriptive factors *education, hours per week in the living lab* and *floo*r are analysed, however, no support was found for a moderating effect of these factors. An explanation for this can't really be given, because there was no theoretical basis to execute this moderation. It was just based on a trail-on-error principle and a way to potentially create certain user-profiles.

8.5 Conclusions of the questionnaire

This section covers the main conclusions of the empirical investigation stage and presents the answer to the fourth sub research question of this thesis:
To what extent is the Acceptance of IoT-applications affected by the perceived relevant factors?

After the first round of interviews and the execution of the questionnaire, these conclusions can be drawn:

First statistical analysis confirms the following hypothesis:
HL1: A higher perceived performance expectancy positively influences the acceptance of the Climate- and lighting applications.
HP1: A higher perceived performance expectancy positively influences the acceptance of the Wayfinding applications.
HL3: A higher perceived general privacy positively influences the acceptance of the Climate- and lighting applications.
HP3: A higher perceived general privacy positively influences the acceptance of the Wayfinding applications.

Hence the most important predictors *of Acceptance* of the IoT applications are *Performance Expectancy* in a positive correlation and *General Privacy* in a negative correlation. Put differently, if future-user perceive a high *Performance Expectancy*, then they will score higher on *Acceptance of an application*. If future users perceive high *General Privacy* concerns, then they will score lower on the *Acceptance of an application*.
An explanation for this significant relation for *Performance Expectancy* could lay in the fact that in all other UTAUT studies the factor *Performance Expectancy* has been found of highest influence on *Acceptance* of all factors. This is mainly due to the fact that the direct effect of utility and higher job performance is valued highly by the users of the applications in a working-situation.

An explanation for the significant relation between *General Privacy* concerns and *Acceptance* can be found in the fact that the applications are perceived by employers to be intrusive on the freedom in their working environment. Being able to temporary withdraw yourself from colleagues is found very important. The use of the applications can reduce this perception and therefore reduce the sense of *General Privacy*.

Then no conformation is found for the relations between *Effort Expectancy, Environmental Concerns, Innovativeness* and *Acceptance.* For the factor *Effort Expectancy*, the cause could lay in the relative ease of use of the applications. During the interviews and survey, several product-movies presented the use of the application in a very simple way. Therefore, the perception of the (future) users could be that these applications were not complex to use. This perception eventually lowers the *Effort Expectancy* concerns.

The lack of statistical support for the influence between *Environmental Concerns* and *Acceptance* could lay in the direct and indirect effect of the applications. During the interviews and survey the applications were 'framed' as energy reducing innovations, however this factor does not play a primary role in the acceptance of the innovation. The reason for this could lay in the fact that user see this contribution to a better environment as an indirect and not a direct advantage. During the first round of interviews this *Environmental* aspect was also called a 'positive side effect'.

The lack of statistical support for the influence between *Innovativeness* and *Acceptance* could lay in the fact that the applications and the use of a mobile devices and applications is found very common that users. Therefore, they do not refer to them as *Innovative*. This line of reasoning is also supported in the high amount of respondents that uses (one or more) smart-phones which implicates that the respondents are used to these devices and their applications.

Then, we can remark to great extent a similarity in scores for both application clusters between the factors *Performance Expectancy, Effort Expectancy, Innovativeness, Environmental Concerns* and *Acceptance*. Only the scores on *General Privacy* differ to some extent. This implies that the respondents perceive more privacy concerns using the Wayfinding applications then for the Climate- and lighting applications. The explanation for this conclusion could lay in the fact that the Wayfinding application use and share the location data of the user much more explicitly than the Climate- and lighting applications do.

Regarding the β-values of the factors *Performance Expectancy* and *General Privacy*, it must be noted that this value for the factor *Performance Expectancy* is higher than for *General Privacy*, for both application clusters. This means that if we want to improve the *Acceptance* of the applications, it is best to focus on improving the *Performance Expectancy* rather than to decrease the *General Privacy* concerns. Put differently, the elasticity of *General Privacy* regarding *Acceptance* is higher than the elasticity of *Performance Expectancy* and *Acceptance.*

For the moderation analysis the most important conclusions are:

1. The relation between *General Privacy* and *Acceptance* is moderated by *age*. The group respondents >60 years does not seem to have significant *General Privacy* concerns, while the other groups do.
2. *Gender* and *experience* do not moderate any relation between an independent variable factor and *Acceptance* of both application clusters.
3. None of the other factors of *education, hours per week or floor*, seem to have a moderating effect. This means that we cannot make user-profiles, based on these factors.

Finally, the analysis shows that especially the overall scores of the factors *Performance Expectancy, Innovativeness, General Privacy* and *Acceptance* give room for improvement. These factors score now between 3 and 5 on a scale of 7. Knowing that the score of *Acceptance* depends on the scores of *Performance Expectancy* and *General Privacy* this also means that the improvement can be found in the factor *Acceptance*. As mentioned before in the regression analysis (chapter 8.4.6) the effect of an increase of *Performance Expectancy* on *Acceptance* is much higher than the effect of an increase of *General Privacy*. This means that if we want to increase the overall score of *Acceptance*, it is best to focus on enhancing the *Performance Expectancy*.

9 Explorative interviews with users about recommendations that enhance acceptance

This chapter covers the last stage in the VSD approach, the technical investigation stage. There where the former empirical investigation stage focusses on the people who configure or use the technical innovations, the technical investigations focus on the technology itself. This stage involves the proactive design of systems to support values that are identified in the conceptual and empirical investigation stage (Friedman & Kahn, 2002, p. 3). Put differently, in this stage we seek for recommendations that support the relevant values or factors that influence the *Acceptance* of the IoT applications. These recommendations can relate to the technical systems or the policy behind the design, introduction and use stage of the applications.

From the former chapter we can conclude that two factors significantly support the *Acceptance* of the applications which are *Performance Expectancy* and *General Privacy*. During this technical investigation stage again interviews are held with a user group of the living lab in order to determine their preferences and recommendations related to the technical redesign of the applications or the implementation policy. The analysis of these interviews is done in four steps: the transcription of the interviews, the construction of a long list of recommendations, assigning weight to the applications and finally the summary of all recommendations.

9.1 Step 1: Transcriptions of the interviews

The transcriptions of the interviews are included in the appendix of this thesis. In order to cover the content and the meaning of the interviews, the transcriptions are as literally made as possible made

9.2 Step 2: The long list mentioned recommendations in the interviews

The content of table 23 gives the description of the recommendations that are mentioned by the interviewees. In the column *frequency* represents the number of people who mentioned the recommendation in the interviews. This frequency is supported by quotes that are included in the complete and comprehensive table in the appendix if this thesis.

9.3 Step 3: Utility of the applications

One of the questions in the interview was to weight the different applications on perceived utility by the interviewees. The most useful application gets 4 points per interviewee, the least useful 1 point. In hierarchical order the cumulative scores given by the interviewees are:

1. Workplace finder (11 points)
2. Colleague finder (7 points)
3. Lighting application and climate application (6 points)

This weight of utility per application is supported by the statistical data of the questionnaire. There you see that the highest *Performance Expectancy* score was given to the Wayfinding applications (hence: Workplace finder and Colleague finder). Respectively 4,29 (SD= 1,36) for the Wayfinding application and 3,98 (SD= 1,40) for the Climate- and lighting application.

Table 23: Step 2 of the interview analysis

Recommendations	Frequency	Technical or policy related recommendation
Don't store the location data of the Wayfinding applications and don't use the data for other purposes.	A 1x, E 2x, D 2x	Technical, reduces the privacy concerns
Include an opt-in / opt-out option	A 4x, E 3x, D 1x	Technical, reduces the privacy concerns
Integrate the colleague finder with the outlook agenda's	A 1x, D 1x	Technical, enhances the performance expectancy
Be able to create colleague groups with each their own privacy options	A 1x, D 1x	Technical, reduces the privacy concerns
Automatically restore to default setting the day after you used the privacy modus	A 1x	Technical, enhances the performance expectancy
Only update your location when you move to another work station. Not if you walk to the printer, coffee machine or the toilets.	A 1x	Technical, enhances the performance expectancy
Maximise the accuracy of the location to 1 meter	A 1x	Technical, reduces the privacy concerns
Create a bigger radius	E 1x	Technical, reduces the privacy concerns
Make the radius as small as possible	D 1x	Technical, enhances the performance expectancy
Update your status only five times per hour	D 1x	Technical. reduces the privacy concerns
People use now the Linq-software to find each other	E 1x	Policy
The closer you get to the actual launch of the applications the more you should participate stakeholders to the project	A 1x	Policy
People should be seduced to use the applications with a demo or demo movie	A 1x, D 1x	Policy
First roll out the applications in a small group	A 1x	Policy
Include a clear disclaimer at the introduction. Stress transparency and that the data won't be used for other purposes.	E 2x, D 2x	Policy, reduces the privacy concerns
The use of the application will become habit after some while	D 2x	Policy
Evaluate the applications after launch	D 1x	Policy
Monitor possible side-effects	D 1x	Policy
Biggest perceived advantage is for …	All	Policy

9.4 Step 4: Summary of recommendations

In this last step of the technical investigation stage the goal is to summarize the former table to a shortlist of technical and policy recommendations. In order to do this, the frequency table is leading. The recommendations that are mentioned most frequent during the interviews are regarded to be the most important. In some interviews contradict with others and therefore some of the given recommendations can be in conflict with each other.

9.4.1 Technical recommendations

One of the conclusions from the empirical investigation stage is that recommendations for technical adjustments that lead to an enhanced *Performance Expectancy* or reduced *General Privacy Concerns* will eventually lead to a higher *Acceptance* of the IoT applications. These recommendations for technical adjustments of the applications are listed here in hierarchical order and clustered per application:

Colleague finder:

1. Include an opt-in / opt-out option in the applications. The user wants to be able to switch the application off when he doesn't want to be found. Also include an option that gives exclusive rights to different user-groups or colleagues. Similar to for instance Facebook, the user wants to be only visible for the people he selects.
2. Don't store the location data of the users and don't make the data available for other applications or analysis than only the Colleague finder application. The user of the application shouldn't be confronted with for instance his attendance-data during a performance evaluation with his boss.
3. Integrate the colleague finder application with the agendas of the users. Then you don't only see the location of the colleagues, but also whether they are available. In the living lab all the agendas are already open and shared with all colleagues.
4. Automatically return to a default (opt-in) modus the day after you have worked in privacy modus. This option prevents that user forget to switch the application on each day.
5. Only update the location several times an hour and only display the change in work stations. Don't display movements to intermediate short term locations like printer, toilets or coffee-machine.
6. The user should be able to manually adjust his radius settings. This means that he can manipulate the accuracy of his location.

Workplace finder:

1. Only update the location several times an hour and only display the change in work stations. Don't display vacancies as a result of short term movements like people that visit printer, toilets or coffee-machine.
2. Don't store the location data of the users and don't make the data available for other applications or analysis than only the Workplace finder application. The user of the application shouldn't be confronted with for instance his attendance-data during a performance evaluation with his boss.

Climate- and lighting-applications:

No specific technical recommendations

9.4.2 Policy recommendations

Recommendations for policy adjustments will have contribute to an enhanced *Performance Expectancy* or reduced *General Privacy Concerns* to eventually lead to a higher *Acceptance* of the IoT applications. In hierarchical order the policy recommendations are:

For all applications:

1. Include a clear disclaimer at the introduction. Stress that the data won't be used for other purposes. This will decrease the suspicion of other people using the applications for improper purposes.
2. Use a demo-version or demonstration movie in support of the large scale launch of the applications. Demonstrability is found important by the user group.
3. Participate more end-users as the process nears the introduction phase. Participation of future users stimulates bottom-up communication about the applications.
4. First roll out the applications in a small test group. In this way you can learn from growing pains and improve the applications.
5. Evaluate after the launch of the applications and incorporate post-launch recommendations.
6. Monitor side-effects of the use of the applications, for instance higher absence or lower occupation of the building. Unintended side-effects can be both positive or negative.

Colleague finder:

Investigate the actual need for a colleague-finder. Other applications like the software tool Linq also seem to be working. The user group stressed that there is no actual need for this application in this small building of the living lab. For larger office buildings more utility is assigned to this application.

Workplace-finder, Climate- and lighting-application.

No specific recommendations.

9.5 Conclusions of explorative interviews with users about recommendations

After the analysis of the interviews in the technical investigation stage, we can conclude that several recommendations can be made in order to enhance the *Acceptance* to use the IoT applications. These recommendations mainly focus on improving the *Performance Expectancy* or on reducing the *General Privacy Concerns*.
In order to enhance the *Acceptance*, several measures can be taken. In line with the VSD theory of Friedman (Friedman & Kahn, 2002), these measures are split into technical recommendations and policy recommendations. In this chapter all the conclusions and recommendations are discussed per application.

After the analysis of the interviews we can conclude that most of the recommendations are made regarding the use of the Colleague Finder application. According to the user-group this application is in need for the most adjustments, because it is perceived to be most intrusive regarding the privacy of the user.
What was really striking during the interviews was the amount of suspicion that the interviewees had regarding the use of the Colleague finder application in relation with their employer. All of the interviewees feared that the information generated by this Colleague finder application, could be used by their boss during review sessions or for other reasons. During the interviews we found that this observation was not only caused by the use of the application but also was due to the lack of trust in this organisation. Even though the factor *Trust* was not included in the research model for the empirical investigation stage of this thesis, we do think that this factor could not have a moderating or mediating effect on the relation between *General Privacy* and *Acceptance.* In earlier research *Trust* is found to be an important predictor for the acceptance of Location Based Services (Thomas, Briggs, & Little, 2011) and also the remarks made during the second round of interviews point out to such an influence. This observation however should be investigated in future research in order to make it a robust conclusion.

A second remarkable observation during these interviews was that although the Wayfinding applications are perceived to be very intrusive in the perception of the interviewees, they are also found to have of the highest utility. So here, we see that during the implementation of the technology, a trade-off has to be made regarding the factors *Privacy* and *Utility*.
This same kind of trade-off has already been made several years ago when sharing ones digital agenda became popular in organisations (Palen, 1999). Also then, research found that balancing privacy and utility was crucial for the acceptance of this feature. Now several years later we see that this feature has accepted to a great extent in many organizations.

A third conclusion of this round of interviews is that slightly less utility then the Wayfinding applications, is assigned to the Climate- and lighting applications. These Climate- and lighting applications are found to be accepted better than the Wayfinding applications, however the overall potential yield in terms of energy reduction is slightly less for this category.

Table 24:Overview of all recommendations

Application	Technical recommendations	Policy recommendations
Colleague Finder	Include an opt-in / opt-out option in the applications and include an option of giving read/write rights to different user-groups or colleagues	Investigate the actual need for a colleague-finder. Other applications like Linq also seem to be working.
	Don't store the location data of the users. And don't make the data available for other applications or analysis than only the mentioned applications.	
	Integrate the colleague finder application with the agenda's. Then you don't only the location of the colleagues, but also whether they are available.	
	Automatically return to a default (opt-in) modus the day after you have worked in a privacy modus.	
	Only update the location several times an hour and only display the change in work stations. Don't display movements to intermediate short term locations like printer, toilets or coffee-machine.	
	User should be able to manually adjust their radius settings.	
	Only update the location several times an hour and only display the change in work stations. Don't display vacancies as a result of short term movements like people that visit printer, toilets or coffee-machine.	
Workplace Finder	None specific	None specific
Lighting application	None specific	None specific
Climate application		Include a clear disclaimer at the introduction. Stress transparency and that the data won't be used for other purposes.
General recom-mendations for all applications		Use a demo-version or demonstration movie in support of the large scale launch of the applications.
		Participate more end-users as the process nears the introduction phase
		First roll out the applications in a small test group.
		Conduct a post-launch evaluation of the applications and incorporate recommendations.
		Monitor side-effects of the use of the applications, for instance higher absence or lower occupation of the building.

10 Conclusions

In this thesis the VSD approach described by Friedman et al. is used to give structure to the research and to come with an answer to the main research question: *Which factors, are important for the acceptance of IoT applications within office buildings?*
This thesis is therefore divided in three stages: A conceptual investigation stage, an empirical investigation stage and a technical investigation stage. Every stage and its conclusions is discussed in this chapter, after which some limitations and recommendations for further research are discussed.

10.1 Conceptual investigation

The first stage of the conceptual investigation deals with the first two sub research questions: *Based on current theories, what factors could be relevant regarding the acceptance of IoT applications in office buildings?* And *Which stakeholders influence the acceptance of IoT applications in office buildings?*

In order to answer to these questions this research started with an extended literature review on the main concepts of this thesis: Internet of Things, the theory of Responsible Innovation and the theory of Technology Acceptance. This literature review was then followed by a stakeholder analysis on the living lab, which was conducted in order to appoint the most important stakeholders in this research. The main conclusions of this conceptual investigation are:

The Internet of Things (IoT) tends to be used as an all-purpose word, embracing even the slightest connotation of the concept in it. Therefore, it is needed to specify this concept for the purpose of this research. In this research IoT is used to describes certain applications that are part of the Smart Building™ concept. In this concept the clusters of Wayfinding and Climate- and lighting control are divided in four applications that are subject of this study. The applications are called the Mapiq Colleague Finder, the Mapiq Workplace Finder, The Comfy climate-application and Philips Connected Lighting application.

The theories of Basic Values (Schwartz, 2012); (Dietz, Shwom, & Fitzgerald, 2005);(Ligtvoet, et al., 2015) and Technology Acceptance (Davis, Bagozzi, & Warshaw, 1989);(Venkatesh & Davis, 2000) conceptually overlap each other to a large extend. The factors that are described as depended variables that influence *Acceptance* in the Technology Acceptance Models can be classified in the value hierarchy of Schwarz and Dietz et al. This finding supports the fact that the Technology Acceptance Models can be used in combination with the Value Sensitive Design Process.

The last conclusion of the conceptual investigation stage is related to the stakeholders. Although several important stakeholders are involved in the design-, implementation-, install- and use-phase of the IoT applications, only one stakeholder group is found the most important when it comes to determine the *Acceptance* of the IoT applications and that is the actual end-user. Regarding this thesis this is of course the governmental employee, however, we assume that to a large extent the profile of this governmental employee matches with several other types of employees in the corporate service organisations, like bankers, lawyers, clerks at other (governmental) departments etc.

Because the end-user was found to be the most important stakeholder that influences *Acceptance*, this research is mainly aimed at the perceptions of the end-user regarding the design, implementation and (future) use of the IoT-applications.

10.2 Empirical investigation

In the second stage of this thesis, several empirical instruments are used to specify the relevant factors that influence the *Acceptance* of the IoT applications. In this section an answer is given to the third and fourth sub research questions: *What factors are perceived relevant by the (future) users regarding the acceptance of IoT applications in office buildings?* And *To what extent is the acceptance of IoT-applications affected by the perceived relevant factors?*
Therefore, this stage is divided in two steps: An qualitative interview survey that gives answer to the third sub question and a quantitative questionnaire survey that gives answer to the fourth sub question.

First the interviews are used to narrow down a long list of potential factors that influence the *Acceptance* of the four IoT applications, to a more usable list of merged factors.
After analysing six interviews this list of merged factors contained the following factors: *Performance Expectancy, Effort Expectancy, General Privacy, Concern for the natural environment* and *Personal Innovativeness.*

In the second step of this empirical investigation stage, this list of merged factors is used to develop hypotheses which are quantitatively tested in a cross sectional survey. In total 217 respondents of a population of 469 building-users completed this questionnaire. After the data-analysis, statistical support was found for the following hypotheses:

HL1: A higher perceived performance expectancy positively influences the acceptance of the Climate- and lighting applications.
HP1: A higher perceived performance expectancy positively influences the acceptance of the Wayfinding applications.
HL3: A higher perceived general privacy positively influences the acceptance of the Climate- and lighting applications.
HP3: A higher perceived general privacy positively influences the acceptance of the Wayfinding applications.

Mainly two factors are found that significantly influence the *Acceptance* of all four IoT applications: *Performance Expectancy* and *General Privacy*. Moderation on *age, gender, experience, education, hours working in the living lab* and *floor number,* found only support for *age* as a moderator on the relation between *General Privacy* and *Acceptance*. For the group of respondents >60 years there is no significant correlation between *General Privacy* and *Acceptance* of all four IoT applications. For other age-clusters this relation is significant.

Also in this second step we found that the scores of the factors *Performance Expectancy, Innovativeness, General Privacy* and *Acceptance* give the most room for improvement. These factors score now between 3 and 5 on a scale of 7. *Environmental Concerns* and *Effort Expectancy* already score relatively high, so less improvement can be found in this factors.

Knowing that the score of *Acceptance* depends on the scores of *Performance Expectancy* and *General Privacy* this also means that improvement of *Acceptance* can be found in improving *Performance Expectancy* and *General Privacy*. From the regression analysis (chapter 8.4.6) we see that the effect of an increase of *Performance Expectancy* on *Acceptance* is much higher than the effect of an increase of *General Privacy*. This means that if we want to increase the overall score of *Acceptance*, it is best to focus on enhancing the *Performance Expectancy* then to reduce the *General Privacy* concerns.

10.3 Technical investigation

The findings of the empirical investigation stage are used as an input for the technical investigation stage. This stage provides an answer to the fifth and last sub question: *What recommendations can be made to mitigate concerns regarding the acceptance of IoT-applications in office buildings*? The focus of this stage will be on how existing technological properties and underlying mechanisms support or hinder the values or factors that influence the acceptance of the innovation. Also it deals with the trade-off between values or factors and comes with recommendations for technological or policy redesign of the innovation.
In this stage, interviews are conducted with a user group of the living lab. After the analysis of these interviews we can conclude that most of the recommendations are made regarding the use of the Colleague Finder application. Apparently this application is in need for the most adjustments, because it is perceived to be most intrusive regarding the privacy of the user.

What was found striking during the interviews was the amount of suspicion that the interviewees had regarding the use of the Colleague finder application in relation with their employer. All of the interviewees feared that the information generated by this Colleague finder application could be used by their boss during review sessions or for other reasons. We relate this observation to a lack of trust in the employer / employee relationship. Although, this factor *Trust* was not included in the research model for the empirical investigation stage of this thesis, it does not mean that this factor could not have a moderating or mediating effect on the relation between *General Privacy* and *Acceptance.* The remarks made during the second round of interviews point out to such an influence, however this observation is not supported by any other facts or statistical observations, so future research has to point out whether there is more support for this observation.

A second remarkable observation during these interviews was that although the Wayfinding applications are perceived to be very intrusive in the perception of the interviewees, they also are found to have of the highest utility. So here we see that during the implementation of the technology, a trade-off has to be made regarding the factor that is most preferred: utility or privacy. This trade-off is practically the same as the trade-off made several years ago when sharing ones digital agenda became popular in organisations (Palen, 1999). Also then, research found that balancing privacy and utility was crucial for the acceptance of this feature. Now several years later we see that this feature has accepted to a great extent in many organizations.

Slightly less utility then the Wayfinding applications is assigned to the Climate- and lighting applications, however these applications are found to be accepted better than the Wayfinding applications. The overall potential yield in terms of energy reduction is slightly less for this category.

Finally, several recommendations are found for each application. These recommendations relate to the technical adjustments of the application, or to the design and implementation-policy and eventually lead to a higher acceptance of the applications, through enhancement of the *Performance Expectancy* of the mitigation of *General Privacy concerns*. The complete list of all recommendations per application can be found in table 24 of this thesis. The most important recommendations are:

1. All applications should have an opt-in / opt-out option. Users should be able to switch the applications off and work in some ‘privacy modus’ or ‘default modus’.
2. The data that is collected with the applications should not be stored for a long period and should only be used for the purpose of the applications.
3. A clear disclaimer and user policy should be included during the launch of the applications. Transparency should be stressed.
4. Include (future)user-participation before during and after the launch of the applications. Evaluate the use and be aware of side effects.

10.4 Limitations and recommendations for future research

The first important cluster of limitations of this study relates to the representativeness of this research. The fact that the research is conducted in a cross-sectional way excludes the influence of long term effects.
Secondly the representativeness is limited because of this research is conducted in one single organisation and in one single building. This means that the generizability of the findings is limited to this population and this location. However, the nature of the work and the activities performed in the living lab are not (very) different then the activities performed in other corporate service organisations like banks, insurance companies, consultancy or lawyer firms etc. Therefore, we assume that the findings of this report are to a large extent also applicable on buildings that house those organisations, however this assumption has not been scientifically confirmed yet.
A third limitation related to the representativeness of this study survey is found in the used sample and the overrepresentation of highly educated respondents (> 87% of the respondents).
In order to find more robust support of the findings of this study, it should be conducted in a longitudinal study on a larger and more heterogenic population.

The second cluster of limitations can be found in the used model of Technology Acceptance. Although it is found that the original UTAUT2 model has a predictive capacity up to 70% (Venkatesh, Thong, & Xu, 2012), this research used an altered version of this UTAUT2 model. This alteration can have an influence on the predictive capacity of the model. Post-launch research should therefore be executed in order determine the actual adoption of the applications and the measure the predictive capacity of the used model.
A second limitation of the use of the UTAUT model is that the findings are based on self-reflection of the respondents. It relies heavily on the perceptions of the (future) users and 'concludes' certain theorems, without making any actual measurements to support them.

The third cluster of limitations is based on the energy-reducing effects of the innovations. As stated in the introduction, not much research is done yet to measure the long term effects of the innovations on the actual energy consumption. This includes the innovations separately as well as the combination of the innovations in the same building. Supported by The Green Village, the TU Delft has already started to investigate these effects in a longitudinal program, but in order to keep up with the rapid developments in the IoT-field this single research should be extended or followed up in order to be able also study the effects of the newest innovations.

The last limitation of this research is in the correlation-causality claim. Even though the regression and correlation analysis support the claim for a significant correlation between certain factors and *Acceptance* of IoT applications, this does not mean that there is a strong support for a *causal* effect. Assuming that there is a strong causal relation is a logic fallacy called *post hoc ergo propter hoc*–fallacy: a faulty assumption that correlation between two variables implies that one causes the other. Actual post-launch adoption measurements should be made in order to confirm this causality.

11 Reflection

This Master thesis is my final assignment in order to graduate at the Technology and Policy Management faculty of the TU Delft. I started this Master course two years ago in 2014, after I was assigned by my employer the Dutch Department of Defence, to retrain my educational skills in a Master course at a technical university. I chose Delft because for its challenging MOT curriculum and for the possibility to combine this Master with an annotation on Sustainable Development (TiSD).

This annotation motivated me to find a research subject regarded to Sustainable Development and through some connections in the Dutch Public Service, I found a matching organisation in the Central Government Real Estate Agency. The colleagues in this organisation helped me to gradually pinpoint the actual subject of this thesis: The acceptance of IoT applications in office buildings. A very interesting research question that is completely aligned with the curriculum of MOT and the Technology in Sustainable Development annotation. On top of that it is also found very relevant for the Central Government Real Estate Agency that is on the eve of making large investments in this IoT applications.

Especially the fact that this research contributes to a real business-case, increased my motivation to put a lot of time and effort in this thesis. In the past five month, I learned a lot, not only about theories, but also about how to put them in practice during the execution of the field researches, interviews and surveys. I also improved my English language skills and became versed in structuring knowledge and reporting in a scientific way. Skills that will become of great use during my future work at the Dutch Department of Defence.

Of course there are also some lessons learned regarding the process and the product. To start with the process, I found that when the critical path of your thesis relies on the input of other people, then you have to be very clear about what and especially when you want this input delivered. During this thesis several days, maybe weeks were not efficiently used due to waiting on other people.

A second lesson learned is that working on a project requires a lot of communication with all the stakeholders around that project. Regarding this thesis that is executed for an external (non TU Delft) organisation, this communication part is especially difficult because not all parties have the same interests and speak the same jargon.

Regarding the product, I leaned that only a small piece of research can be covered by a Master Thesis. I hoped that after this thesis I would completely understand all aspects of IoT applications in offices, but that is simply not possible in such a small time-bracket.
A second product related reflection, is that structuring a thesis is not so easy as it seems. I found It hard to separate main and side issues. Now that the report is completed it is much more clear to me how to approach such reports in the future.

Then finally the reflection towards the total MOT curriculum in relation to my thesis. The setup of the MOT curriculum combines topics of all kind of sciences like finance, sociology, philosophy etc. On top of the mandatory courses, students can choose several electives on subjects of their own interest. These two approaches of broad generic management courses and elected speciality courses allowed me to combine the MOT curriculum with the TiSD annotation and at the same time prepare myself for this thesis by following relevant real estate related courses like Zero Energy Design or Environmental Sustainability in the Build Environment. I appreciated this freedom of composing your own Master program very much and I'm certain it allowed me to maximally prepare for this thesis. Therefore, I can highly recommend this MOT curriculum.

12 Acknowledgements

First of all, I want to thank the Dutch department of Defence for giving me the opportunity to withdrawal from active duty for two years and let me conduct this Master education. I see it as a great form of recognition and appreciation, that an employer is willing to invest so much in their employees.

Then, I want to thank all the people who supported me in making this Master thesis, including all the respondents that were kind enough to help me and to provide me with input during my field research, interviews and questionnaires.

Especially I want show my appreciation to Merel de Lint-Zorge, Willy Spanjer and Nadia Schoormans for their support towards the Central Government Real Estate Agency, The Green Village and the Dutch Department of transportation. Without their help, cooperation and feedback it was not possible for me to conduct this thesis.

For the support from the TU Delft staff, I want to thank the thesis-committee for providing me of feedback on my proposal, midterm-update and green light update. A special thanks goes to Dr. Eefje Cuppen, who was my first supervisor and supported me a lot during the last five months with her subtle observations and critical remarks.

Of course I want conclude by thanking my family and especially my wife Joyce for her support during the last two years. Without her help, back-up and support I was never able to complete this Master course.
Finally, a big thumbs-up for my kids, Veerle, Jack and (very recently) Valérie, for making me realise that there are even more important things on earth than graduating from University. I hope that the completion of this Master will be an example for your future educational career.

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14 List of abbreviations

BI	Behavioural Intention
BIa	Behavioural Intention only for Wayfinding applications
CTA	Constructive Technology Assessment
EC	Environmental Concerns
EE	Effort Expectancy
EEa	Effort Expectancy only for Wayfinding applications
EPC	Energy Performance Coefficient
GP	General Privacy
GPa	General Privacy only for Wayfinding applications
HL	Hypothesis for Climate- and Lighting applications
HP	Hypothesis for Wayfinding applications
HVAC	Heating Ventilations Air Conditioning
IN	Innovativeness
IoT	Internet of Things
IS	Information System
IT	Information Technology
NZEB	Nearly Zero Energy Building
PE	Performance Expectancy
PEa	Performance Expectancy only for Wayfinding applications
PGT	Programma Groene Technologieen
RFID	Radio Frequency IDentification
RGT	Repertory Grid Technique
RI	Responsible Innovation
RVB	Rijksvastgoedbedrijf
RWS	Rijkswaterstaat
SD	Standard Deviation
STEM	Science, Technology, Engineering or Mathematic
TA	Technology Acceptance
TAM	Technology Acceptance Model
TGV	The Green Village
TRA	Theory of Reasoned Action
UTAUT	Unified Theory of Acceptance and Use of Technology
VSD	Value Sensitive Design