HOW TO CREATE A SMART CITY?

CO-CREATION OF A SMART CITY WITH CITIZENS

Graduation Report

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PREFACE

The document before you is my graduation thesis and my last work to complete the master Construction Management and Engineer at Eindhoven University of Technology (TU/e). This thesis explores a new phenomenon in the urban environment; the smart city. The smart city is formed by technology and cities, two concepts that I have always followed with great interest. I am one of the first that is researching smart cities and this was not easy. I have learned that no progress is made without risks, and therefore I am proud I took the risk. I have successfully researched the phenomenon and am proud of the result that is before you.

I would like to thank my supervisors from the university. Firstly Bauke de Vries for your clear and critical view on my research. I struggled sometimes with progress and did not always have a clear view of the road ahead. You helped me with clear and critical advice, and showed me methods to give answers to my questions. Qi Han, thanks for your engagement. You always added valuable critical remarks and helped me get to the essence of the problem.

Secondly I would like to thank my supervisors from Park Strijp Beheer for the opportunity you gave me to do my research at Strijp-S. Your vision and ideas greatly inspired me in my quest to research the smart city. Joep van Eijkeren, thank you for your supervision and practical approach to my research. Your clear way of communicating and always critical view helped me to get to the root of the smart city. Also your positive feedback helped me through the research, even when making progress was very difficult. Thijs van Dieren, many thanks for giving me opportunity to work at Strijp-S and be part of the company. It has learned me a lot and I had a very nice time working with you. Alwin Beernink, thanks for your support on my project and for sharing your vision of the world around us. Also thanks to all the other people whom I worked with at Strijp-S. You made my time there unforgettable and the most learning experience I ever had.

Finally, many thanks to my friends and family. You were always there when I needed you and I could not have finished this without you. I want to thank you for your help, support, and feedback. But especially for distractions and entertainment.

With all your help I created this thesis and graduated. It has been the most learning experience of my life and I hope that you read this report with great interest and enjoyment.

Joris Peter Jessen
August 26th, 2015

MANAGEMENT SUMMARY

The smart city is a new concept that arose by advances in technology. Evidence is presented that demographic transition and urbanization are trends that can be influenced by the smart city. The smart city is efficient with resources and can provide thorough analysis that help solve the problems related to these trends. Additionally, the quality of life and economic performance can be enhanced by a smart city. The services themselves can enhance the quality of life by solving needs that are currently not fully addressed. While the development process of these services has the potential enhance economic performance by creating new opportunities.

This report provides an extensive literature review on the smart city and finds out that a smart city is described as "*a city that invests in human and social capital and traditional (transport) and modern (ICT) communication infrastructure to fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance"* (Caragliu et al. 2009). So a smart city does not only invest in technology, but also in human and social capital and aims to achieve this by participatory governance. Therefore the topic of participatory governance is extensively reviewed; in this report also referred to as co-creation in social innovation. The idea is to work together with citizens to solve their needs. To understand the smart city, some technologies that will be very influential to smart cities are discussed such as big data, Internet of Things, and Ambient Intelligence. Also a remark on privacy and security is made. A conceptual model is developed that summarizes what the smart city precisely entails. This model was designed based on the findings of literature and contributes to the understanding of the concept of smart cities. The general idea behind this report is that technology should not be leading, as it will advance nonetheless and is a means to an end. The real end is addressing the needs of end-users, citizens in the case of smart city development.

A best practice in enabling citizen innovation in the urban space is the urban living lab. Therefore urban living labs are already being used to create smart city solutions. An explanation on how to increase citizen participation is given and ways to ensure good group dynamics are discussed.

The hook model by Eyal (2013) forms the basis of the model and the rest of the analysis. The hook model builds on four steps that are repeated in the process of forming a habit: trigger, action, reward, investment. This model is translated to smart city development by co-creation with citizens with open data from Buurtmonitor Eindhoven (2015). The open data is used to calculate the components 'social motivation', 'material motivation', 'openness to experience', 'ability to participate', and 'willingness to participate'. These components are calculated from neighborhood characteristics of neighborhoods in Eindhoven. The willingness to participate is a score that is a rating for neighborhoods on its suitability for smart city development from the citizen's perspective. So it is only based on the willingness of citizens to participate and no technological or other prerequisites for smart city development are considered.

This knowledge was used to create a model on co-creation in System Dynamics that takes the neighborhood data as an input. From literature the Causal Loop Diagram is developed that contains four processes in co-creation on which the Stock and Flow Model is based: internal personal trigger to participate, external media trigger to participate, participation from word of mouth and excessive expectations from participants.

Strijp-S is used as a case study because extensive knowledge on this neighborhood and area development was gained in the creation of this thesis. Strijp-S in an integrated area development in Eindhoven and in this brownfield (existing) development, the former industrial area of Philips is transformed to a vibrant and vital urban working, living and cultural area. Strijp-S has the ambition to become a smart city and is regarded an urban living lab. The idea is to become a smart city by co-creation with all the stakeholders.

A GIS analysis is performed in which the neighborhoods of Eindhoven that are most suited for starting a smart city development are found based on the willingness to participate. The neighborhoods (7) Rochusbuurt, (12) Looiakkers, and (84) Schoot, have the maximum reported value of 0,60 on willingness to participate. They are therefore regarded as the most suited neighborhoods for the start of a smart city development project by co-creation with citizens. For Strijp-S there is unfortunately not enough data available to calculate the willingness to participate.

The modelling effort in System Dynamics (SD) resulted in the first SD model on co-creation and the first SD model that takes the hook model as a foundation. Additionally some concepts that were pointed out by literature are also described by the model. The main ways to influence the co-creation project in a positive way are: education and training, increasing control by participants to ensure ownership of projects, enabling accomplishments to be achieved, and encouraging media to have attention for accomplishments.

From the Strijp-S case it is clear that the willingness to participate is essential, but also very hard to determine. Additionally, it describes that at first technology partners were attracted to create a technological infrastructure. Three recommendations for Strijp-S are given. Firstly, Strijp-S should continue its development on smart cities as the unique possibility that presents itself should not be wasted. Secondly, more interaction with other neighborhoods should be sought to increase the potential participants and to create more scalable solutions. Schoot is recommended as a neighborhood to cooperate with. Finally, the project should follow the main ways to positively influence co-creation discussed above.

The main question of this research is *“How to create a smart city?”.* The subtitle gives a short but complete answer to the main question: *“Co-creation of a smart city with citizens.”* How to exactly create it is impossible to answer, because every city is different and constantly changing. Therefore the smart city must be built with the help of those people who are the experts, the citizens. A neighborhood that scores well on the willingness to participate score is preferred and actual initiatives in the area or an organization that is developing the area is considered very helpful. With the new advances in technology, citizens can interact more with their environment. They can more and more communicate with each other, but also with the public sector and even with objects in the public space. Cities have always been smart thanks to its citizens, and this will not change. The only thing that is changing is that the smart people will now have the opportunity to use that smartness to smarten up their city.

SAMENVATTING

De smart city is een nieuw concept dat ontstond door technologische vooruitgang. Bewijs is geleverd dat demografische transitie en urbanisatie trends zijn die beïnvloed kunnen worden door de smart city. De smart city is efficiënt met haar grondstoffen en kan diepgaande analyses verrichten die problemen met beschreven trends kunnen oplossen. Daarnaast kan de kwaliteit van leven en het economische prestatievermogen toenemen door de smart city. De diensten die aangeboden worden kunnen direct de behoeften vervullen die niet volledig worden vervuld. Terwijl het ontwikkelingsproces van deze diensten de potentie heeft om de economische prestatie te verbeteren door nieuwe kansen te creëren.

Dit rapport bevat een uitgebreide literatuurstudie van de smart city en ontdekte dat de smart city beschreven kan worden als *"een stad die investeert in menselijk en sociaal kapitaal en traditionele (transport) en moderne (ICT) communicatie-infrastructuur om duurzame economische groei en een hoge kwaliteit van leven te bereiken met goed management van natuurlijke grondstoffen door participatie bij maatschappelijke organisaties.* (Caragliu et al. 2009 (vertaald)). Dus een smart city investeert niet alleen in technologie, maar ook in menselijk en sociaal kapitaal en bereikt dit door participatie in maatschappelijke organisaties. Daarom is participatie uitgebreid onderzocht in dit verslag; in dit rapport ook wel co-creatie in sociale innovatie genoemd. De idee hierachter is dat burgers samenwerken om hun behoeften te vervullen. Om de smart city compleet te begrijpen is het belangrijk om kennis te hebben over invloedrijke technologieën die in ontwikkeling zijn: big data, Internet of Things en Ambient Intelligence. Daarnaast wordt privacy en beveiliging besproken. Er is een conceptueel model ontwikkeld dat samenvat wat de smart city inhoudt. Dit model is ontwikkeld vanuit de literatuur en draagt bij aan het begrip over smart cities. De gedachte achter dit verslag is dat technologie niet leidend moet zijn, omdat het zich toch ontwikkelt en slechts een middel is om een doel te bereiken. Het echte doel is het invullen van de behoefte van burgers.

Een werkend concept om burgers te laten innoveren in de openbare ruimte is het urban living lab. Deze worden dan ook al gebruikt om smart city oplossingen te ontwikkelen. Een uitleg hoe de welwillendheid om deel te nemen aan een dergelijk project vergroot kan worden is besproken, alsmede manieren om en goede groepsdynamiek te bereiken

Het hook model ontwikkeld door Eyal (2013) vormt de basis van het model en de rest van de analyses. Het hook model beschrijft vier stappen die herhaald moeten worden om een gewoonte te vormen: trigger, actie, beloning, investering. Dit model is vertaald naar smart city development door co-creatie met burgers met behulp van open data van Buurtmonitor Eindhoven (2015). De open data wordt gebruikt om de componenten 'social motivation', 'material motivation', 'openness to experience', 'ability to participate' en 'willingness to participate' te berekenen. Deze componenten worden berekend uit de data van de buurten van Eindhoven. De 'willingness to participate' is een score die een cijfer toekent aan een buurt en beschrijft de geschiktheid voor smart city ontwikkeling vanuit het de burger. Dus het is enkel gebaseerd op de welwillendheid van burgers om deel te nemen en geen technologische of andere voorwaarden van smart city ontwikkeling zijn meegenomen.

De opgedane kennis is ook gebruikt om een model van co-creatie in System Dynamics te maken, die de buurtdata als input neemt. De Causal Loop Diagram is ontwikkeld met behulp van literatuur en bevat vier processen in co-creatie die de basis vormen voor het Stock and Flow Model: interne persoonlijke trigger om deel te nemen, externe media trigger om deel te nemen, deelname door mond-op-mond-reclame en hoge verwachtingen van deelnemers.

Strijp-S is gebuikt als een case study omdat veel kennis over deze buurt en gebieds-ontwikkeling is verkregen bij het maken van dit verslag. Strijp-S is een integrale gebiedsontwikkeling in Eindhoven en in deze 'brownfield' (oud industrieterrein) ontwikkeling wordt het oude Philipsterrein getransformeerd naar een dynamisch en levendig woon-, werk- en cultuurgebied. Strijp-S heeft de ambitie om een smart city te worden en wordt gezien als urban living lab. De idee is om een smart city worden door middel van co-creatie met alle belanghebbenden.

Een GIS analyse is uitgevoerd waarin de buurten van Eindhoven die het meest geschikt zijn om een smart city te gaan ontwikkelen zijn gevonden met behulp van de 'willingness to participate'. De buurten (7) Rochusbuurt, (12) Looiakkers en (84) Schoot, hebben de maximale waarde van 0,60 op 'willingness to participate'. Zij worden daardoor gezien als de meest geschikte buurten om een smart city te gaan ontwikkelen door middel van co-creatie met burgers. Van Strijp-S is helaas niet genoeg data beschikbaar om de 'willingness to participate' te berekenen.

Het modelleren in System Dynamics (SD) resulteerde in het eerste SD model van co-creatie en het eerste SD model dat het hook model neemt als fundament. Daarnaast worden enkele concepten uit de literatuur ook beschreven in het model. De belangrijkste manieren om het co-creatie project op een positieve manier te beïnvloeden zijn: opleidingen en trainingen, verhogen van de controle door deelnemers om eigenaarschap te creëren, zorgen dat er dingen bereikt worden en de media aansporen om aandacht te besteden voor dingen die bereikt worden.

De Strijp-S case maakt duidelijk dat de welwillendheid om deel te nemen essentieel is, maar ook heel moeilijk om vast te stellen. Daarnaast wordt duidelijk gemaakt dat eerst de technologiepartners warden aangetrokken om een technologische infrastructuur aan te leggen. Drie aanbevelingen voor Strijp-S zijn gegeven. Allereerst zou Strijp-S door moeten gaan met de ontwikkeling naar een smart city vanwege de unieke mogelijkheid die zich voordoet. Ten tweede, meer interactie met andere buurten zou moeten gezocht worden, zodat het potentiële aantal deelnemers toeneemt en zodat beter schaalbare oplossingen kunnen worden gecreëerd. Schoot word aanbevolen om mee samen te werken. Tenslotte zou het project de manieren om een co-creatie project op een positieve manier te beïnvloeden, moeten volgen die hierboven beschreven zijn.

De hoofdvraag van dit onderzoek is: *"Hoe creëer je een smart city?".* De ondertitel geeft een kort maar vrij compleet antwoord op de vraag: *"Co-creatie van een smart city met burgers".* Hoe je het precies maakt is onmogelijk om te beschrijven, want iedere stad is anders en verandert constant. Daarom moet de smart city gecreëerd worden met die mensen die experts daarin zijn, de burgers. Bij voorkeur een buurt die goed scoort op 'willingness to participate' en daadwerkelijke initiatieven in de buurt of een organisatie die het gebied ontwikkeld zijn positief. Door de nieuwe technologische vooruitgang kunnen burgers sneller en gemakkelijker communiceren met hun omgeving. Zij kunnen steeds meer communiceren met elkaar, maar ook met de publieke sector en zelfs objecten in de openbare ruimte. Steden zijn altijd al slim geweest dankzij hun burgers en dit verandert niet. Het enige dat wel verandert is dat slimme burgers nu de mogelijkheid hebben om hun slimheid te gebruiken om hun stad nog slimmer te maken.

ABSTRACT

The smart city can be used to solve demographic transition and urbanization. Additionally, the quality of life and economic performance can be enhanced by a smart city. A smart city does not only invest in technology, but also in human and social capital and aims to achieve this by co-creation in social innovation. The idea is to work together with citizens to solve their needs. A conceptual model based on literature summarizes what the smart city precisely entails. Technology should not be leading, as it will advance nonetheless and is a means to an end. The real end is addressing the needs of end-users, citizens in the case of smart city development. The hook model by Eyal (2013) forms the basis of the model and the rest of the analysis. This model is translated to smart city development by co-creation with citizens with open data from Buurtmonitor Eindhoven (2015). The willingness to participate is calculated; a score that is a rating for neighborhoods on its suitability for smart city development from the citizen's perspective. Strijp-S is used as a case study and has the ambition to become a smart city by co-creation with stakeholders. A GIS analysis revealed that the neighborhoods Rochusbuurt, Looiakkers, and Schoot, are the most suited neighborhoods for the start of a smart city development project by co-creation with citizens. For Strijp-S not enough data was available to calculate the willingness to participate. The first System Dynamics model on co-creation and the first System Dynamics model that takes the hook model as a foundation have been developed. It is found that the main ways to influence the co-creation project in a positive way are: education and training, increasing control by participants to ensure ownership of projects, enabling accomplishments to be achieved, and encouraging media to have attention for accomplishments. Three recommendations for Strijp-S are given. Firstly, Strijp-S should continue its development on smart cities as the unique possibility that presents itself should not be wasted. Secondly, more interaction with other neighborhoods should be sought to increase the potential participants and to create more scalable solutions. Schoot is recommended as a neighborhood to cooperate with. Finally, the project should follow the main ways to positively influence co-creation discussed above.

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PART 1 – PROBLEM INTRODUCTION

1 INTRODUCTION

1.1 Problem Statement

Urbanization has moved rapidly since 1800 and is still not at its peak (Davis 1955). People have been moving to cities mainly in the pursuit of improved economic opportunities and social benefits. More and more manufacturing and agricultural jobs have become automated or obsolete and therefore cities hold the promise of employment in the increasingly service based economies. Additionally larger cities offer infrastructure and services that are less available in rural areas, for example public transportation, healthcare and education. The urbanization rate of today is at a record high and never have there been so many people living in cities. The top 30 metropolises house 10% of the world population, the top 600 house 25% (Dobbs et al. 2011). Cities occupy less than 2% of the world's landmass, but urban residents consume over three quarters of the world's natural resources and are primarily responsible for green-house gas emissions (Marceau, 2008, as cited in Nam & Pardo, 2011). Rapid urbanization has caused problems with waste management, resources, pollution, human health, traffic congestion and infrastructures (Washburn et al. 2010; Toppeta 2010). Rather than technical, physical and material problems there are also social and organizational problems such as multiple diverse stakeholders, high levels of interdependence, competing values, and social and political complexity. In this sense, problems become wicked and tangled (Rittel & Webber 1973; Nam & Pardo 2011).

1.2 Solving the Problem

The city is at the heart of the problem, but there is a strong belief that the solution is in the same spot. Technology can play a large role in overcoming the challenges and problems that have come with urbanization.

The world we are living in is becoming more digitalized every day. In the past this digitalization was only visible in large institutions, but in the last few years this digitization began to inhibit our daily life. There are now many new ways to communicate (e.g. Instant Messaging Services (Whatsapp), Social Media (Facebook), Voice over IP (Skype), etc.), but also sensors.

At this moment we are surrounded by millions of sensors that collect data regarding climate information, social media posts, digital pictures and videos, GPS signals, and many more. These sensors sense, create, and communicate data using the internet and save it in large databases. The amount of data we create on a daily basis is 2.5 quintillion bytes (2.5 Exabytes (10^{18})), so much that 90% of the data in the world today has been created in the last two years alone. These massive amounts of data are big data (IBM 2015).

Sensors and actuators have become more and more embedded in physical objects. They are in cars, telephones, roads and even pacemakers, connected using wired and wireless networks to use the Internet Protocol (IP) to connect to the internet (Chui et al. 2010). This trend of embedded sensors is known as the Internet of Things (IoT). These networks send big data to computers that can respond to it swiftly, some even work without human interaction.

The huge opportunity that the IoT realizes, comes with a great challenge. Big Data applies to information that can't be processed or analyzed using traditional processes or tools (Zikopoulos et al. 2012). As technology advances over time, the size of datasets that qualify

as big data will also increase (Manyika et al. 2011). Many organizations face the fact that they have access to a wealth of information, but they don't know how to get value out of it. 80% of the world's information is unstructured and is growing 15 times faster than the rate of structured information (WEF 2014). However, big data is booming as a Gartner survey revealed that 73% of organizations have invested or plan to invest in big data in the next two years (Gartner 2014).
Research by McKinsey Global Institute reveals that the scale and scope of changes by big data are at an inflection point and will expand extensively as technology trends are developed. According to Manyika et al, (2011), big data can create value for organizations in five ways: (1) Creating transparency, (2) Improve performance, (3) Improve segmentation of customers, (4) Replace human decision making by automated algorithms, and (5) Innovate new business models.
The IoT and the big data that come with it will have an infinite amount of ways to increase the quality of life, and we are about to find out in what ways.

1.3 Context

Two trends have been described; urbanization and digitalization. The idea of bringing these two trends together was started by large ICT companies such as IBM and Cisco. They called this new phenomenon smart city and hope that by doing so they can play a role in the development of cities. The term smart city has many definitions, but the key aspect is the implementation of technology to enhance the quality of life. The market for (smart) city development is huge, mostly because cities have been quite 'dumb' and have only been interested in ICT development for the last years.
Smart cities are being developed and researched all over the world, also in Eindhoven. Since 2005 Strijp-S is being transformed into a new dynamic heart for Brainport Eindhoven, more information on Strijp-S can be reviewed in Paragraph 5.10 and 5.15. With a progressive view to innovation, the goal is to make Strijp-S a smart city. It is acknowledged as an inspiring leading example and is simultaneously a fertile ground for innovations. Park Strijp Beheer has as developer and owner a centralized role in the development of Strijp-S. As developer they fulfill they function as the Public Private Partnership (PPP)(NL: Publiek Private Samenwerking) between the municipality of Eindhoven and Koninklijke VolkerWessels Stevin N.V.. Several powerful parties have joined by assisting in the real estate development program, among them two local housing associations (Woonbedrijf and Trudo). As part of the Smart City development, Park Strijp Beheer searched and found multiple partners that can achieve synergy in the realization of the smart city at Strijp-S: TU/e, KPN, Reggefiber, CGI, VolkerWessels Telecom, TNO, Cisco and Bosch. The created consortium uses the communities in Strijp-S as a test panel for the smart city applications that have to be invented, developed and tested. The Strijp-S community is a solid group of residents, a unique community of entrepreneurs and an unprecedented amount of visitors (approx. 1,5 million per year).
The smart city that will be developed at Strijp-S is connected with a project from the European Commission; Triangulum. The underlying concept of this project is to demonstrate to cities across Europe how to integrate smart city technologies with a high technology readiness level (TRL 7 – TRL 9) into existing socio-technical urban systems and how to adapt existing socio-political frameworks for an improved and accelerated smart city development. Triangulum will develop the selected areas as urban living labs, where new technologies and innovative approaches will be tested, with a view to successfully replicate solutions to other

neighborhoods within the city and beyond. From the start of the project, the follower cities, and at set moments, other interested local authorities, will be engaged in this process, with a view to ensure the development of solutions with a replication potential across Europe. In this project three leading cities (Eindhoven (NL), Stavanger (NO) and Manchester(UK)) will first develop the concepts and make them ready for implementation in three follower cities (Sabadell (ES), Leipzig (GE) and Prague (CH)) (European Commission 2014).
Strijp-S is a smart city under development and has great potential to be inspirational to other cities in the world. Smart cities are future cities and can change our image of cities.

1.4 Motives

The built environment has been the main subject of my education for the last 4 years. To broaden my education in innovation I followed the minor in Entrepreneurship and Innovation and last year also got the certificate with the same name. Out of my interest in management I also got the Technology Management certificate.
IT has always been an interesting trend that I followed, but I was unable to combine this with my education until now. The smart city is the subject that combines my interests with my education as a perfect match. Following the set definition for smart city, I am proud to say that I have been interested in and deepened my knowledge of all the aspects of the definition.
After I found the subject that interests me the most, my desire was to turn my knowledge into practical relevance by combining my graduation project with an internship at a company. The developer of Strijp-S, Park Strijp Beheer, granted me the opportunity to work with them on the smart city development at their newly created subsidiary named VolkerWessels iCity B.V.. I worked with them for seven months and it learned me many things. It was a very learning experience in which I could for the first time witness the process of urban development in practice. And maybe it is not the last time…

1.5 Problem Analysis and Research Question

“It is not about smart cities, it is about smart people.” (van Gijzel 2014). This quote perfectly summarizes the key problem with the term smart city. People have created cities for ages and while they did not do this perfectly, they advanced and adapted and many older cities are perceived as very nice places to live. So we cannot build cities without involving the people, the citizens themselves.
So a smart city attempts to enhance the quality of life and solve problems caused by urbanization. This leads to the main research question: *“How to create a smart city?”*.

1.6 Research Objectives and Limitations

The objective of this research is to reveal how a smart city can be built, stimulate the development of smart city services, what the characteristics are for a suitable location to start smart city development, improve knowledge of the co-creation process with citizens in urban development, and hereby contribute to development of smart cities.
The sub-questions of the main research question contribute to the understanding of the research objective. By answering these questions, a good insight in answers to the research question can be gained.
To start answering the main question it is first of all important to find an answer to the question (1) *“Why a smart city?”* and (2) *“What is a smart city?”*. These two questions can lineout what is at the base of smart city development and can explain why anyone would

want a smart city to come into existence. It is expected that literature and experience in the topic of smart cities can answer these questions.
To answer the research question additional research must be conducted to find out (3) *"How to influence smart city development?"*. If people are the main creators of cities, their support is essential for the successful development of a smart city. With help of literature, neighborhood characteristics that are important for smart city development are established. These form the basis of the developed model. In modelling the process of development, new information on external and internal information is gained and recommendations for smart city development can be given.
Next there is the need to explain (4) *"Where to start a smart city?".* To achieve the support of citizens, a neighborhood with high potential of participation is preferred as starting place. The characteristics established as answer to the third research question form the foundation of this analysis. Neighborhoods are examined to find out what location is most suited for smart city development. The result are maps with statistics of regions that determine where a the development of smart city should start.
An important note is that once technologies are implemented and used, new uses will almost certainly develop. Especially if considering sensors that generate data, these sensors can make the urban environment more interactive in ways beyond our imagination.

The limitations set in this research are already somewhat explained in the sub-questions. This is an overview of the set boundaries of this research:

- The research focuses on smart city development in co-creation with citizens;
- Question (3) only considers the neighborhoods of Eindhoven;
- Open data is used as input for the analysis to increase the possibilities of reusing the model;
- Strijp-S is discussed as a case, but there is no data available to use Strijp-S as neighborhood for the simulation, therefore an average neighborhood is used for the simulations

1.7 Methodological Justification

The research was conducted by using the following methods: Literature review, Interviews with experts, Case Study, Geographic Information System (GIS), and System Dynamics (SD). First a literature review will be conducted which will provide theoretical information about reasons for smart cities to be built and contents of smart cities (sub 1-2). Next, System Dynamics is used to research and come to a model that uses input from a region and can be used as a decision support system for smart city strategy and development (sub 3). Subsequently, the case of Strijp-S is reviewed to gain additional information of an actual smart city development. At last Geographic Information Systems (GIS) will be used to find out where to best start the smart city development (sub 4).

1.8 Research Model

The purpose of this research is to create find out how to facilitate the creation of a smart city. A literature review forms the foundation of the research. Afterwards information extracted from experience and experts is used to set the further goals for this research. Accordingly it was found out that where to start and how to influence are questions that literature fails to answers completely. Therefore the end of this research focuses on these questions. The whole process can be reviewed in Figure 1-1.

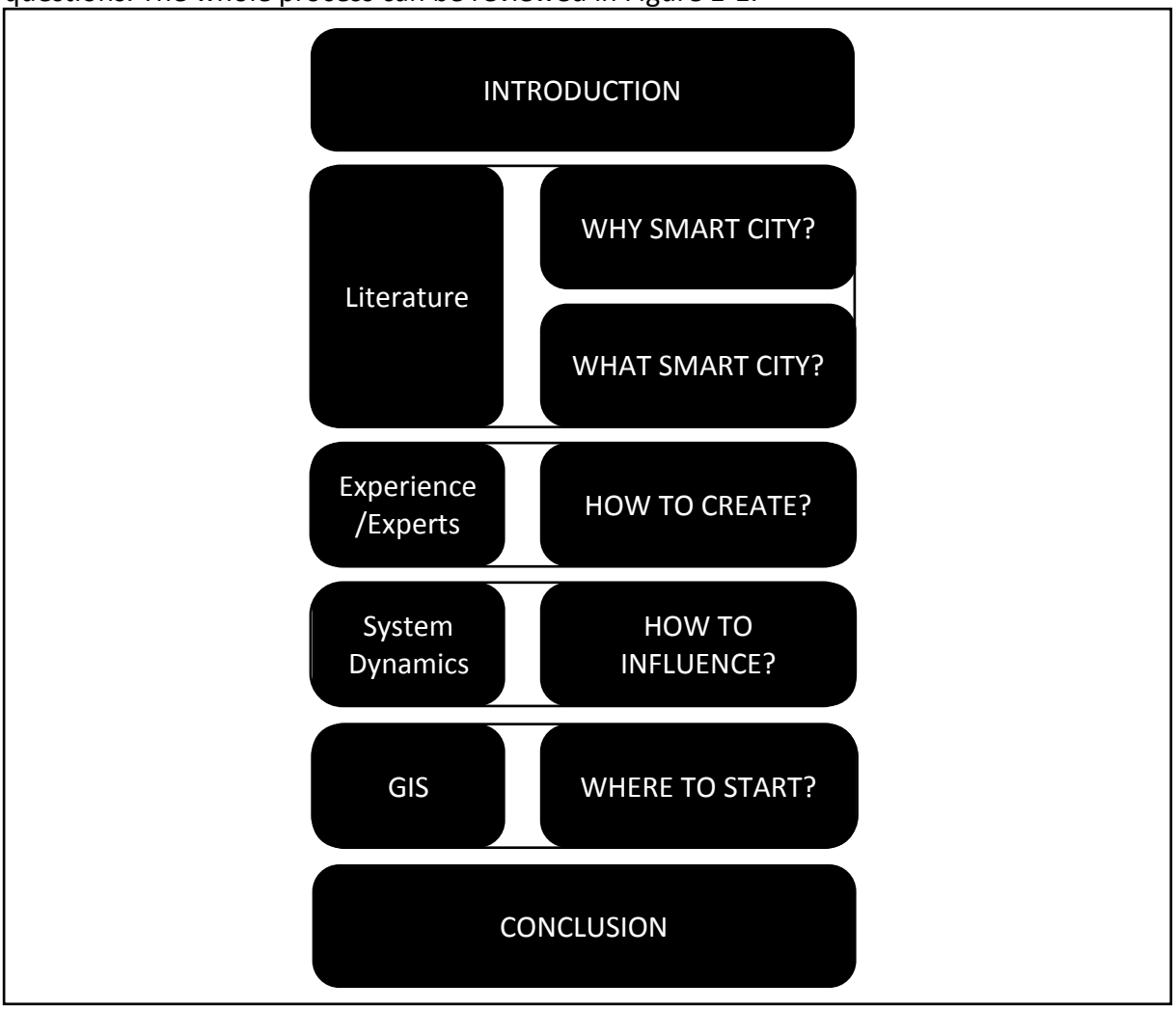

Figure 1-1 The Research Model

1.9 Expected Results

The expected result is report that gives a recommendation on how facilitate the creation of a smart city. By examining motivations for smart cities, smart cities themselves, co-creation and social innovation, recommendations for smart city development can be given. All information obtained will be used in a model in System Dynamics (SD) that can be used as a decision support system for smart city strategy and development. This will help the development of Strijp-S and smart cities in general. Analysis in Geographic Information Systems (GIS) will visualize needs that can be seen as major opportunities for starting facilitating the creation of a smart city.

Smart cities are under development and no answer to the research question is already found. Therefore if all steps of this research provide usable information, this research is not only unique, but also very valuable as it gives a potential solution to an existing problem.

PART 2 – LITERATURE REVIEW

Cities house many people, while they occupy little space. This has, together with their rapid growth, caused problems with waste management, resources, pollution, human health, traffic congestion, infrastructures, and more. *"We are continually faced by great opportunities brilliantly disguised as insoluble problems"*, John W. Gardner. He explains that in great problems are great opportunities, as is the case with urbanization. It is not only because of the great problems that opportunities are created, because cities generate more than 80% of global GDP today (Dobbs et al. 2011).

Smart cities are of particular interest because they have the potential to solve four major problems: demographic transition, urbanization, quality of life, and economic performance. Accordingly, describing why is the topic of the second chapter.

After the why question is answered there is still little understanding of what a smart city exactly entails. Therefore the topic of the third chapter is describing what the smart city is. This is done by explaining multiple city typologies and giving information on viewpoints and definitions of a smart city. Additionally, the trend that is responsible for the existence of the term smart city, digitalization, is discussed. A theoretical explanation of social innovation gives a look at answering the research question by explaining co-creation. Next, a conceptual framework summarizes the third chapter. The third chapter ends this part by explaining in what way this research can complement to the existing literature on smart city development.

Chapter 4 synthesizes literature on the topic of co-creation and smart cities. Additionally, it is found out that two questions remain unanswered in literature. Accordingly the third part of this report focuses on these questions.

2 WHY A SMART CITY?

Why? This question is a logical starting point, however it is a question that is often forgotten. Many companies do not know why their customers are theirs. Sinek (2009) developed the golden circle, a model based on the most successful brands of the world. He found out that these brands all have a common way of thinking handling and communicating, completely the opposite to the thinking process of most of the world. According to him, successful and influential companies approach their customers by asking the why question.

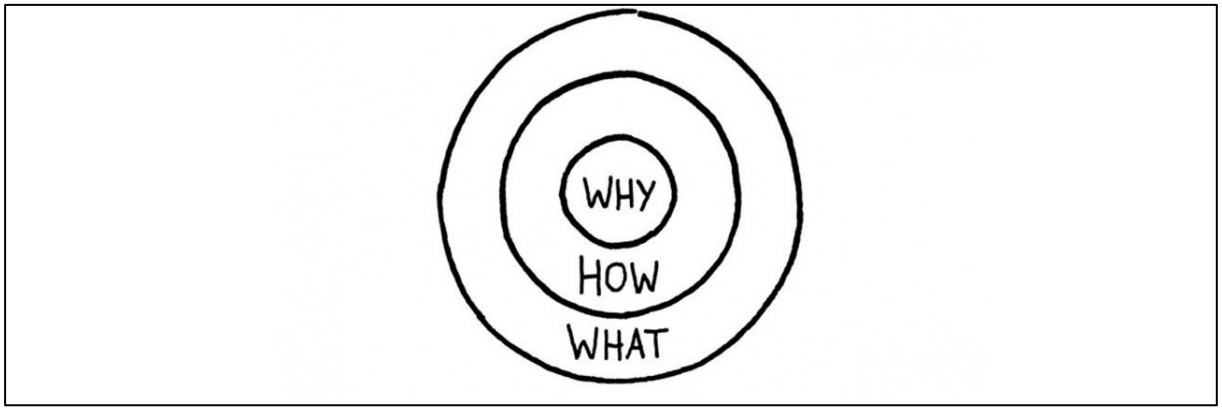

Figure 2-1 The Golden Circle by Simon Sinek (2009)

The Golden Circle contains three circles as can be seen in Figure 2-1. The what circle represents the products or services that the company sells, how describes the way in which they deliver what and why describes what the company believes in and what their driving force is. Most companies start with the outside ring (what) and then work outside-in. The most successful companies start with the core (why) and work inside-out.
Sinek argues that people do not buy products because of what you do, but rather why you do it. The differences between large companies are small, but customers believe these differences to be much larger. This goes for leaders as well; employees who believe in the same things as their leader are more motivated and more loyal.
The Golden Circle is also compared to the human brain. When people communicate outside-in, they can understand complex information such as features, benefits, facts and figures, but this does not drive behavior. When people communicate inside-out, they use the part of the brain that controls behavior and decision-making and after that the language part attempts to explain the decisions using the neo-cortex. So it is better to influence the feeling (why), than to attempt to manipulate the ratio of people (what).

This report starts by answering the why question. Though the smart city is a complex concept that can benefit from an outside-in communication, the smart city requires more than simply understanding to be actually developed. In later chapters the action part of the smart city will be made clear as the development towards smart cities requires participation by all stakeholders. But first; *"Why a smart city?"*.

2.1 Demographic Transition

The first reason for smart city development is demographic transition. According to Boundless (2015), resources are needed to have population growth. However, currently the regions with lowest resources are growing the fastest. Demographic transition theory explains this phenomenon by describing four transition stages.

The first is the pre-industrial stage. This stage is characterized by high birth and death rates, with only slow growth and a relative young population. In this stage, families benefit from children as they contribute to the household and generate income as they grow up. They are also the primary form of old age insurance for parents.

The second stage is the industrial revolution stage. Here countries are starting to industrialize and death rates drop because of improved food production and health and sanitation. Birth rates remain high, so the population growth is extremely high. Western Europe passed this stage during the 19th century and more developed countries in the 20th century, which explains the recent population growth. The average age in this stage is increasingly low.

Stage three is the post-industrial revolution. In this stage the birthrates fall because the advantages for having children from the pre-industrial stage fade. Other changes that occur in this stage are *"better access to contraception, higher wages, urbanization, commercialization of agriculture, a reduction in the value of children's work and increasing parental investment in the education of children"* (Boundless 2015). With dropping birthrates and longer living people, the average age of the population is growing.

The fourth stage, stabilization, is named after its stabilized population growth. Birth rates drop further and can even cause a shrinking population. Death rates remain constant or can increase because of bad lifestyle and ageing population. The large generations born before this stage put a growing economic burden on the new generation. Difficulty funding pensions or other social security is possible.

European cities are in the latter stage of the shift from high birth and death rates to low birth and death rates. Resources form a challenge, with the *"larger older generations putting a burden on the smaller younger working population"* (Goulden 2014). This goes hand in hand with a switch from a perspective of 'growth and increase' towards a 'maintain and improve' perspective that better suits the stabilization stage (Lee 2003; Reher 2004; Morgan 2011; Goulden 2015). The development of a smart city can contribute to the demographic transition by being very efficient in its resources, while maintaining a high wellbeing rate.

2.2 Urbanization

The urbanization trend is first mentioned in the introduction. Summarized, cities form the economical basis of the current society, present huge opportunities of growth and prosperity and thus grow even more. This presents the cities with problems of all sorts, making cities problematic in terms of emissions, waste, health, traffic, etc. Cities are at the cause and at the solution side of the problem of urbanization. But every city is unique, with different contexts, cultures, histories and people living within their borders. There is no and will never be a single solution to the problem of urbanization, due to this uniqueness. Smart cities as seen can address the issues of urbanization, given the fact that they are context specific. This also greatly relates to the answer of the main research question of this report. Paragraph 3.4 explains in what way the smart city can be developed in a context specific way.

2.3 Quality of Life (QoL)

An increase in the Quality of Life (QoL) is coupled with the demographic transition. The most basic needs of food, shelter, safety and social contact become more easy to fulfill as the stages of industrialization pass by. But QoL is a complex concept and in this paragraph its definition is explored and lined out.

The concept 'Quality of Life' has been in use since 1964 and there is still no single definition. Definitions vary in their constructs. Some use terms such as happiness, life satisfaction and positive affect, while others consider external influences such as crowding, noise pollution, criminality and income level as important, and a third group considers it to be strictly limited to personal aspects of life. Rice (1985) defines it as follows: *"QoL is the degree to which the experience of an individual's life satisfies his/her personal wants anti needs (both physical and psychological)."* Another definition is:" *QoL may be defined as subjective well-being. Recognizing the subjectivity of QoL is a key to understanding this construct. QoL reflects the difference, the gap, between the hopes and expectations of a person and their present experience. Human adaptation is such that life expectations are usually adjusted so as to lie within the realm of what the individual perceives to be possible. This enables people who have difficult life circumstances to maintain a reasonable QoL."*(Janssen as cited by GDRC n.d.).

The definition that will be used is one developed by University of Toronto's Quality of Life Research Unit (n.d.), because of its clarity and comprehensiveness. According to them, QoL is: "The degree to which a person enjoys the important possibilities of his or her life". This concept is further specified in Figure 2-2. Enjoyment has two components; experience of satisfaction and the possession or achievement of some characteristic. Possibilities are split down in three domains that also have three domains each; being (who one is), belonging (connections with one's environments), and becoming (achieving personal goals, hopes, and aspirations).

- *"Physical Being: physical health, nutrition, exercise grooming and clothing, and general physical appearance.*
- *Psychological Being: psychological health and adjustment, cognitions, feelings, self-esteem, self-concept and self-control.*
- *Spiritual Being: personal values, personal standards of conduct, spiritual beliefs.*
- *Physical Belonging: home, workplace/school, neighborhood, community.*
- *Social Belonging: intimate others, family, friends, co-workers, neighborhood and community.*
- *Community Belonging: adequate income, health and social services, employment, educational programs, recreational programs, community events and activities.*
- *Practical Becoming: domestic activities, paid work, school or volunteer activities, seeing to health or social needs.*
- *Leisure Becoming: activities that promote relaxation and stress reduction.*
- *Growth Becoming: activities that promote the maintenance or improvement of knowledge and skills, adapting to change."*

The QoL can vary from one individual to another, because of the importance and enjoyment of each of the three main or sub-domains. But this comes with a limitation of this concept; individuals can be satisfied in a context with low quality. But this is realistic as people can be unaware of possibilities or suppress feelings for certain reasons. So to be able to compare different cases of QoL, the environment is included. A quality environment is seen as one which: *"provides for basic needs to be met (food, shelter, safety, social contact), provides for*

a range of opportunities within the individual's potential, and provides for control and choice within that environment.". Many definitions of the smart city refer to QoL as can be seen in Paragraph 3.2. The smart city is an environmental concept, thus related to a quality environment. Researchers expect that the smart city will be very influential in maintaining a QoL, with trends as demographic transition and urbanization influencing it.

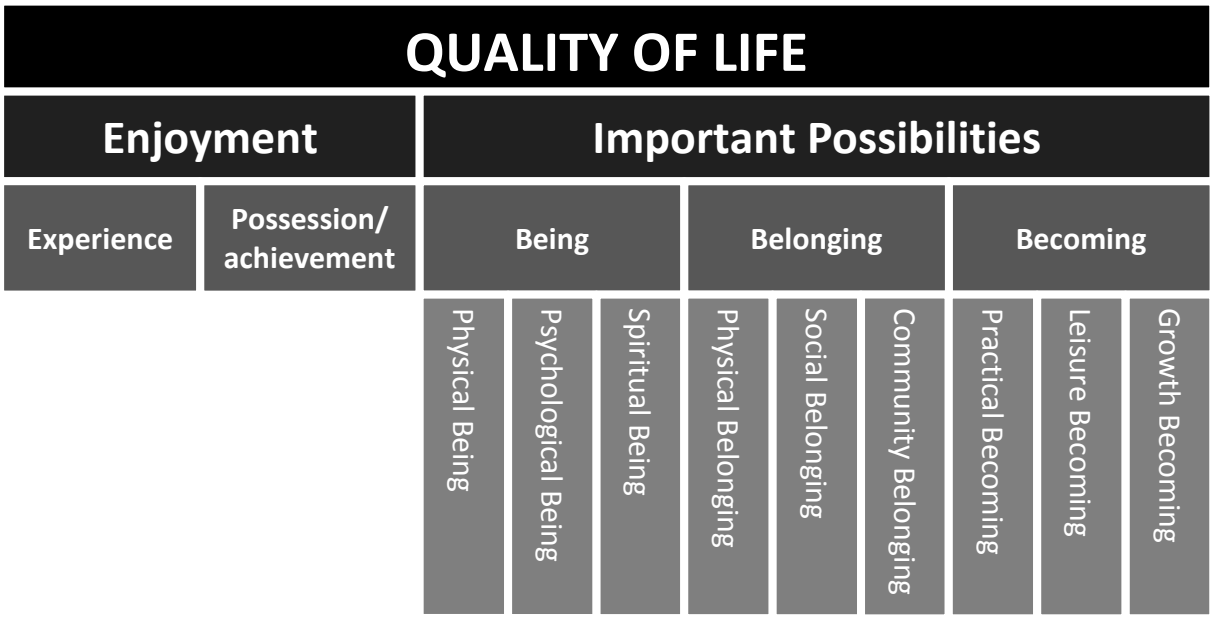

Figure 2-2 Quality of Life definition (University of Toronto's Quality of Life Research Unit n.d.)

2.4 Economic Performance

In addition to the quality of life, the economic performance of a city can be enhanced by the smart city as well. This is because a direct link between creativity and smart city development exists. The idea behind it is that to create an innovation such as a smart city, creativity is needed. In mobilizing this creativity, the economic performance van be greatly influenced as is discussed below. Paragraph 3.4 continues on how this creativity can be mobilized.

Social researchers define economic growth and performance according to human capital. The local availability of skilled and highly educated people is the main indicator of local economic performance. This is due to the fact that the creation of new ideas and innovation is reliant on the human capital endowment. Subsequently, higher human capital gives an advantage for the localization of innovative enterprises and this improves local firms and productivity.

Human capital is mostly measured by the educational success, mostly by taking the share of people with a university degree. However, Hall (1999) predicted that there is more than education to economic development. Therefore the traditional view of human capital has been questioned, since it does not full capture capabilities of individuals in the sense of skills such as creativity and innovativeness, and on experience. Florida (2002 as cited by Marrocu & Paci 2011) suggested a new way to measure human capital, revolving on 'the creative class'. In his measurement the actual occupation in specific job sectors is taken as starting point. Marrocu & Paci (2011) tested this new type of measurement and found out that *"highly educated people working in creative occupations are the most relevant component in explaining production efficiency"*. They conclude that there is extensive evidence that *"highly*

educated, innovative, open and culturally diverse environment is becoming more and more central for productivity enhancements".
The smart city attempts to mobilize this innovative and open environment in its development. Opportunities are created in the process of development, and these opportunities can be taken by people, which can enhance the economic performance.

2.5 Conclusion

The sub question of this chapter is: *"Why a smart city?".* Answering the sub question at this point is fairly straightforward looking at the paragraphs of this chapter. Evidence is presented that demographic transition and urbanization are trends that can be influenced by the smart city. The smart city is efficient with resources and can provide thorough analysis that help solve the problems related to these trends. Additionally, the quality of life and economic performance can be enhanced by a smart city. The services themselves can enhance the quality of life by solving needs that are currently not fully addressed. While the development process of these services has the potential enhance economic performance by creating new opportunities. These factors answer why a smart city development is something that everyone should want.

3 WHAT IS A SMART CITY?

The Golden Circle starts with why. Mostly it is followed by the question how, but the complexity of the term smart city requires further explanation first. Therefore the choice is made to first answer the question: *"What is a smart city?"*. The question will be answered by first listing other types of cities, followed by a definition of a smart city. Thirdly, the trend that lead to the creation of the concept of smart cities is discussed; digitalization. The chapter ends with a theoretical background on co-creation with citizens as this is seen as an important topic in answering the research question.

3.1 City Typologies

Over the last decades, cities have devoted a great deal of attention to try to resolve their problems. These problems are often related to the topic of urbanization. A new term to characterize the interventions by cities is a smart city. What this term actually means and related trends are explained in this chapter.

There is still no precise definition or accepted characterization of smart cities. The development of this is limited by the vagueness and ambiguity of the term 'smart'. Smart can on one hand describe something as *"uses computers to make it work so that it is able to act in an independent way"*. But on the other hand can also imply that something is *"intelligent, or able to think quickly or cleverly in difficult situations"* (Cambridge University Press 2015). The former of these definitions will be referred to as smart technology and the latter as smart people. This is where the translation of the term smart has a potential misfit with the rollout in urban development.

The problem of a misfit is not limited to the choice of a word. There is a tendency of cities to label themselves according to commonly used typologies (smart/eco/livable/etc. cities). Because of this ,*"who would not want to live in a smart or ecofriendly city?",* cities have transformed these terms into hypes. And as more and more people began to use these terms, the terms lost their distinctiveness and have become buzzwords.

As part of this, the cities have named their solutions in various ways: 'sustainable cities', 'green cities', 'digital cities', 'smart cities', intelligent cities', 'information cities', 'knowledge cities', 'resilient cities', 'eco cities', 'low carbon cities', 'liveable cities', 'ubiquitous cities', and even combinations, such as 'low carbon eco cities' and 'ubiquitous eco cities'. These sometimes new categories of cities are all used by policy makers, planners and developers. However, they often embody distinct perspectives (Jong et al. 2014). To understand what a smart city is, an understanding of the interrelationships and differences across city concepts is necessary. First five distinctive and commonly used city types are discussed ('sustainable city', 'eco city', 'low carbon city', 'knowledge city' and 'resilient city'), followed by four typologies closely related to smart cities ('information city, 'digital city', and 'ubiquitous cities'

The 'sustainable city' is the most frequently occurring category and the largest and most interconnected city typology (Jong et al. 2014). This concept addresses the ecological, economic and social dimensions of sustainable development (UNEP 2002). These three, also known as the three pillars of sustainability, are the most common view on sustainable cities, but there are others (Camaren & Swilling 2012). These other views arise from the three pillars, but focus more on one of the three. This reason and the fact that this term is the most comprehensive of all cause that the sustainable city is used most and that all other categories can to a certain extent be named a sustainable city.

‘Eco or ecological cities’ aim to reconstruct cities in balance with nature (Register 1973). The original definition was therefore focused at ecological preservation, but it was recently broadened. More mainstream use lead to more social and economic factors were underlying to this category, making this definition barely stand out to the sustainable city in definition. Eco cities represent a narrow view on cities combined with nature and ecology, therefore it has been used less in literature than the related sustainable and low carbon cities (Jong et al. 2014).
Compared to the eco city, the ‘low carbon city’ is a recent response to the climate change debate. The main idea is to reduce the carbon footprint by reducing non-renewable energy sources (DTI 2003). Mostly eco cities and low carbon cities are seen as the same thing, but in academic literature the difference is that low carbon cities point more towards energy issues and are associated with engineering and economic thinking.
The next category is ‘knowledge cities’, integrated cities that physically and institutionally combine functions of a knowledge ingredients. This is done in local developments to offer a platform for the city to develop in a sustainable way, for example a science park with civic and residential functions (Yigitcanlar et al. 2008). This category does not contain either a focus on ICT or ecological sustainability, however it can be instrumental to this as this type of city relies on the community participation. Once that is achieved, ICT or ecological sustainability can be focused on when the community requests this as a collective innovation process (Valkering et al. 2013). This category appears to be solo in the field compared to the other categories, however it is connected with sustainable, eco and low carbon cities (Jong et al. 2014).
The ‘resilient city’ is another city typology. A very complete definition of resilience is: *“resilience means the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including the preservation and restoration of its essential basic structures and functions”* (UNISDR 2010)**.** So it means that a system is self-sustainable, but can also be self-providing if necessary**.** Combined with city, academic literature describes a resilient city in multiple ways, but the idea is a city that is able to handle problems and disasters, adapt to trends and develop its form to maintain its sustainability.

The ‘information city’ is closer related to the smart city than the previous discussed typologies. Various definitions are used, but all contain the following: *“digital environments collecting official and unofficial information from local communities and delivering it to the public via web portals are called information cities*" (Sproull & Patterson 2004). So there is a sharp focus on information, not on knowledge or social activities.
The ‘digital city’ fills the gap that the ‘information city’ fails to address by being *“focused on the key role of ICT in improving the quality of services and information supplied to citizens”* (Cocchia 2014). It is first mentioned somewhat twenty years ago, similar to the ‘smart city’. But unlike the smart city this city follows the internet diffusion and has been quite stable in its development. Whereas smart city has developed very slow, but with a strong outburst in research in the last years. Because ICT is included in smart city definitions the last years, the digital city can be seen as a subset of smart cities.
Another related city is the ‘ubiquitous city’ or abbreviated as ‘u-city’. It focuses on the strengthening of the role of ICT in civic planning and management (Shin 2009). A broad but widely used definition is given by Anthopoulos & Fitsilis (2010): *“a city or region with*

ubiquitous information technology". From this definition it is clear that this city typology has a very strong IT focus.

3.2 Smart City

The 'smart city' is the relatively new successor of the older 'information city', 'digital city' and 'ubiquitous city'. In 2013 it was even more frequently used in literature than the sustainable city (Jong et al. 2014). This popularity and the ambiguity of the word smart has caused the definitions to be spread out as well. Some argue that smart cities are the equivalent of a city filled with smart people, while others argue that only technology can make a city smart.

3.2.1 Smart Technology

This is one of the definitions used by people out of the first category that focus on smart technology: *"Smart city is the one that uses information and communications technologies to make the city services and monitoring more aware, interactive and efficient"* (Belissent et al. 2010 as cited by Jin et al. 2014). Definitions such as this were used when the term smart city was first mentioned. The combination of the city as main driver of change and (smart) technology that provides solutions to societal challenges lead to the concept of smart cities.

Those parties who have specific concern to develop, deploy and innovate technology innovations tend to focus on the technology side. Examples of parties that have this view are large technology and ICT companies. A focus on ICT is not necessarily a bad thing as it can help cities to develop and transform positively (Florida 2003). However, the term smart city is designed to be more than this and labelling it smart without focusing on other aspects of being smart negates the power that the smart city can yield (Begg 2002 as cited in Hollands 2008).

IBM has a vision that corresponds with this IcT focus. They have the idea of a control room for a city that provides an IcT-based overview that allows for (automatic) interaction with the city (Dirks et al. 2009).

Concepts as this are criticized by many, among them is Adam Greenfield. He goes 'against the smart city' in his book with the same name. He explains that technology focused companies give a vision of smart city as a turnkey installation, but that a city is formed total contrary to this. A city, he argues is a product of distinctive geographies, social milieus and inhabitants. People do not live their lives divorced from the physicality of the city and themselves. The thrust is that a person, not the city as a whole, must be the atomic unit of urban data and that the smart aspect is formed by alterations in response to the uniqueness of the city (Greenfield 2013).

Townsend is another critic IBM's smart city. He believes in the creativity of citizen-concerned civic hackers to create smart cities. But these will not take on the work of IBM's engineers and large ICT companies such as IBM are indispensable for successful large-scale, city wide projects. A smart city needs both. *"Cities are not businesses; put people first"* (Townsend 2013 as cited by Pool 2013).

3.2.2 Smart People

The view on smart cities has changed from smart technology to smart innovation and smart people, taking a citizen-centric approach. Smart people are considered to be the urban problem solvers instead of high-tech computers. Concepts such as user innovation, social innovation, co-creation and stakeholder collaboration are mentioned in definitions. Their

goal seems to be to improve the quality of life by using innovation, stakeholder participation, and innovative technologies. They review technology as a means to an end, rather than an end itself (Baccarne et al. 2014). This lead to the following most cited definition: *"We believe a city to be smart when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance."* (Caragliu et al. 2009). So the basic idea of the smart city is that by providing IT in an urban area, citizens can be provided with new services and information that allows them to influence the city (Lee et al. 2013). Citizens' participation is seen as a powerful and transformative form for both political and socioeconomic development (UNDP 2002). It has been used widely in democracies to establish democratic norms and practices, but has also stimulated public actors to develop responsive and accountable programs and policies. This is fueled by the recent rise in the use of digital technology among citizens and civil society organizations that offer the possibility of strengthening citizens' voice in politics. These new technologies change interrelationships between citizens, public institutions, organizations (NDI 2013). So an investment in ICT only cannot make a city smart because management and policy need to change accordingly (Hollands 2008). This is the reason why smart cities go beyond 'information cities', 'digital cities' and 'intelligent cities' by the additional focus on the influence of people and changing government (Allwinkle & Cruickshank 2011; Leydesdorff & Deakin 2011).

3.3 Digitalization

The concept of smart cities uses Information and Communication Technology (ICT) in a way that addresses the quality of life by tackling urban living challenges. To understand what a smart city can be, further information on the systems that are used and in development is presented in this paragraph.

ICT is developing rapidly and creating opportunities to improve the quality of life. The development in ICT has been be summarized by Moore's law; the observation that over the history of computing hardware, the number of transistors in a dense integrated circuit doubles approximately every two years. Moore's law has been true since its statement in 1963, and with the new trending phenomenon such as big data, this is not expected to change (Jagadish et al. 2014).

Data that is currently already being collected, offers great potential to help solve all sorts of problems related to cities. This data is commonly referred to as big data. Big data is acquired in various ways, one of them is by sensors. These sensors are becoming more embedded in the environment and are becoming increasingly interlinked. This trend is referred to as the Internet of Things (IoT).

3.3.1 Big Data

Basically big data are datasets so large and complex that new technologies are necessary before we can use them to their full potential. The term big data has been used in literature for years, but as industries became aware of its value a few years ago, the word has to a large extent become a buzzword (Chen et al. 2014). Big data is a relatively new term as the interest in it increased exponentially since 2011 (Blasiak 2014; Google 2015). The two words that form this term are not complex by themselves, but the term big is in this case not defined by a quantifiable amount. Because quantity of data is growing very fast, data

volumes that are big now, can be small tomorrow. Big describes the relative large size compared to the current size of technological capabilities to store and analyze data.
The first appearance of big data was in 2001, presented by Doug Laney, an analyst of META (now Gartner). He used a three V's model to describe big data: *"high-volume, high-velocity and high-variety information assets that demand cost-effective, innovative forms of information processing for enhanced insight and decision making"* (gartner.com 2014; Zikopoulos et al. 2012). In this model, Volume describes that the masses of generated and collected data, make the data scale increasingly big. Velocity means the timeliness of big data, specifically, data collection and analysis, etc. must be rapidly and timely conducted, so as to maximally utilize the commercial value of big data. Variety indicates the various types of data, which include semi-structured and unstructured data such as audio, video, webpage, and text, as well as traditional structured data (Gartner 2011). The company oracle uses this definition to complement the three V's with a fourth V; value. Value is added as a characteristic because this word clarifies why there is so much interest in big data; it has a big potential value that is not yet captured (Dijcks 2013).
Big data itself must be generated in some way. For the Urban environment, the IoT will be responsible for this. It is the connection between these two technology trends that creates opportunities for value creation of big data.

3.3.2 Internet of Things (IoT)

Big data is generated in a variety of ways. One of these ways is an enormous amount of networking sensors embedded into devices, machines, anything. These sensors can collect various kinds of data, enabling mobile equipment, transportation facilities, public facilities, and home appliances to become data acquisition equipment, creating the Internet of Things (IoT). In the IoT all these data acquirers are linked through wire or wireless, often using the same Internet Protocol that connects to the internet (Chui et al. 2010). The data collected by the IoT is different from big data, because of the different types of data collected, characterized by its heterogeneity, variety, unstructured feature, noise, and high redundancy (Chen et al. 2014). IoT is expected to create big data of the urban environment and hereby create huge opportunities for the development of new services that form the basis of smart cities.
The value of big data and IoT is created in the optimization of physical city infrastructures such as road networks and power grids (Miorandi et al. 2012). IoT technology can for example provide advanced traffic control systems. Traffic can be monitored very precisely and services for traffic routing can be used to avoid congestion. The technology can also be used for a smart parking system by monitoring parking places and provide nearby car drivers with information. Another example is the monitoring of traffic to obtain information on speed and cars, but also pollution, smog etc. Additionally IoT could detect criminality and automatically alert enforcement agencies, identify the violator or obtain data on criminality to enable later improvements to the public space to be made.

3.3.3 Ambient Intelligence (AmI)

"The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it". - Mark Weiser

Mark Weiser's quote is directly applicable to IoT and the closely related phenomenon of Ambient Intelligence (AmI)(also known as ubiquitous computing). The widespread

availability of sensors sparked the realization of AmI. Science fiction movies have been using the possibilities of the IoT to give us a view of the future that for example identify someone without the need to mention a name. These features indicated more and more that the system acted as a sensible autonomy, creating (AmI). The term has only been used recently with the new computational and electronic advances that increased the level of autonomous semi-intelligent behavior exhibited by systems, such as smart homes and smart healthcare. The idea behind AmI is that the environment is enriched with the IoT, allowing for the system to be built as an 'electronic butler'. This 'electronic butler' senses features of users and their environment, then reasons about this data, and finally selects actions to benefit users in the environment (Cook et al. 2009).
The definition of AmI is given by a literature review as *"a digital environment that proactively, but sensibly, supports people in their daily lives"* (Augusto 2007). It must be noted that the characteristics of AmI are sensitive, responsive, adaptive, transparent, ubiquitous, and intelligent (Cook et al. 2009). This can be very helpful, but also very frightening if used in the wrong way, the next paragraph elaborates on the continuous battle between the endless possibilities and threats of the newest trends in ICT.

3.3.4 Privacy, Security

The interest for big data, the Internet of Things (IoT) and smart cities is a result of the significant effect that these topics will have on our society. In the current global economy, ICT developments are the major driver of both economic growth and improved quality of life (Atkinson & Castro 2008). Supposedly these developments will change the way in which places are connected, the way people work, and therefore significantly change life (Blasiak 2014). Atkinson & Castro (2008) additionally give a list of progresses and changes that ICT will make to our lives and society. Among them are (5) Giving us a vast array of choices, (7) Letting us monitor our homes and loved ones, (9) Making our lives safer, (13) Giving people greater control over their own lives. The list mentions 'monitor', 'safer' and 'control', these changes can greatly benefit our lives, but there is also a dark side to them.

This duality is the central topic in Brin's book, The Transparent Society. He describes two cities that both have tiny on each lamppost, rooftop, street sign, everywhere. So both cities make extensive 'monitoring', 'safety' and 'control' possible, but these are the only similarities between the two.
City one, the City of Control is where *"myriad cameras report their urban scenes straight to Police Central, where security officers use sophisticated image processors to scan for infractions against the public order – or perhaps against an established way of thought".*
The second city, the City of Trust is where *"each and every citizen of this metropolis can lift his or her wristwatch/TV and call up images from any camera in town. Here, a late-evening stroller checks to make sure no one lurks beyond the corner she is about to turn. Over by the mall, a teenage shoplifter is taken into custody gingerly, with minute attention to ritual and rights, because the arresting officer knows the entire process is being scrutinized by untold numbers who watch intently, lest his neutral professionalism lapse"* (Brin 1998).
However, the thing that bothered Brin two decades ago – the ubiquity of cameras – is no longer the defining technology of our cities. The IoT is finding its way into our society. The way it interlinks the real world with the virtual has the potential to transform our cities more dramatically than even the introduction of the railway. But while the railway opened up our cities, bringing in new things like soap and foreign goods, the coming of the IoT threatens to

restrict our cities. To make them more closed, not open (Kranenburg 2006). The Transparent City of Brin has established a common good by making surveillance equal to all, so enabling the public to have the same access as those in power. In the same way Kranenburg (2006) argues that the architecture of the IoT should be equal for all, public having the same tools as those in power.
The discussed ICT trends offer great benefits to users by offering extensive insight (big data) or customizing their environments (IoT and AmI), meeting their needs without being intrusive. This can give more control to humans, making the environment more responsive to intended actions, by supplying humans with customized information and by reducing the cognitive or physical effort that is required to perform a task (Brey 2005). However AmI can remove the control when the environment adapts incorrectly and humans need to take corrective actions, or when it shares information with third parties or gives access to third parties. Take for example personalized services, they hold the immediate negative effect that personal information is stored and shared (Wright 2005). The saying of *"the walls have ears"* are becoming reality, frightening as it is to many (Bohn et al. 2005). A survey even indicated that privacy protection is regarded more important than the benefits of technologies that use AmI. This is complicated with the fact that the privacy considerations differs by age group and culture (Hensel et al. 2006).
These privacy issues are very important to take into consideration when developing new services. But it does not stop there, security is a second issue that is intertwined with the latest ICT trends (Delsing & Lindgren 2005). Security risks can be created by errors in and around sensors by for example installation errors, sensor reliability, but also sensor communication reliability and security and sensor data security. Encryption is a potential solution, but the challenge remains to implement required security with only minimal resources and with minimal performance reduction (Sen 2009).
Earlier in this chapter was mentioned that ICT developments are increasing the quality of life in various ways. Among these qualities is control: *"Giving people greater control over their own lives".* This means access to information, communication and other possibilities of ICT, but also disabling access to ICT whenever someone feels the need to escape the developing digital society. A survey by Joinson et al. (2006) revealed that potential users of the newest ICT, need privacy to function as a preference that should be customizable by users. Situational aspects trigger different privacy concerns in different people. Privacy should therefore be a decision influenced by context, only then the promise of more control can become reality.

3.4 Smart City Development With Citizens

In Paragraph 3.2.2 it is mentioned that citizens' participation is seen as a powerful and transformative form for both political and socioeconomic development. This is not different for smart cities. Lately there has been more interest in the development of cities with help of citizens. This comes from the logical perspective that citizens themselves know how to solve their needs the best. In a smart city development, the help of citizens is crucial to eventually end up with solutions that actually solve the needs of citizens.
Another advantage of working together with citizens is that the solutions that are created are context specific, meaning that every other location will give other solutions. While this is sometimes seen as a lack of generalizability, it is an advantage. Every city is different and has different needs. There is no one-size-fits-all solution for smart cities, therefore the citizens are needed in the development.

From a very large scale, processes of innovation are commonly described using the triple helix model. This model describes the intensive collaboration between university, industry and government to stimulate the innovation process. All three parties are responsible to generate economic growth, but each have a specific task related to their function. Industry is responsible for the generation of wealth in the economy, university is responsible for the creation of new knowledge and the government has to create policy to control all this (Leydesdorff 2010).
The triple helix model works for innovation, but innovation focused on citizens requires its them to be incorporated as well. Arnkil (2010) first mentions the quadruple helix in which the citizen is the fourth party to complement the helix. The citizens will be integrated in a process of co-creation for new solutions. An advantage is that the needs of citizens can be obtained without noise, resulting in better solutions and reducing the chance of failure. Both helixes are displayed in Figure 3-1.

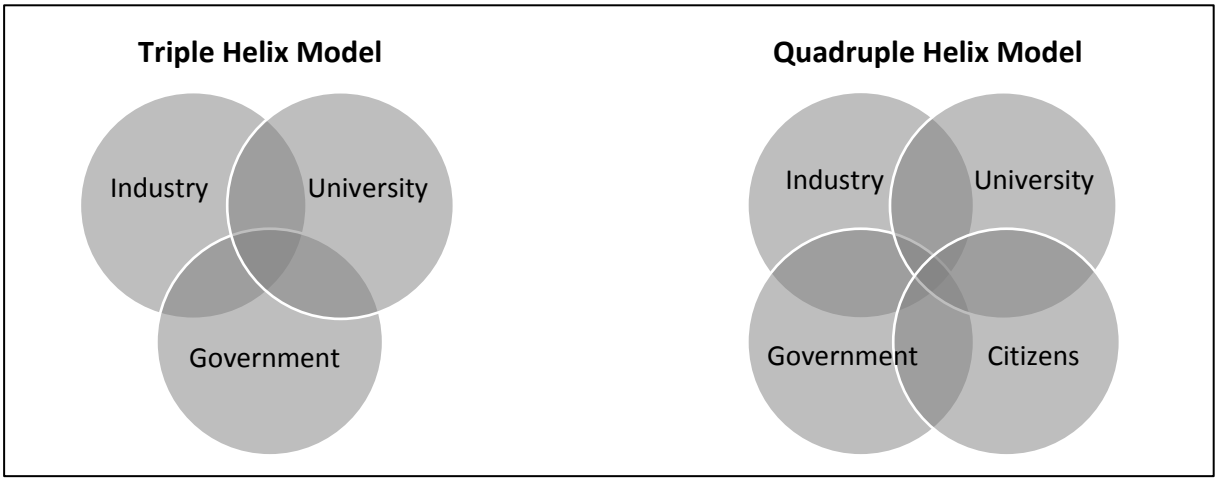

Figure 3-1 The triple helix model and quadruple helix model (Leydesdorff 2010; Arnkil et al. 2010)

Smart cities are not created for citizens, but with and by citizens. This process of involving citizens to solve their problems is called social innovation. The concept of social innovation has gained much popularity in the last years. As a result, there is less clarity on the definition of this phenomenon. The origin of this concept lies in within organizations. The Dutch center for social innovation defines social innovation as follows: *"Social innovation is a new approach to labor organizations and in professional relationships that results in better achievements of individuals' talents and organizations as a whole"* (translated from (NCSI 2011)). However, the last years the concept was extended to the complete social system. The European Commission defines social innovation as: *"the development and implementation of new ideas (products, services and models) to meet social needs and create new social relationships or collaborations"* (European Commission 2013). In the United States president Obama has created a Social Innovation Fund in which public and private funds are combined to *"grow promising community-based solutions that have evidence of results in any of three priority areas: economic opportunity, healthy futures, and youth development"* (The White House: President Barack Obama 2009).

These distinct definitions reveal how much the interpretation of the concept of social innovation can vary. This is also caused by the fact that social innovation is regarded as a

quasi-concept. Such a concept can unite multiple beliefs and maintain a reasonable level of ambiguity. So it explains more an attitude than a belief, leaving room for interpretation. This is very useful in politics because by emphasizing different aspects, can unite different beliefs. Thus the term social innovation is used in a pragmatic way, mainly caused by the fact that existing projects find the development of a fundamental theory not relevant. These rather focus on social problems and attempt to solve them accordingly.

The problem-oriented approach is closely related to the type of problems that social innovation attempts to solve. These are mainly wicked or tangled problems that are almost impossible to solve in a conventional way, given the circumstances. Primarily because wicked problems are unstructured, exploring relationships in the causes and consequences is very hard. The result is that no clear path to solve the problem exists and the problems are additionally dynamic, changing the objectives constantly. Every attempt to solve the problem, changes the properties of the problem. Finally these problems are mostly multidisciplinary, therefore they are not matching policy framework and steered from multiple directions. To effectively solve these problems it is necessary to bring together knowledge from various sources to build a new foundation of knowledge to challenge these wicked problems (Weber 2008). Wicked problems require ambitious interventions that are driven by the problem itself and not the theory behind it. This means that the absence of theory on the concept of social innovation is not in itself a weakness, but rather a necessary flexibility for the wicked problems it attempts to solve (Fenger & Vaandrager 2014).

3.4.1 Definition of social innovation

Social innovation is hard to define in one single definition, because of its quasi-concept state. But to gain clear insight in what this term precisely means, it is necessary to develop a global definition. The two views of social innovation acknowledged by Nicholls and Murdoch (Molico 2014) are taken as a starting point. The first focuses on systems and processes of change in social relationships, while the second emphasizes conceptualizing, designing and producing innovative products to address social, market and environmental needs. In short, the first one focuses on the process and the second one on the product.

Objectives of products are addressing needs that are not seen as important by the market or the state, or needs that are simply too complex to address. The objective of the process change is to increase the participation of people, especially groups that are easily forgotten. Literature points out that social innovation has three core elements. First, social innovation should be new. Either new to the field, sector, region, market, user or application. Second, it must be implemented and applied (innovation), not just developed as an idea (invention) (Shockley 2013). Finally, the social innovation itself should have a higher effectiveness than the existing solution (Julie et al. 2012).

Various sources in literature agree on critical factors of social innovation. stakeholders should be included in the design, execution and usage of the innovation. This process is decisive in the successfulness of social innovation (Bason 2010). Additionally open innovation is seen as a key aspect of social innovation. Open innovation entails participation, distributing knowledge, sharing responsibility and centralizing needs of the user (Chesbrough 2003). Other crucial factors of the innovation process are trust, social capital, network and relationships (Bekkers et al. 2013).

The starting point of social innovation should be the end-user, the citizen in smart city development. As discussed, open innovation is closely interlinked with social innovation. Open innovation centralizes the needs of the user and builds innovation on these needs and to obtain these needs it is vital to start the innovation process with the citizens. This is considered a very effective way to address the needs since people are assumed to be experts in solving their own problems. Besides this, it creates a crossover of sectors, leading to creative solutions that result often in innovation (Mulgan 2006).

So social innovation can be seen as the development and implementation of a new solution (product or process) that addresses a social need more effectively than the old solution. It follows the principles of open innovation and thus builds on the problem-solving capacities of the citizens in the development of the solution (Julie et al. 2012).

3.4.2 Starting social innovation

Now that it is clear what social innovation entails, the process of enabling it is to be discussed. A common perception is one that considers social innovations to be the result of accidental and random processes. These innovations make their way into politics and end up being implemented because of their effectiveness to address needs. Though this perception is true, literature agrees that social innovation can be coordinated (European Commission 2013). First some recommendations for the highest governmental level (EU) are discussed, followed by drivers of innovation on the lower level.

3.4.3 Overcome innovation barriers on the highest level

Bason et al. (2013) give recommendations on how to overcome the barriers of innovation for the European Union. They recognized four principles that should form the basis for innovation:

1. *"Co-design and co-creation of innovative solutions (with other Member States, other parts of government, businesses, the third sector and citizens);*
2. *Adopting new and collaborative service delivery models (across public, private and non-governmental actors, both within and across national borders);*
3. *Embracing creative disruption from technology (the pervasive use of social media, mobility, big data, cloud computing packaged in new digital government offerings);*
4. *Adopting an attitude of experimentation and entrepreneurship (government itself needs to become bolder and more entrepreneurial)."*

These four are already more or less being used by governments. They do for example use contracts with private parties to offer social services, creating opportunities for partnerships. Public parties do also use social media more often and are also starting to use big data to create better solutions. However, the idea of open innovation is still not commonplace within governments. As a result, the needs of the end user are still not centralized and it is questionable whether net solutions actually properly address these needs. The main reason for this is that social policy is mostly delivered by the public sector using the taxpayer's money. Therefore active programs are only started if the outcome is reliable and risks of failure are very low.

3.4.4 Drivers of innovation on the lower level

Once the view on innovation has changed on the highest level of government, great opportunities for innovation on the lower level arise. Four drivers to achieve a working innovation process will be discussed.

Leadership

The first driver is leadership. Public sector leaders can enable innovation by generating support within departments or agencies and can create spaces within organizations to encourage innovative behavior. They have connections in organizations in the public sector, giving them the perfect position to work across silos to develop overarching solutions (Calleja 2015). This leadership is referred to as linking leadership. This type of leadership is linking in four different ways. First boundary spanning, which is reaching across organizations to link knowledge, expertise, information and perspectives of actors. Secondly is the connecting to the political realm to mobilize resources. Thirdly, linking and balancing values that are the interests and claims of stakeholders. Lastly, because openness is important in innovation, so other developments might be able to co-evolve and linking to these other initiatives and linking these is crucial to successful innovation (Bekkers et al. 2013).

Support and co-creation with end-users

The second important driver refers to support and co-creation with end-users. From the perspective of open innovation, this is argued to be the most important driver of social innovation. It is also argued that innovative ideas come from actors who are not at the center of a network. They are not closely connected to each other or the key players in the network and therefore often present new insights and ideas (Bekkers et al. 2013). Citizens are the most important end-users in social innovation. Mainly because they are often neglected, whereas it are their needs that need to be addressed in the government's programs. Co-creation is defined as a thorough involvement by citizens in designing and initiating public service delivery. In the case of smart cities, the initiating party is a public party, while the goal is to develop social innovation. The whole involvement can then be referred to as 'public co-creation during social innovation'. Public co-creation is defined as: *"the involvement of citizens in both the design and production process of public services in order to (co)create beneficial outcomes"* (Voorberg et al. 2014).

Three types of co-creation are identified by Tummers et al. (2015). First citizens as co-implementers in which they are only involved in the execution of delivering a service. Secondly, the citizens as co-designer where they decide how services are delivered, giving them the opportunity to contribute their ideas. Thirdly, co-creation with citizens as initiators and the government as accompanying or supporting actor. Citizens can take the initiative to for instance improve livability and later involve the government for juridical and financial assistance. In the rest of this report, only the second and third form of co-creation (co-designer and initiator) will be meant by the term co-creation.

The support of citizens is critical to determine the success of a social innovation. Only if the views of citizens are taken into account and when they feel that the innovation has substantial value, they will adapt the innovation. The most powerful way to gain support is to let citizens participate in the innovation (Judson 1991 as cited by Bekkers et al. 2013). Research was conducted to find out which factors have the greatest effect on the participation on citizens.

Expectations of the possible outcomes form the first factor. Frequently citizens are very skeptical about what the government will actually accomplish once needs and wishes are communicated to it by citizens (Berman 1997 as cited by Bekkers et al. 2013). Only if accomplishments or outcomes that are in interest of citizens can be shared, citizens are willing to participate in social innovation projects. Outcomes or accomplishments do not have to be self-serving, but can also be motivational or social values as a whole. Important is that these outcomes or accomplishments should be motivational and actually encourage citizens to take action. Once these citizens are involved, the attention paid to the participation grows and the chances of the innovation being adopted grow rapidly. Important to take into consideration a certain amount of the trust in the government and satisfaction with the possible innovations is necessary to have a high enough level of willingness to participate for people to actually participate (Vigoda-Gadot et al. 2008).
The second factor is the effort needed to participate. Knowledge, competences, information and skills are necessary to participate. A higher complexity requires a higher effort. Fortunately the internet has made information sharing and finding much easier, creating more possibilities for co-creation (Mulgan et al. 2008).
Thirdly, policy makers are giving some power away to citizens when they are co-creation solutions. It is important to consider that people in public organizations are afraid to lose control and status and therefore might negatively influence progress in co-creation projects (Bovaird & Loeffler 2013).
The fourth factor relates to representativeness. Citizens who participate will participate again or become more evolved if the possibility arises, which can in time result in the same people participating over and over. This can limit the creativity and new ideas that are brought to the table, ultimately taking away one of the main benefits of co-creation. Representativeness can also become an issue if an intermediary party takes the position of the citizens. They often have the presumption to be perfectly in position to formulate citizen needs, whilst often internal goals and personal motives replace representation goals (Bekkers et al. 2013).

Risk attitude
The third driver is risk attitude. Uncertainty is closely interlinked with innovation, and with uncertainty comes risk. As discussed earlier, public organizations use taxpayer's money to fund innovation, making them wary of taking risks. Additionally politics prefer to get quick wins to get reelected. Possible negative media attention on failures further increases risk avoidance.

ICT and social media
The fourth and final driver are ICT and social media. These have two main functions in the enhancement of innovation. First there is ICT and social media as sources of innovation. They are an enormous source of information and are ubiquitous in the current society, can process large amounts of data, can increase transparency of all kinds of processes and behaviors and give extensive communication possibilities by visualization and interaction. Secondly, the role ICT and social media can play is an open information exchange and communication infrastructure. Information can be linked with various people and thus knowledge can be created and shared. Crowdsourcing and open source software would not exist without ICT and communities and organizations use them to innovate.

3.5 Conclusion

The sub-question of this chapter is *"What is a smart city?"*. To answer this question completely, the conceptual model of Figure 3-2 is designed. The model is based on the combination of three topics discussed in this chapter: cities, technology, and citizens. And their related trends after the arrow. Combining these major topics leads to certain concepts that have been referred to in this chapter. Citizens are more and more included in development processes with technology companies and cities and are co-creating solutions. Technology is advancing quickly and the digitalization trend discussed in this chapter reflects this. Cities are also advancing, but this relates to a currently more problematic trend of urbanization.

When citizens co-create the city together with cities to solve societal needs, this is referred to as social innovation. In case citizens work together with technology companies, product development takes place (not discussed in this report). When cities cooperate with technology companies to solve needs, they use solutions such as big data, the Internet of Things (IoT), Ambient Intelligence (AmI), etc. When the three parties work together to solve needs, this is referred to as a smart city in this report. The smart city cannot be created without the technology support, not without cities' support, but also not without citizens' support.

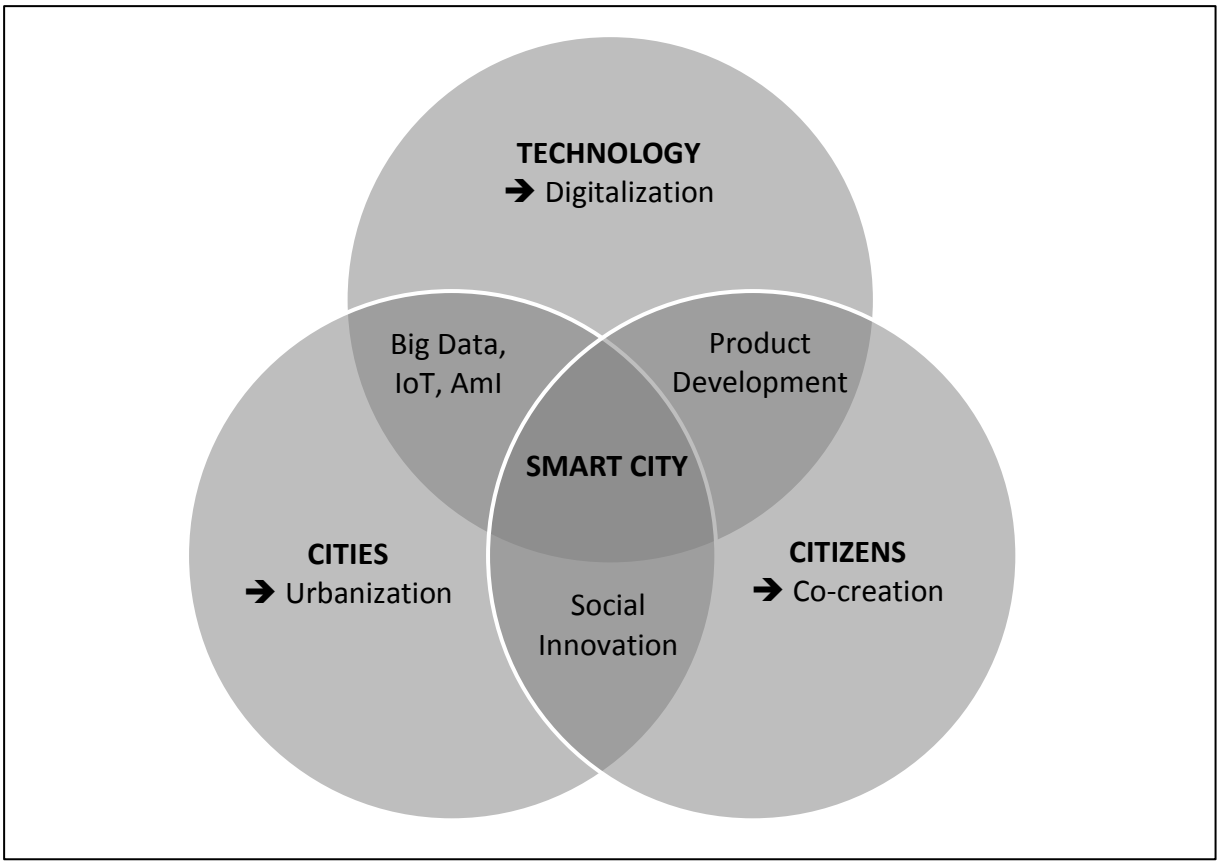

Figure 3-2 Conceptual model smart cities

4 HOW TO CREATE A SMART CITY?

The previous chapters have answered why we would want a smart city and what it entails. This chapter asks the research question to find out what parts are still not completely investigated in literature. It is predicted that technology will continue to advance rapidly, so this is not something to worry about at the city-scale of smart city development (Abdoullaev 2011; Buscher & Doody 2013; Cuddy et al. 2014). Rather the focus should be the process of co-creation, since this process has proven to be very complex (Bason 2010; Liu et al. 2014; Caccamo 2015). Co-creation cannot simply be arranged for the whole city at once, therefore the concept of a living lab is used to start intensive collaboration on a smaller scale. The living lab is discussed in the first paragraph, followed by literature findings on participation to make a living lab work. Next, attention is paid to another factor that can strongly influence the co-creation process; group engagement. At the end the last two sub questions are asked that form the rest of this report.

4.1 Living Lab

A living lab is different from the triple and quadruple helix model. The helix models facilitate exchange of ideas and technologies, whereas the living lab is an *"ecosystem in which end-users and other stakeholders are involved in the development of an innovation over a longer period of time, in a real- life environment, using a multi-method approach, following an iterative process"* (Baccarne et al. 2014). A living lab facilitates intensive relationships between the university, large companies, SME's, start-ups and of course end-users (citizens) as well. The living lab is considered a best practice in enabling end-user interaction. End-users become involved constantly in the development of solutions to suit their needs (Arnkil et al. 2010).

The living lab is a development platform in which user innovation is practiced to create innovation that best suit the end-user's needs. There are two ways in which this is done. Firstly, because end-users are actively participating and co-creating solutions and secondly because the experts and companies have a chance to study user behavior that is otherwise not possible to see. The whole process is accomplished by collaboration with multiple stakeholders. In technological development the group is often composed as follows: *"two or more state-of-the-art technologies, firms (large and SMEs), various organizations that utilize technology or are candidates to utilize technology in the vertical dimension of a value chain, public organizations, users/consumers/citizens, and research organizations."*(Eriksson et al. 2005). The smart city development is for a large part a technology development and therefore this group composition can be useful.

A distinct category of living labs are the urban living labs. This is defined as *"a physical region in which different stakeholders form public-private-people partnerships of public agencies, firms, universities, and users collaborate to create, prototype, validate, and test new technologies, services, products, and systems in real-life contexts"* (Juujärvi & Pesso 2013). Living labs focus on the interaction between end-users and private parties, while urban living labs focus on social innovation. For this reason the government is more closely connected to urban living labs.

Characteristics of a successful living lab have been researched by Veekman (2013). This report summarizes principles that should provide for more successful implementation of living labs with increased possibilities for more user-centered innovation.

Firstly, the living lab should have a technical infrastructure to measure the impact of projects and to monitor it.
Secondly, there should be a minimum level of shared value creation and sharing among stakeholders. To accomplish this, a clear thematic focus and a mixed set of various stakeholders is recommended. The former will lead to shared motives and less differentiated topics, while the latter will increase the level of openness and the number of opportunities.
Additionally a minimum level of openness is required to build up a good ecosystem. This also means that there should a mutual shared interest to enable collaboration with and between partners.
Finally, a minimum set of users and good communication is required. A specific set of participants is required, preferably an already established community. Trust and communication are vital to keep the participants motivated.

4.2 Citizen Participation

To make the concept of the living lab work, participation by citizens is required. One could argue that almost every citizen could participate, as it is after all their needs that are to be satisfied. However there is one large barrier to citizen participation; time (Kleinman et al. 2011). To overcome this barrier, incentives can be used to increase the motivation to participate. An external source of motivation that seems to work according to literature is payment. It helped in the recruitment process and ensured the continued participation of citizens. Internal motivation such as acquisition of knowledge or interests in the topic of innovation are also a reason to participate. It is even proven that people with prior commitments in the innovation topic often produce valuable and useful outcomes (Kleinman et al. 2011). Requirements for citizen participation projects are given by Cornwall (2002). She describes that *"citizens must gain meaningful opportunities to exercise voice and hold account those who invite them to participate".* The notion of accountability is an important one, as there have been issues with representation in citizen participation projects. It must be clear for the people participating that the coordinators ensure that wrongful representation can only be caused by the coordinators themselves and not the citizens who are participating.

Gathering the citizens is another topic that needs further discussion. This concept has not much conceptual design research, but Franz (2014) proposes one that centralizes the needs of citizens. Local stakeholders such as urban renewal offices or local community groups are involved as intermediate actors to gain access to local residents. The first phase is 'Get to know' in which the access to the community and getting to know the needs is the first step. Afterwards options for value creation are lined out. This is followed by the 'Involve' phase in which the options are evaluated by citizens through for example a group discussion or a questionnaire. In the 'Activate' phase, follow-up interviews or role-play for specific options are performed to get greater understanding of the phenomena in the neighborhood and interdependencies. If the options are considered valuable enough and realizable, the phase of 'Co-Creation' can take place in which solutions to the problems that were examined in the previous phases can be created. All phases are displayed in Figure 4-1.

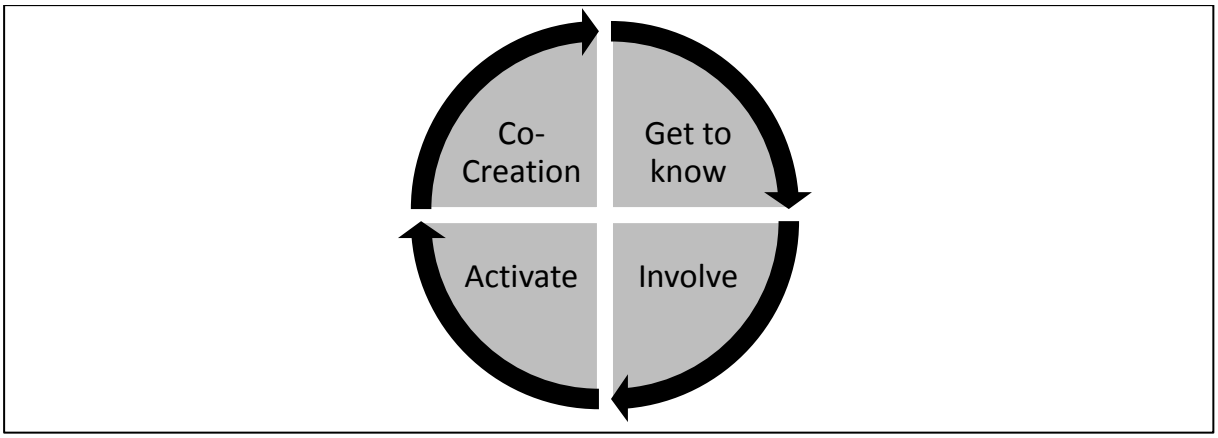

Figure 4-1 The cycle of co-creation (Franz 2014)

It is important that the participants represent the community correctly. Research has shown that *"people who take part in civic or associational life tend to be those with higher socio economic status, the well-educated, employed and affluent"* (Wilson and Musick 2008 as cited by Davies & Simon 2013). However this group alone cannot make social innovation successful since not all the interests of society are equally represented. This representation issue is closely related to projects of social innovation, because no community can be treated as a cohesive whole. Most projects with co-creation present solutions that to a very large extent represent the opinion of those *"with more power and the ability to voice their views publicly"* (Davies & Simon 2013). This is acknowledged by Platteau (2008) who argues that *"the areas where inequalities are the highest and most entrenched, and where one would like to implement participatory approaches in order to correct them, are also those where these approaches are least likely to succeed.".* However, it must be noted that in this report the development of a smart city is researched and therefore the focus is only partially on social factors, because it is complemented by technological factors.

4.3 Group Engagement

Even if the group is representative for the community, the development is still not a guaranteed success. Group dynamics can negatively influence the outcomes and result in for example high risk solutions and solutions in which no-one agrees as the result of groupthink or groupshift.

Groupthink can occur when there is strong group identity that members hold positive and want to protect. When the image is threatened, members will quickly persuade others who are in doubt. Members with doubts suppress their doubts and this forms an unanimity in their behavior. This strengthens the group identity further, with the potential of leading to a solution that no-one agrees with (Robbins et al. 2010).

Groupshift is the change in decision risk between a group's decision and an individual decision that a member within the group would make. Basically the initial risk position of the individual member is exaggerated. It can be that the group decides to be more conservative, but more often the shift is towards greater risk. The cause of this is likely to be the diffusing responsibility within the group. Because the decision is made by the group, individual responsibility for a decision fades away. Whether or not the group will shift towards greater risk is mostly determined by the inclination of the members before the discussion takes place (Robbins et al. 2010).

To prevent negative group dynamics, coordination or control can be used. This coordination is also essential because in a totally open approach, there is the threat of fragmentation of ideas, security and privacy, and problems of too little interconnectedness to the complex system that is called a city. To connect to the city, not only the citizens should participate, but all stakeholders involved in this process towards a smart city. But this must be done with caution as too much control or coordination limits the degree of openness of thinking by end-users (Goulden 2015). The way to do this is referred to by Goulden (2015) as choreographed democracy: *"Choreographed democracy presents a pragmatic and nuanced approach to 'openness' by proposing that an expert choreography, curator-ship, content creation and collaboration support will more likely inspire and enable a stakeholder community to lift their ability and increase their capacity and motivation to engage, act and innovate".* So the goal is to find an optimum between openness and support by experts and stakeholders, because it is believed that with their help the ability and motivation are increased that enlarges the innovative capabilities of citizens. The experts can come from any field of the current urban environment (infrastructure, lighting, planning, legal, etc.), and the fields that are yet to become part of the urban environment (data visualization, app builders, etc.), but also specialists in creative development (architecture, design, communication, prototyping, etc.).

4.4 Conclusion

It is clear from literature that an urban living lab can be effective to create innovations that best suit the end-user's needs. Therefore urban living labs are already being used to create smart city solutions. Literature also explains how to increase citizen participation and how to ensure that the group dynamics are good.

The general idea behind this report is that technology should not be leading, as it will advance nonetheless and is a means to an end. The real end is addressing the needs of end-users, citizens in the case of smart city development.

It is unclear how to influence such a development once it is active. Accordingly, the next chapter will focus on the question: *"How to influence smart city development?".* It is expected that neighborhood characteristics that favor co-creation and social innovation in smart city development can be found. These serve as a foundation for the model. By modeling the process of citizen participation in the co-creation process, the third research question will be answered.

And where should an urban living lab be started? No literature answering this question can be found, therefore the next chapter will also focus on answering the question: *"Where to start a smart city?".* This question uses the established neighborhood characteristics to perform a GIS analysis in which the neighborhoods most suited for smart city development are found.

PART 3 – FIELD RESEARCH

This part covers the main contribution to scientific research and is therefore the added value of this report. The second part has given background information on smart cities and studied the literature by reviewing it. The main findings were that literature fails to answer the two questions that form the chapter of this part.

Chapter 5 will answer the third and fourth sub question: *"How to influence smart city development?" and "Where to start a smart city?".* To do this, first background information on behavior of people is given by the hook model. This information is translated into neighborhood characteristics that favor smart city development by co-creation with citizens. The data on neighborhood characteristics and the hook model form the foundation of the model that is developed using system dynamics. Existing literature will form the basic idea of the processes in the model and to ensure that it has a scientific base. Accordingly, a causal loop diagram and a stock and flow model will be used to research co-creation with citizens. Next, the case of Strijp-S is reviewed. Accordingly, a GIS analysis is conducted to find out what neighborhoods are most suited for smart city development by co-creation. Then the model results of the model are given and the model is validated and discussed. At last the results of the Strijp-S case are used to give recommendations on the smart city development at Strijp-S.

5 HOW TO INFLUENCE SMART CITY DEVELOPMENT?

Smart city development is an innovative process. These processes are never straightforward and are often hard to completely understand. Most of the time a pragmatic approach is used to make choices, because scientific research is a slow process that can rarely keep up with the pace of innovation. In conversations with experts, it is often argued that the time for talking about smart city is over, and we should just do it; just build the smart city. This is ambitious, but possible. This chapter will contribute on the knowledge of such a development by modeling the process of co-creation and analyzing it to find out in what way it can be influenced. First understanding of what drives the behavior to participate is gained, followed by neighborhood characteristics that are influential to this behavior. Next, a model is made to further understand the participation process. Strijp-S is used as a case study and background information on this case is provided. This knowledge is also used to answer the fourth sub question: *"Where to start a smart city?".* Literature does not give a view on where to start, so this is where this report is distinctive and brings added value. GIS analysis are performed to find out in which neighborhood of Eindhoven the willingness to participate is highest. Then the model is simulated and results are acquired. Finally, the results are applied on the Strijp-S case and recommendations for the future are given.

5.1 Limitations

Before the modeling effort is discussed, it is important to acknowledge the limitations that were set and encountered in the model. First of all, the data on which this report is built is open data. This is chosen to enable the calculations methods to be used in other cities as well. These cities can now with only minor adjustments to the data they have, calculate which neighborhoods are most suited for smart city development and how such a process would go using the developed system dynamics model.

As a case study Strijp-S and the municipality of Eindhoven are taken. Strijp-S, because extensive knowledge about this project is gained during the creation of this report. At Strijp-S an attempt is made to start a smart city and their experience has proven very valuable for this report. Because Strijp-S is a neighborhood in Eindhoven, the idea was to incorporate Strijp-S data into the analysis so their position as a smart city can be reviewed. It would then be possible to give an honest opinion about the decision to start a smart city at Strijp-S. There is however one major limitation to this. The open data for Eindhoven is gathered at Buurtmonitor Eindhoven (2015), but this does not contain much data on Strijp-S. Only some data on residents and the area is there, but no population study has ever been conducted there. So the mode is created with knowledge acquired at Strijp-S, but cannot use Strijp-S data as this data is unavailable. For the basic scenario of the model an average neighborhood is used. This neighborhood is Schrijversbuurt and this is discussed in Paragraph 5.12.1.

5.2 The Hook Model

To find out what drives behavior, the hook model developed by Nir Eyal (2014) is used. His theory describes how habits are formed and this theory will also provide basis for the analysis further in this report. The hook experience is designed to connect the user's problem to the developed solution. Two things matter most when forming a habit: frequency and attitude change. It is the cyclic model presented below in Figure 5-1. It contains four steps that will be discussed.

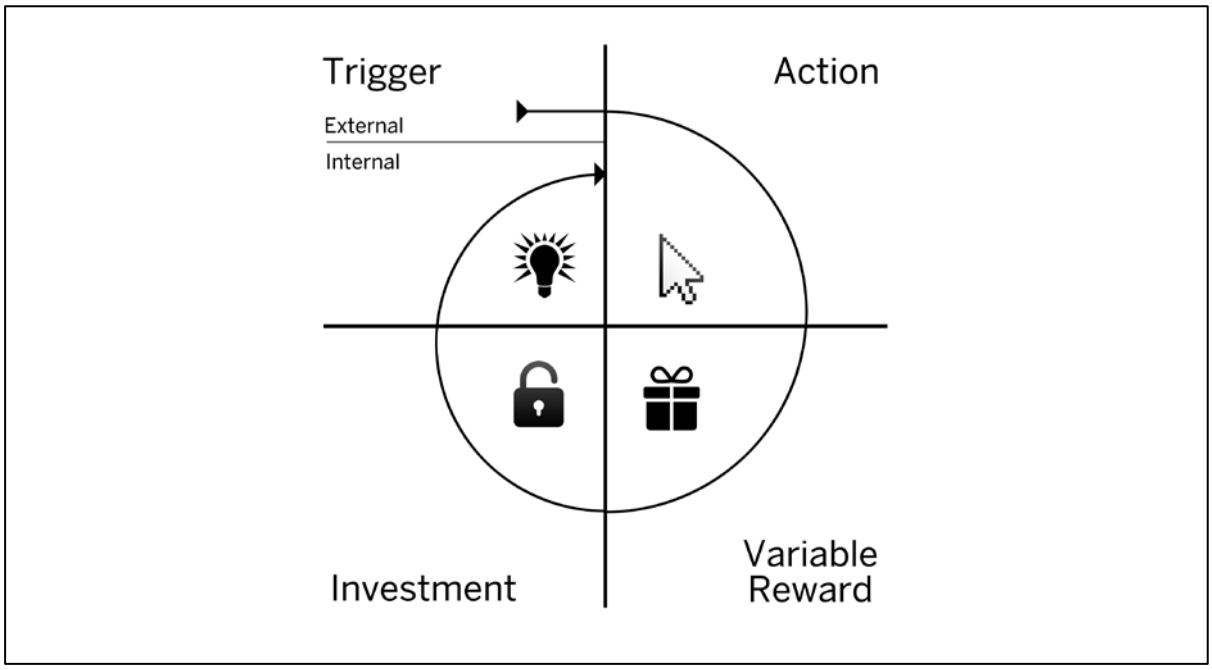

Figure 5-1 The hook model (Eyal 2014)

The first step is 'Trigger'. This is the driver of behavior and it comes in two types; external and internal. Most of the time the starting point is an external trigger such as an email, a phone call, information on media, etc. The information what to do next is within the external trigger. Internal triggers are associations in someone's memory (places, people, emotions, routines, situations, etc.). Emotions are very powerful triggers.

'Action' is the next step in the model. This is the behavior done in anticipation of a reward. Fogg (2009) describes that for any behavior (B) to occur, motivation (M), ability (A) and a trigger (T) are required. The formula B=M+A+T describes this. Motivation can be increased by six factors: seeking pleasure, avoiding pain, seeking hope, avoiding fear, seeking acceptance, and avoiding rejection. Ability can also be influenced by six factors: time, money, physical effort, brain cycles, social deviance, and non-routine. As Figure 5-2 points out, only if the motivation and ability are above a threshold, the trigger succeeds and leads to behavior (action).

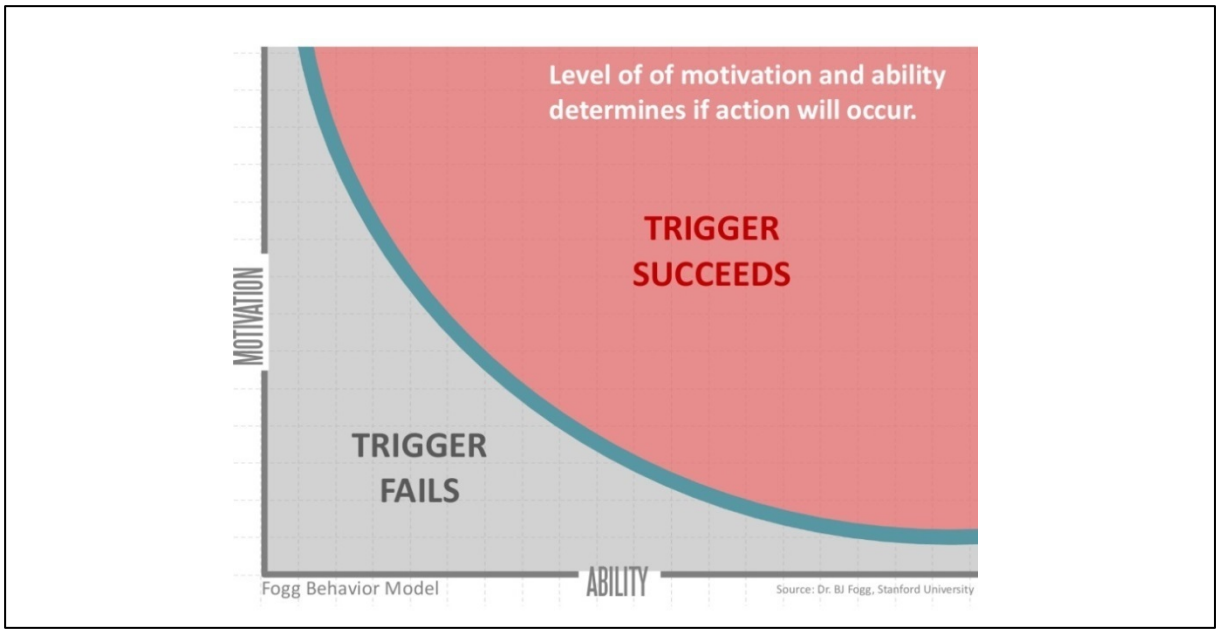

Figure 5-2 Motivation and ability determine action (Fogg 2009; Eyal 2013)

The next step is 'Reward'. Effective rewarding is not about stimulating pleasure, but rather about stimulating the stress of desire. Our reward system activates with anticipation and calms when we get what we want. To stimulate this anticipation, variable rewards can be used. Three types of variable rewards are distinguished; social rewards (empathic joy, partnership, competition), resources (material, information) and self-achievement (mastery and competency, consistency and completion).
'Investment' is the fourth step of the hook. Users invest in something for future benefits. This investment increases the chance of another cycle taking place. Investments load the next trigger for the hook, every successful investment is an open innovation to someone else to return an external trigger. Additionally, investments store value that improve the product with use. When work is put into something, it gets an higher value.
Each time the whole hook is passed, more are more user preferences and attitudes are formed. If the frequency of passages is high enough, a habit is formed (Eyal 2014).

5.3 Translating the Hook Model

The hook model is mainly used to understand and create habit forming products. In the case of smart city development by social innovation, forming a habit is not the goal itself. But the model forms a valuable basis for the understanding of participation and long-term engagement.
To find out where to start a social innovation process, the characteristics of a neighborhood that favors this kind of development must be found. It can be stated that a neighborhood with higher probability of participation is favored over one with lower probability. The probability of participation is calculated using the hook model. Participation occurs in the 'Action' phase of the model and this phase is formed by three factors; Motivation, Ability, and Triggers. The next paragraphs describe how each of these three factors can be measured an at the end they are combined to one value; willingness to participate.

5.3.1 Motivation

The participation in social innovation is closely related to volunteerism, because of its free of charge character. Widjaja (2010) lines out various models and theories that explain volunteer motivation. There are unidimensional models that suggests that there is only one dimension for motivation, but this dimension varies from one person to another. Two-dimensional models distinguish between egoistic and altruistic motivation. Three-dimensional models suggest that there are altruistic motives, material motives, and social motives. Additionally there are various multi-dimensional models that consist of multiple categories of motivations. Because there is a need to make the motivation measurable, the choice is made not to use un- and multi-dimensional models. The former varies too much and is not quantifiable, while the latter is too extensive to make quantifiable. The two-dimensional model contains the egoistic category of motivation that is described by materialistic and social innovation in three-dimensional models. Because of its comprehensiveness, the three-dimensional model is chosen as a basis for motivation in this report.

The three-dimensional model contains altruistic, material and social motivation. However it is very hard to measure altruistic motivation, because it is a very personal motivation. This analysis takes the scale of a neighborhood and it is nearly impossible to distinguish social motivation from altruistic motivation. The choice is made to combine social motivation and altruistic motivation into social motivation, because this term more suits what is actually measured. Social motivation is namely composed of voluntary work, people active to improve the neighborhood, social cohesion and actual neighborhood initiatives. Afterwards also the variables underlying material motivation are discussed.

Social motivation is the motivation to create or enhance relationships with others. In this concept, the other is seen as a some sort of reward instead of being solely instrumental to achieve something else (Tyler 2010 as cited by Goulden 2015). This concept is measureable on a neighborhood level by measurement of: voluntary work, activities to improve neighborhood, social cohesion and actual neighborhood initiatives. The calculation of social motivation can be seen in Table 5-2 and Figure 5-4.

Voluntary work is work done for free for someone else than a close relative. Only out-of-pocket expenses are paid for and volunteers may get training to improve their work. Since January 1st 2015, municipalities can choose to obligate people which have been receiving social welfare payment for a long time to do voluntary work (Citizens Advice Bureau 2013).

People who are active to improve the neighborhood are not only doing so for themselves, but for others as well.

Social cohesion is *"the willingness of members of a society to cooperate with each other in order to survive and prosper. Willingness to cooperate means they freely choose to form partnerships and have a reasonable chance of realizing goals, because others are willing to cooperate and share the fruits of their endeavors equitably"* (Stanley 2013). So the society acts as a whole to keep everyone at a minimum level of welfare. The social cohesion is calculated using six questions that can be found in Veiligheidsmonitor 2014 (CBS 2014 p. 25). A higher social cohesion score means that people are more likely to have social motivation, because they are then more engaged with their neighbors.

At last actual neighborhood initiatives contribute to the social motivation. As discussed in Paragraph 5.2, when people have invested in something its value is increased. In neighborhood projects people cooperate and these relationships become more valuable as

these initiatives last longer. Finding out where these initiatives take place is a difficult task, because they are often not coordinated centrally. Therefore the choice is made to have one example initiative that is centrally coordinated in municipalities implemented in this research; neighborhood watch. A neighborhood watch is a group of people that voluntarily provide surveillance in a neighborhood. They have a passive role and report to the police when they see something suspicious. Mostly members get training and materials and closely cooperate with the police (Gemeente Eindhoven 2015). Neighborhoods with a neighborhood watch report a higher decrease in criminality than neighborhoods without a watch and therefore it is suspected that a neighborhood watch is very effective (Eindhovens Dagblad 2015).

Material motivation is the motivation for some material rewards (Monga 2006 as cited by Widjaja 2010). In the case of social innovation, these are motivations to get rewards that are result of the process; improvement of the neighborhood in some way. This is the case because it is the anticipation of every reward except social and altruistic rewards. The standpoint is that no payment will be made and therefore it can only be the rewards of the process. These can of course also be individual rewards such as skills, and this is okay as long as the participants keep actively participating in the innovation process. Material motivation contains presumed values of the neighborhood; perception criminality increased last year, presumed safety, presumed physical quality facilities, percentage satisfied with quality of housing, presumed parking nuisance, presumed traffic nuisance. All of these neighborhood characteristics contribute to the overall valuation of the neighborhood. If these characteristics are negative, there is more room for improvement of the values. And when people are less satisfied with their neighborhood, they will have a higher material motivation. The material motivation is calculated in Table 5-2 and Figure 5-4. Below the six characteristics are discussed.
Perception of criminality increased last year and presumed safety both have to do with the safety and security feeling of the area. These are included as safety and security are basic needs and failure to supply in them can be devastating for the quality of life of residents (Hipp 2009; Corrado et al. 2010).
Presumed physical quality facilities and percentage satisfaction with quality of housing are also related to neighborhood satisfaction (Ha & Weber 1991). Though housing satisfaction is considered more important, both are significant factors in neighborhood satisfaction.
Dissatisfaction with traffic is also a determinant of neighborhood satisfaction (Oktay et al. 2009). Here presumed parking nuisance and presumed traffic nuisance are measured. Additionally these can be very important factors in smart city development as there are major opportunities in technology development (Miorandi et al. 2012).

5.3.2 Ability

Ability can be influenced by six factors according to Eyal (2013): time, money, physical effort, brain cycles, social deviance, and non-routine. *"Time refers to how long it takes to complete an action. Money represents that fiscal cost of taking an action. Physical effort is the amount of labor involved in taking the action. Brain cycles involve the level of mental effort and focus required to take an action. Social deviance is the extent to which the behavior is accepted by others. Non-routine refers to how much the action matches or disrupts existing routines."*. As discussed in Paragraph 4.2, time is the largest barrier to citizen participation. But having time is a very personal aspect and therefore not measurable with the help of only open data. On

the other hand, money can be measured. From the standpoint of non-payment, the only way in which money plays a role is whether people have enough financials to be able to participate. Therefore the people who are struggling to keep up will be deducted from the people who are able to participate as can be reviewed in Table 5-2 and Figure 5-4. But who are able to participate? To answer this question a paper by Jokela (2015) is used and discussed below.

Jokela (2015) researched how life satisfaction and personality traits are geographically distributed within the UK London metropolitan area, and how the strength of associations between personality traits and life satisfaction vary by residential location (i.e., personality–neighborhood interactions). The results of this research were very useful to determine the ability to participate. This is because they found that openness to experience showed the highest degree of clustering, meaning that they could determine very well which neighborhood characteristics are related to this personality trait.

Openness to experience is also referred to as openness, originality and open-mindedness. It *"Describes the breadth, depth, originality, and complexity of an individual's mental and experiential life"* (John et al. 2008). High scores on openness to experience predict more years of education completed and high creativity tests scores (McCrae & Sutin 2009). It can also predict entrepreneurship (Zhao & Seibert 2006). Therefore openness to experience is seen as a very beneficial personality trait for participants of the innovation process of smart city development.

Jokela (2015) found that the personality openness to experience relates to lower percentage of couple households with children, higher population density, lower percentage of older people (65+), and more. Unfortunately there was no data available in the for all characteristics in the Buurtmonitor (2015). So they could not be all incorporated in the calculation of openness to experience. The correlations were given in the report and will also be used to calculate the ability to participate in Table 5-2 and Figure 5-4. The following characteristics are used: percentage of older people (65+), percentage of couple households with children, population density, percentage of people with white ethnic background, total crime rate, income, and employment rate.

5.3.3 Triggers

Triggers are the driver of behavior as discussed in Paragraph 5.1. External triggers are for example mass media and social media, while internal triggers are part of people's memory (places, people, emotions, etc.). Triggers are essential to create behavior. In this report they are suggested to be the answer to the fourth sub question: *"How to influence smart city development?"*. Given that there is a motivation and ability, the triggers can make or break the initiative of co-creation. Therefore researching how these triggers can be influenced is an important part of this research. In Paragraphs 5.7, 5.8, and 5.9 the focus is on answering the next research question and uses theory about triggers as a foundation. Now that all components of the hook model have been translated to co-creation, the hook model for this research is built. Figure 5-3 summarizes all components of the hook model and forms the basis for the model of the next paragraphs. All components of this picture have already been discussed, except for the link between *Reward* and *Media*. This link is displayed in this picture and regarded as important since it can be of great influence to the trigger that determines participation. *Media* come into play only when things are accomplished, whereas the *Personal Trigger* is active continuously as people invest in the participation.

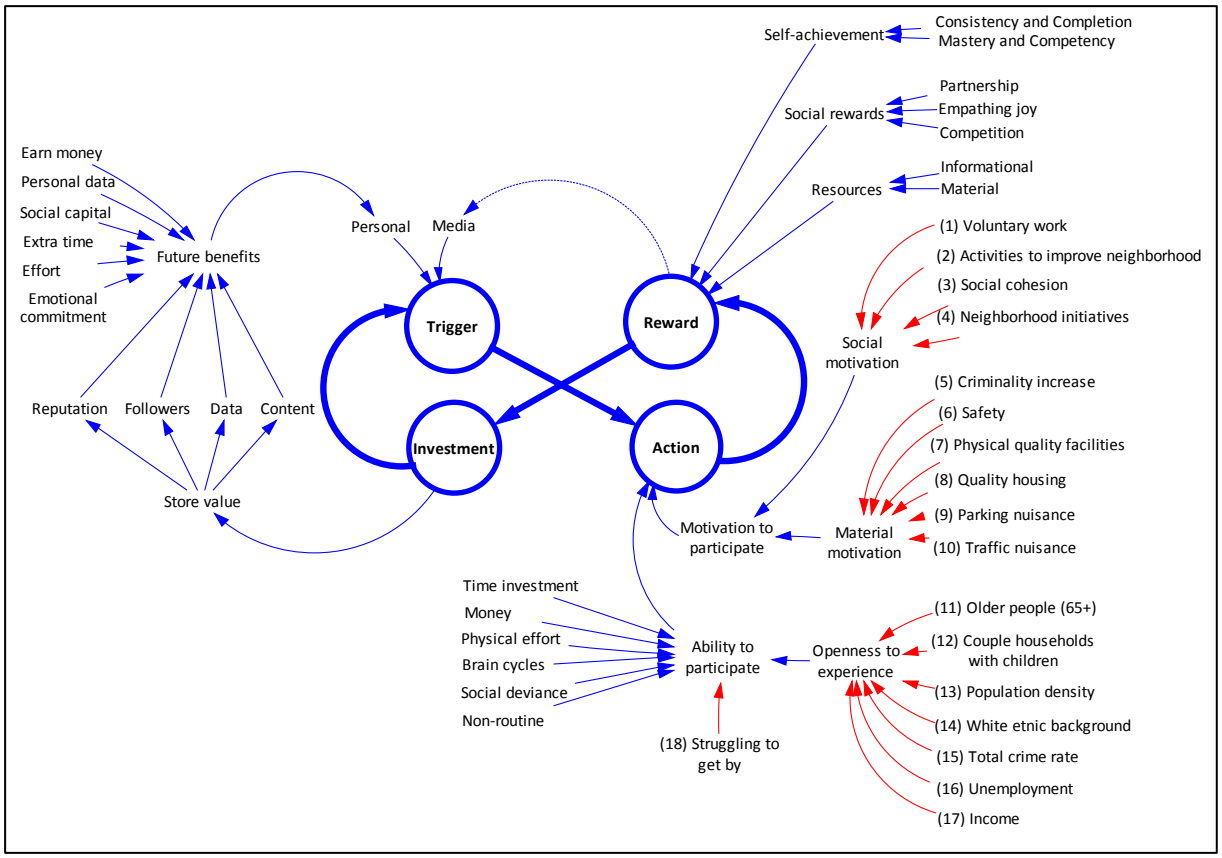

Figure 5-3 The hook model for co-creation

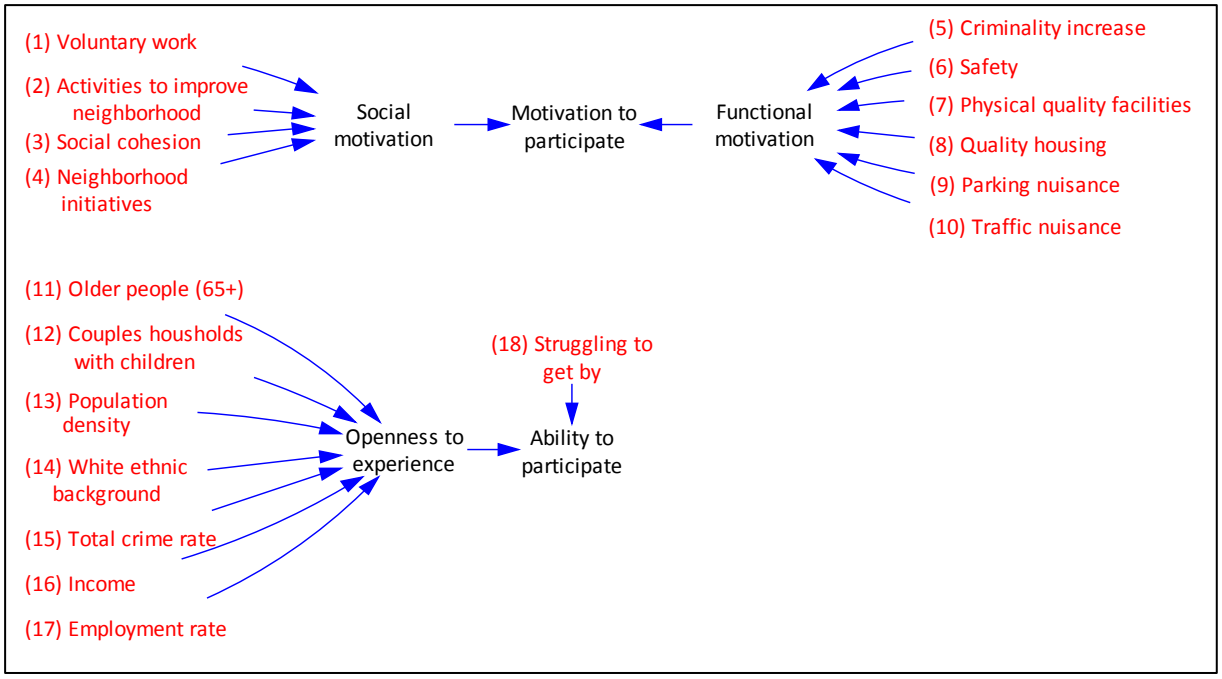

Figure 5-4 Calculation scheme for Motivation to participate and Ability to participate

5.4 Willingness to Participate

Now that all neighborhood characteristics for the willingness to participate are explained, they must be combined to form the willingness to participate. In order to combine them the units of the characteristics must be assessed, these are displayed in Table 5-1 and Figure 5-4.

Table 5-1 The components of willingness to participate and their underlying neighborhood characteristics. Data is retrieved from: (Buurtmonitor Eindhoven 2015; Buurtpreventie Eindhoven 2015; CBS 2014a)

COMPONENT	NEIGHBORHOOD CHARACTERISTICS	UNITS	CORRELATION
Social motivation	**(1)** voluntary work	%	1[1]
	(2) activities to improve neighborhood	%	1[1]
	(3) social cohesion	(0-10)	1[1]
	(4) actual neighborhood initiatives	(0 or 1)	1[1]
Material motivation	**(5)** perception criminality increased last year	%	1[1]
	(6) presumed safety	(0-10)	-1[1]
	(7) physical quality facilities	(0-10)	-1[1]
	(8) satisfied with quality of housing	%	-1[1]
	(9) parking nuisance	%	1[1]
	(10) traffic nuisance	%	1[1]
Openness to experience	**(11)** older people (65+)	%	-0.58[2]
	(12) couple households with children	%	-0.68[2]
	(13) population density	people	0.61[2]
	(14) people with white ethnic background	%	-0.31[2]
	(15) total crime rate	crimes	0.34[2]
	(16) income	income	-0.34[2]
	(17) employment rate	%	-0.44[2]
Ability to participate	**(18)** struggling to get by	%	-1[1]

[1] **The correlations of Social motivation(1-4), Material motivation(5-10), and Ability to participate(18) are constructed by the author. The author set each correlation at 1 or -1, as they are all equally used to calculate their components. Because the correlation is used as a weighing factor, is does not matter what value is set, as long as all correlations are equal. Some correlations are -1, because these characteristics have a negative relationship with the component they are representing.**

[2] **For the openness to experience the correlations are known from Jokela (2015)and therefore added. The correlations are used as a weighing factor to calculate Openness to experience.**

Clear from Table 5-1 is that the neighborhood characteristics cannot be combined by simply taking the average. Each neighborhood characteristic is calculated by using the maximum and minimum value of that characteristic; the range. If the neighborhood characteristic has the highest value, the score is 100%. Another example is if the score ranges from 1 to 5 and the neighborhood characteristic is 2, the score is 25%. The formulas can be seen in Table 5-2. Additionally, Figure 5-4 shows how the components are calculated.

Table 5-2 The formula's used to calculate the willingness to participate, see also Figure 5-4.

COMPONENT	FORMULA
Neighborhood Characteristic (X)	((**X**) – Minimum(**X**)) / ((Maximum(**X**) – Minimum(**X**))
Social motivation	((**1**) + (**2**) + (**3**)) / 3 + (**4**) x 0.2
Material motivation	((**5**) + 1 - (**6**) + 1 - (**7**) + 1 - (**8**) + (**9**) + (**10**)) / 6
Motivation to participate	(**Social motivation** x 2 + **Material motivation**) / 3
Openness to experience	(((1 - (**11**)) x 0.58 + (1 - (**12**)) x 0.68 + (**13**) x 0.61 + (1 - (**14**)) x 0.31 + (**15**) x 0.34 + (1- (**16**)) x 0.34 + (1-(**17**)) x 0.44) / 7
Ability to participate	**Openness to experience** - (**18**)
Willingness to participate	Maximum(**Motivation to participate**, **Ability to participate**)

Table 5-2 gives more formula's that are used to calculate the components. The social motivation is the average from characteristics (1) through (3), but a fixed value from (4)(actual neighborhood initiatives). The reason for this is that an actual neighborhood watch is very helpful in the establishment of a co-creation initiative for smart cities. In addition it shows that residents of the neighborhood are actively engaged to improve their neighborhood, proving that their social motivation is high.
The material motivation is calculated by taking the average score. However some values are calculated by 1 – (X), because their correlation is negative as can be seen in Table 5-1.
Motivation to participate is calculated by taking the weighted average of social motivation and material motivation, with a weight of 2 for social motivation and a weight of 1 for material motivation. This is done because the material motivation does not contain all negative characteristics of the neighborhood, but it is rather a small summary of some important characteristics. Therefore the social motivation is seen as more important, because if there is a social motivation, the material motivations can be explored and be addressed by the development.
The openness to experience is calculated similarly to material motivation, but with the correlation scores by Jokela (2015). This is done to account for the fact that some characteristics are more influential than others.
Ability to participate is calculated by taking the openness to experience and deducting the percentage of people that is struggling to get by. This is done under the assumption that people who have so little financials that they are struggling to get by, will not have the ability to join.
At last the willingness to participate is calculated by taking the maximum value of motivation and ability. While it can be argued that this should be the average score, the assumption is made that both are needed (and a trigger) for action. If either one of the values is low, the chances of action taking place is as low as well, therefore the maximum is taken.

5.5 Modeling Co-Creation in Smart City Development

As soon as the process of co-creation starts, questions arise that are very hard to answer. These questions are related to the management of co-creation processes. This process is influenced by various external and internal processes, that deem further understanding. By becoming aware of the internal and external factors that are influential, the process of co-creation can be influenced. Accordingly, the question on which the model is based is: *"How can the co-creation of a smart city be influenced?".*
Co-creation is a complex phenomenon that is influenced by multiple types of agents that can be large in number. These agents can be participants, media attention, accomplishments, and more. A single participant influences the progress by being productive, but his participation is at the same time influenced by his productivity. Similar to this, every agent in the system continuously influences and is influenced by the participants. This makes it very hard to perform statistical calculations on the participation. So to gain understanding of the processes that influence the participation in the co-creation process, modelling on an abstract level is required. System Dynamics (SD) is a modelling approach that excels on modelling at the highest abstraction level (Borshchev & Filippov 2004). The main advantage of the SD modelling approach is that all processes can simultaneously influence agents and variables that form the processes. SD will be used to understanding in the influence of external and internal processes on the co-creation process.

5.6 System Dynamics (SD)

"System Dynamics is a top-down modelling approach that assumes that complex behavior arises from the causal structure and the endogenous properties of the system" (Lorenz & Jost 2006 as cited by Romero & Ruiz 2014). So the system itself is influencing itself, creating complex behavior that can be overseen in system dynamics. The causal structure of the system considers feedback loops, time delays, flow diagrams and stock accumulation (Ford 2009). A SD model describes the behavior of a complex system and allows to predict changes while simulating different scenarios. This capacity is useful in the process of recommending and examining policy decisions (Han et al. 2009 as cited by Haase et al. 2012). SD is commonly used in large-scale projects such as the design and construction of civil works and infrastructure (e.g. bridges, tunnels, power plants, and telecommunications networks), military systems (e.g. aircrafts, ships, and weapons systems), and new products in every industry (e.g. software, automobiles, semiconductor chip design, and wafer fab construction) (Sterman 2000).

The analysis of the research question requires a different thinking process. SD excels in the abstraction of fundamental problems and this will be helpful to find the causal structures and fundamentals that are at the base of the co-creation process. SD uses Causal Loop Diagrams (CLDs) as a baseline for the problem analysis. This is discussed further in Paragraph 5.8. Afterwards a simulation model is made to examine the phenomenon in different scenarios. This simulation model is better known as a Stock and Flow Model (SFM). By doing so, knowledge on the processes that affect and are affected by the phenomenon that is modelled is acquired. The model is further discussed in Paragraph 5.9.

5.7 Model Preparation

Co-creation is first mentioned in Paragraph 3.4. In smart city development, the initiating party is public, meaning that the process is referred to is public co-creation: *"the involvement of citizens in both the design and production process of public services in order to (co)create beneficial outcomes"* (Voorberg et al. 2014).

Voorberg (2014) researched the process of public co-creation and this research has been very valuable for the modeling process. They found that co-creation is already successful if only established, it does not have to be measurable. The projects themselves are seen as accomplishment of the co-creation process, rather than results of these projects. Subsidies make that municipalities go into a director role, so these are seen as negative. Willingness of citizens to participate is very important for successful co-creation. This willingness is based on personal characteristics and a feeling of ownership. The feeling of ownership is strongest if it has a professional orientation, rather than a geographical orientation (neighborhood or city). Co-creation efforts are built on social capital (informal networks between citizens) and therefore it is a precondition. Public officials' involvement is not very influential for co-creation initiatives and the organizational structures and procedures of public organizations do not have to change. But a smooth organization on the citizen side of co-creation is very helpful in establishing co-creation.

Literature helped in finding different processes that affect the public co-creation process. The first process that was found is based on the hook model that was described earlier in Paragraph 5.2. This involves the process that when someone invests in the project, it becomes more valuable. The investment phase can then become the trigger to participate once more or stay participated in the project. The underlying factor is given by Voorberg

(2014), ownership of the project. Ownership grows as the project progresses (is invested in) and increases the chance of prolonged participation. So this process can be seen as the creation of an internal trigger that enables the hook to be repeated.
Another way to increase the likelihood of participation can be an external trigger. In the case of smart cities this is likely to be media attention. This attention can be either mass media or social media, no distinction is made in this report. Media attention occurs if accomplishments are made. The results of media attention are an increase in ownership and increased participation (Hill et al. 2006).
The participants themselves are also responsible for new participants. As co-creation builds on social capital, a successful project is easily shared. This has the potential to increase the participants, the only requirement is that a minimum level of ownership is required. If there is no ownership, the word of mouth is not active (Sterman 2000).
Expectations can also have great influence on the participation as was already discussed in Paragraph 3.4.4. Citizens are frequently skeptical of co-creation initiatives (Berman 1997 as cited by Bekkers et al. 2013). Accomplishments and outcomes that are of interest to citizens have a great effect on the willingness to participate in the co-creation process (Bekkers et al. 2013). The public sector is slower in the implementation of solutions than the participants would prefer (Jakobsen 2013). So the participants' expectations are higher than the actual progress and therefore progress is slowed down.

5.8 Causal Loop Diagrams (CLDs)

One of the main concepts of System Dynamics is providing feedback. This can be done by implementing Causal Loop Diagrams (CLDs). Causal Loop Diagrams are flexible and useful tools for diagramming the feedback structure of systems in any domain. CLDs are simply maps showing the causal links among variables with arrows from a cause to an effect (Sterman 2000). CLDs are particularly suitable for summarizing hypothesizes, capturing the mental models of people and for proper communication among these people. Therefore there are some generally accepted and commonly used notations in CLDs. One of these is that causal links between variables should be shown by arrows and each link is assigned a polarity (+ if positive, - if negative). It is also useful to show in the model whether a specific loop is reinforcing or balancing. Finally, numbering and naming each loop helps to find each loop as you talk about it and to keep track of the many loops in the model.
CLDs should also include important delays, because these are critical in System Dynamics. Delays give systems inertia, can create oscillations, and are often responsible for trade-offs between the short- and long-run effects of policies (Sterman 2000). As explained in the previous paragraph, four main processes that affect co-creation were found, namely the personal trigger, the media trigger, the word of mouth and the excessive expectations. With these processes in mind the CLD displayed in Figure 5-5 was developed.

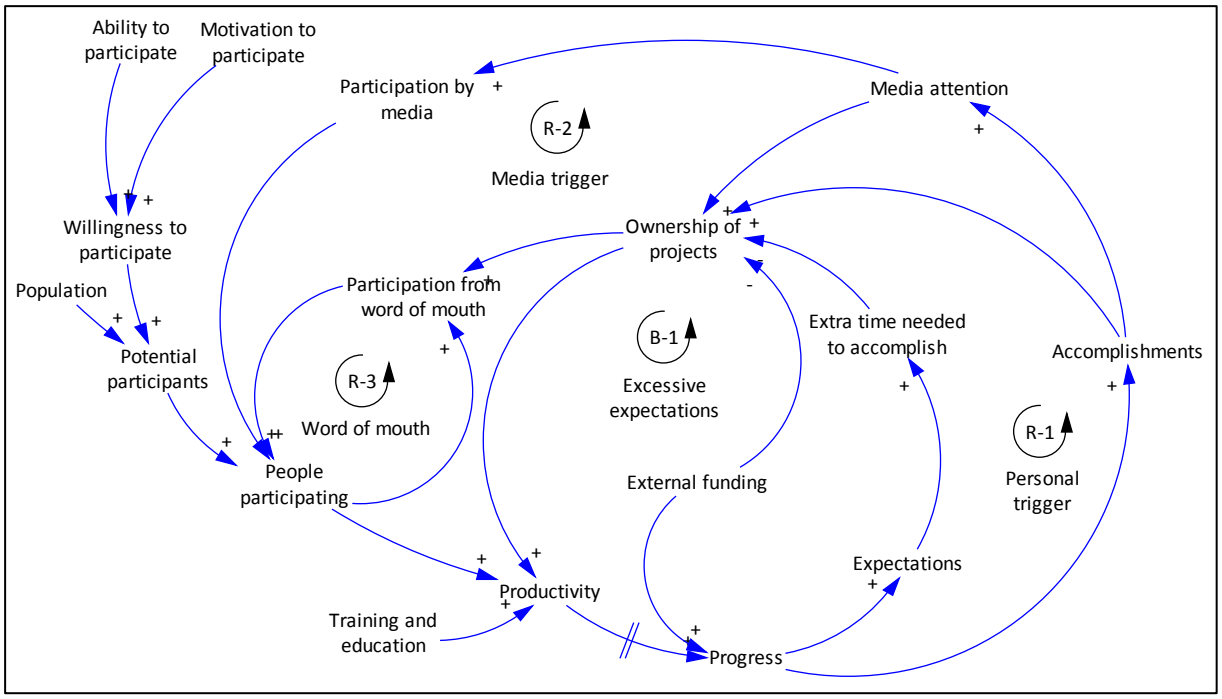

Figure 5-5 The Causal Loop Diagram (CLD)

The Causal Loop Diagram (CLD) can be seen in Figure 5-5. The loops consist of variables connected by causal links (arrows) with polarities (+ or -) and delays (= symbol through arrow line) to describe the causal links.

The amount of *People participating* is the result of the *Willingness to participate* score that was calculated in Paragraph 5.4 and the *Population* of the neighborhood(s) in which the co-creation will take place. A larger *Population* and a higher *Willingness to participate* both increase the potential amount of participants. These external variable form the basis of the model and also attribute to differences between neighborhoods. Next the loops are described step-by-step, starting with R-1.

In loop R-1 the *People participating* work with a certain *Productivity* that becomes *Progress* after a delay. More people can do more work, thus the *Productivity* increases as the participants increase. Once the progress is high enough, *Accomplishments* happen, resulting in an increase in *Ownership of projects* because they are proud of themselves. High *Ownership of projects* increases the *Productivity*, because highly engaged participants work harder. Thus this loop is modeled as a reinforcing loop.

Loop R-2 visualizes that on the other hand the same *Accomplishments* obtained by *People participating* also lead to *Media attention*. Although this media attention is small, it will be shared and can make others enthusiastic of the project. This has the potential to increase the *People participating* as they see what great opportunities there are for them if they join as well. So this phenomenon is also a reinforcing loop.

In loop R-3, these *Accomplishments* can also increase the *People participating* in another way. Because the *Accomplishments* lead to a higher *Ownership of projects*, this leads to word of mouth advertising that increases the *People participating*. This word of mouth occurs because people are proud of their *Accomplishments* and share this with their social environment. Therefore this loop is also modeled as a reinforcing loop.

Loop B-1 tells that the *Progress* often leads to higher *Expectations* among the participants. When people see what is possible, they cannot wait until it is implemented. However, often the public sector is not very fast in the implementation process because of policy. Higher

Expectations can lead to *Extra time needed before accomplishments* are made. This influences the *Ownership of projects* in a negative way, which in turn decreases the *Productivity* and the *Progress* gained. This loop is therefore a balancing loop. This delay can be seen as the opposite of an accomplishment and is therefore influencing the ownership in a negative way.
There are also two external variables that must be mentioned. First there is *Training and education*. It is assumed that this only has positive consequences on the progress and thus the model as participants are still free choose whether they use the things they learned or not. The second variable is *External funding*. This variable does increase the progress, but also negatively influenced the *Ownership of projects*. That is because the municipality then takes the director role, limiting the freedom of participants.

5.9 Stock and Flow Models (SFM)

As described in the previous section, CLDs are useful tools to provide feedback in clarity in many situations. However, CLDs contain a number of limitations as they cannot capture the stock and flow structure of systems. Besides CLDs, Stock and Flow Models (SFM) can be considered as main concepts of System Dynamics. Stocks are accumulations, characterizing the state of the system and generate the information upon which decisions and actions are based. Stocks create delays by accumulating the difference between the inflow to a process and its outflow (Sterman 2000). As in CLDs, there is also a common notation for Stock and Flow modelling. Stocks should be represented by rectangles. Inflows are shown by pipes pointing towards the stock, whereas outflows are shown by pipes pointing out of the stock, both controlled by valves. Finally the sources for the flows are represented by clouds (Sterman 2000).
While composing the SFM, first the stocks have to be identified. In the case of co-creation the following stocks are distinguished; *People participating, Ownership of projects, Work done, Accomplishments, Media attention, Time to accomplish, and Accomplishment time.* Seven stocks are used in total to match the problem under study. The stocks are the most obvious places to start the model with because they are the most easily recognized variables in the system. The associated flows represent the change in these stocks over time. However, in this model the stocks *Time to accomplish* and *Accomplishment time* are necessary to make the model work. These are not so much the most easily recognized variables. All the variables and underlying assumptions are summarized in Appendix D and were used to create the SFM in Figure 5-6.

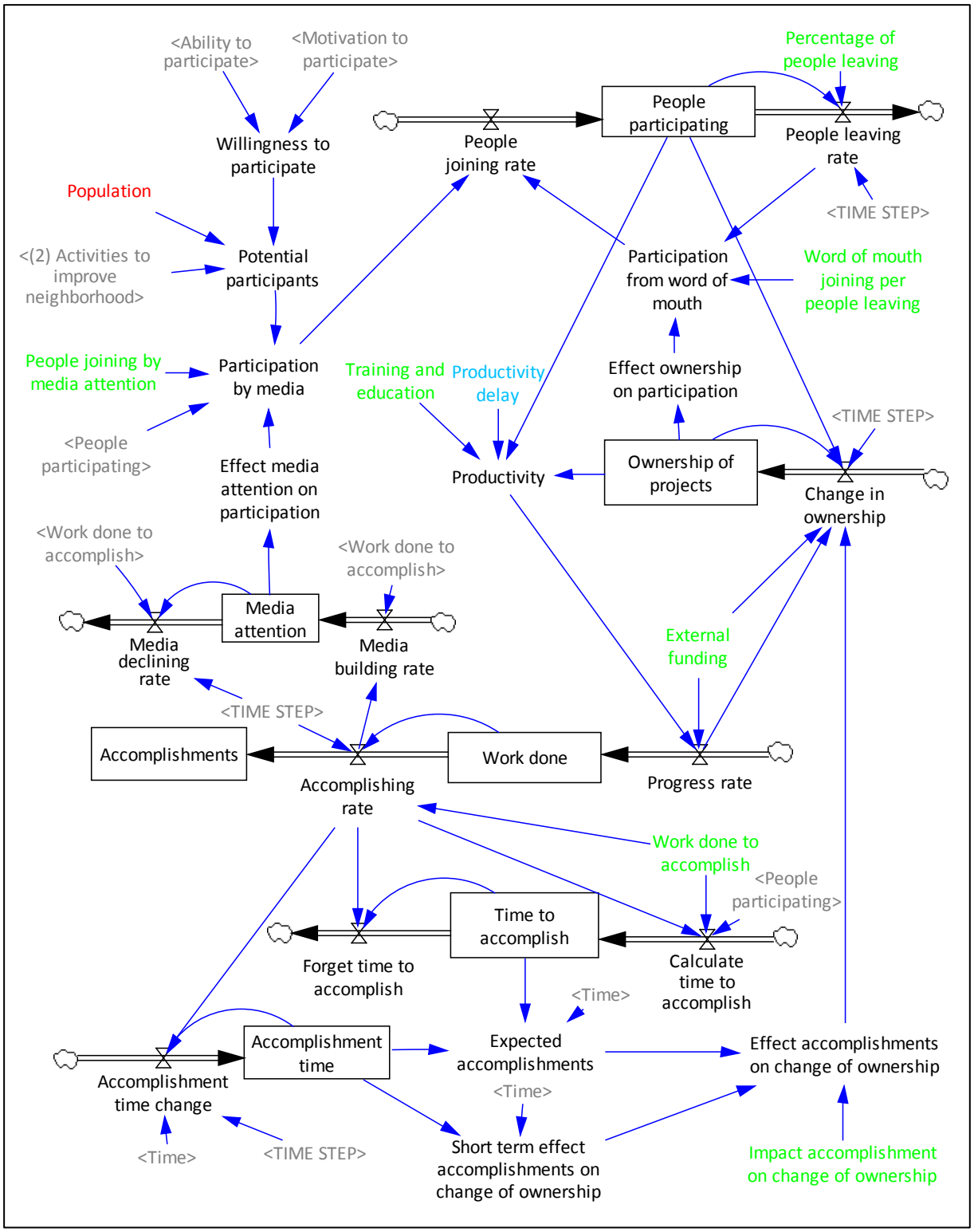

Figure 5-6 The Stock and Flow Model (SFM)

5.9.1 People participating

First the *People participating* is modeled with a starting level of 10 and depending on the inflow of the *People joining rate* and the outflow *People leaving rate*.

The *People leaving rate* is calculated by the *Percentage of people leaving* and the *People participating*. This comes from the viewpoint that always a fixed number of people leave because of reasons not related to the project. The *Percentage of people leaving* reflects this number. Other reasons that the amount of people who leave declines are not modeled in this model.

The *People joining rate* is formed by *Participation from word of mouth* and *Participation by media.*
Participation from word of mouth is influenced by *Word of mouth joining per people leaving* and *Effect ownership on participation*. The *Word of mouth joining per people leaving* gives the value of how many people would join by word of mouth, compared to the people who leave. So if the influence from *Effect ownership of participation* is 1 and the value for *Word of mouth joining per people leaving* is 1 as well, there would be as many people leaving as joining. The *Effect ownership on participation* is based on the fact that when ownership levels are low, people will not use word of mouth to motivate other people. But after a certain point, people will. They will do it even more and this accelerates as their ownership increases, until the maximum value is reached. This results in the left graph of Figure 5-7.
Participation by media is dependent on the *Potential participants* and the *Effect media attention on participation*. The *Potential participants* is calculated by the *Willingness to participate*, the *Population* and the *(2) Activities to improve neighborhood*. This is done because not the whole population is suited for co-creation development. Only those people who are active to improve the neighborhood are and this is reduced by multiplying it with *Willingness to participate*.
The *Effect media attention on participation* is fairly simple as can be seen in Figure 5-7. This is modeled in this way, because the *Media attention* is loaded all at once, but decreases over time. The simple graph still makes the *Participation by media* perform goal seeking behavior, as it is limited by the media attention that fades away. The graph also incorporates -1, because although the media attention can barely rise below 0, it will still do so a little bit. To ensure that the lookup covers all values, the graph is modeled in this way.

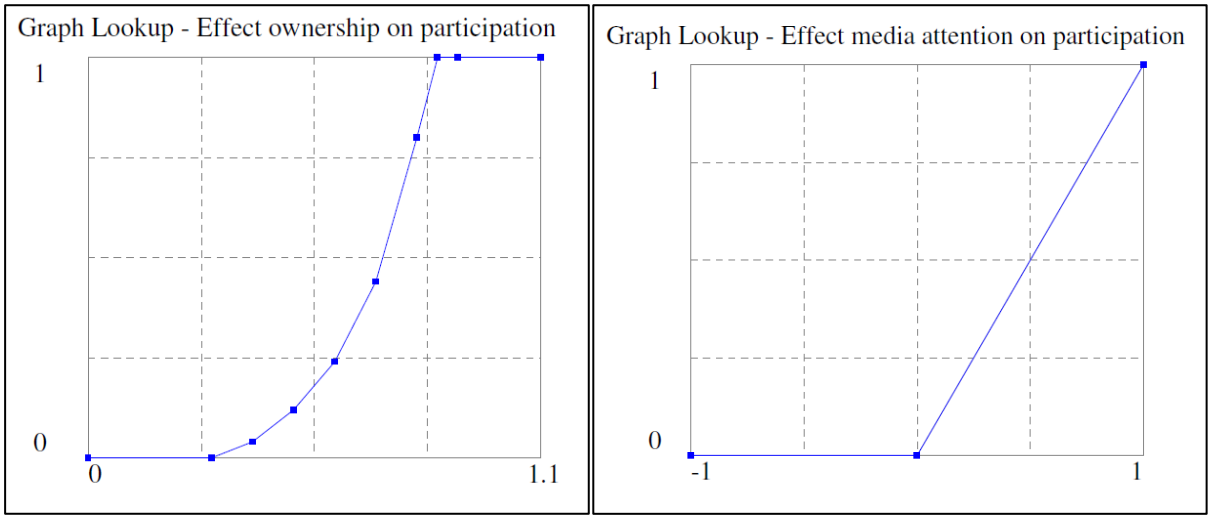

Figure 5-7 Lookup graphs *Effect media attention on participation* and *Effect ownership on participation*

The *Productivity* is influenced by the *People participating* because it this contains the work that people can actually do. *Productivity* is additionally delayed by 1 month and influenced by *Ownership of projects* and *Training and education*. The delay is because there is never an immediate result of work. The *Training and education* has a maximum value of 1, but is set at 0.8. That is because it is assumed that it is impossible for a group to work with 100% *Productivity*. Because *Training and education* will be provided to aid in the process, the value of 0.8 seems to visualize realistic behavior of the model.

5.9.2 Ownership of projects

The *Ownership of projects* is influenced by the *Change in ownership*. This rate is influenced by itself, the *Progress rate*, *People participating*, *Effect accomplishments on change of ownership*, and *External funding.*

The *Progress rate* increases the level of *Ownership of projects*. The amount of progress per person is calculated with the *People participating*, so if nothing hinders *Productivity* this equals 1.
Then the *Effect accomplishments on change of ownership* is deducted, because this is modeled as a negative value. The reason behind this is that when *Accomplishments* need to be achieved as they are expected, the ownership should decrease. However, the value for *Effect accomplishments on change of ownership* can also be positive. That is the case when an *Accomplishment* has just been achieved, as explained by *Short term effect accomplishments on change of ownership*. The value *Effect accomplishments on change of ownership* is based on *Impact accomplishment on change of ownership* and *Short term effect accomplishments on change of ownership*. *Impact accomplishment on change of ownership* is set at 3, because this gives realistic behavior. The lookup graph of *Short term effect accomplishments on change of ownership* can be reviewed in Figure 5-8. It is based on a graph Hill (2006) and it basically shows how the ownership is influenced within 1 month of reaching accomplishments. So at first the ownership is increasing rapidly, because an *Accomplishment* as recently achieved, but this has exponential decay until after 1 month the effect is 0.
External funding negatively influences the ownership directly, but is modeled as 0 in the null scenario. It does also positively influence the progress, therefore it indirectly increases the *Ownership of projects*.

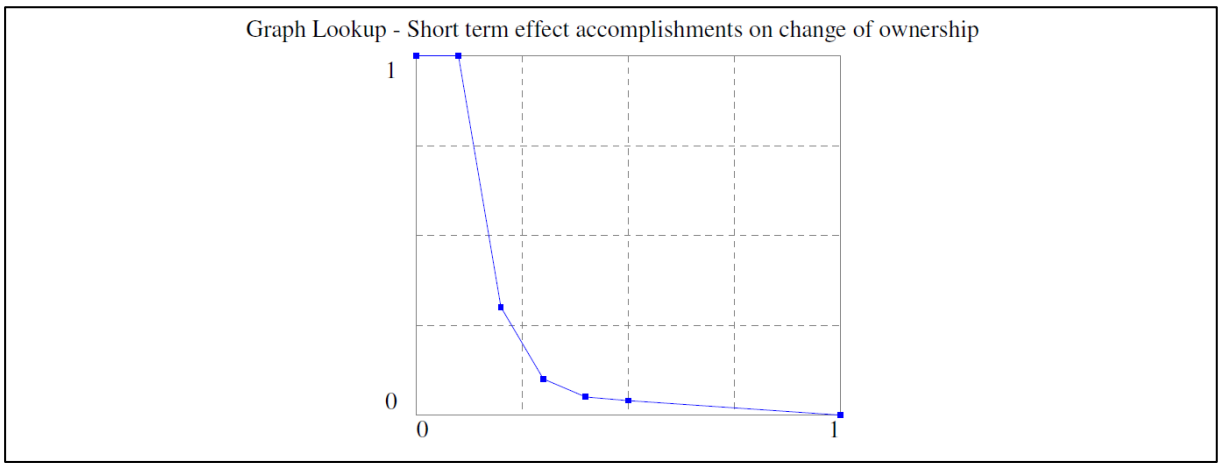

Figure 5-8 Lookup graph *Short term effect accomplishments on change of ownership*

5.9.3 Work done & Accomplishments

The *Work done* is influenced by the *Progress rate* and the *Accomplishing rate*. As people work with a certain *Productivity*, work is done. Once the *Work done* is more than the *Work done to accomplish*, the *Accomplishing rate* releases all the *Work done* in one *TIME STEP* into *Accomplishments.* The *Accomplishing rate* influences many other variables, because it is seen as the reward that drives behavior. These variables are discussed below.

5.9.4 Media attention

The *Media attention* is influenced by the *Media building rate* and the *Media declining rate*. The *Media building rate* uses the *Accomplishments* of the *Accomplishing rate* to load *Media attention* in a similar way. The *Media declining rate* releases the *Media attention* in one month, causing the *Participation by media* to be very high immediately after the *Accomplishments* are made, followed by rapid decay in participation amount.

5.9.5 Time to accomplish

Calculate time to accomplish and *Forget time to accomplish* are the two rates that influence this stock. This level holds the time for the next *Expected accomplishment* to be achieved. It is needed to calculate whether progress is lagging behind or not.

5.9.6 Accomplishment time

The *Accomplishment time* is influenced by *Accomplishment time change* and is actually the time of the last *Accomplishment*. This variable is needed for the same reason as *Time to accomplish*, because the model saves valuables in levels.

5.10 Case-Study Strijp-S

The case study of this report is Strijp-S. In this paragraph background information on this neighborhood is provided. However, as discussed in Paragraph 5.1, there is no data from population studies available. So therefore another neighborhood is used for simulation in the model. Recommendations for the smart city development at Strijp-S in Paragraph 5.15.

Strijp-S is an integrated area development in Eindhoven, the Netherlands. In this brownfield (existing) development, the former industrial area of Philips is transformed to a vibrant and vital urban working, living and cultural area. Strijp-S has the ambition to become a smart city and is regarded an urban living lab. Because extensive knowledge from experts and experience was gained from this development, this is discussed as a case-study of smart city development.

5.10.1 History

The history of Strijp-S is closely intertwined with the growth of electronics giant Philips. Philips enabled Eindhoven to be more than a collection of small villages, because of the great employment the company created.

Anton Philips started producing light bulbs in 1892 and produced 1.5 million light bulbs 10 years later. To ensure continuity, he built the first factory in 1916 at Strijp-S. This factory provided Philips with glass and shortly after a cardboard factory, a gasworks factory and a physics laboratory (NatLab) for research were also built at Strijp-S. Philips developed Strijp-S rapidly from 1928, building the 'Hoge Rug', the 'Klokgebouw', an engine room and a boiler house. With the 'Veemgebouw' constructed in 1942 as a storage building, Strijp-S made Philips completely self-sufficient. Their slogan was therefore 'from sand to customer's

hand'. At NatLab radio technologies, televisions, shavers, the CD, the DVD and even X-ray technology were invented. After every invention Philips grew tremendously and to support this growth, Strijp-R and Strijp-T were built. Strijp-S was became the 'Forbidden City', because of the fences and barriers around it, it only opened for those with a valid pass (Strijp-S n.d.; Hurk 2009).
Philips decided in 2000 to leave Eindhoven, turning the once very dynamic 27 hectares of Strijp-S into a vacant area. Philips organized a tendering procedure in 2001 for the redevelopment of Strijp-S, on which market players could subscribe with a plan and a bidding. VolkerWessels won this tender and decided to cooperate with the municipality to redevelop the area. Both parties participate for 50%, equally spreading the risk, as a Public Private Parnership (PPP) known as Park Strijp Beheer (PSB). For VolkerWessels the profitability of the land development was not the most important reason to participate, it is rather the continuous flow of construction works for the future (Blauw 2011). Philips sold Strijp-S to PSB in 2004 and the buildings still in use by Philips were hired back. In the same year the Masterplan (Nieweg-Montero Alvarez et al. 2004) was finished and a vision for the development was formulated.

5.10.2 The Masterplan

Strijp-S is becoming a new creative center for design, innovation and technology to form a connection between the High Tech Campus (technology) and Eindhoven University of Technology (knowledge). Some statistics of Strijp-S are presented in Figure 5-9. A very dense urban area, an international population, an abundant offering of innovative culture and a combination of living, working and recreating, make Strijp-S a 24-hour city (Eijkeren 2012; NRP Gulden Feniks 2013). To accomplish this the Masterplan contains a large and diverse program in which a variety of functions are pictured and the national monuments (±135.000 m^2) are preserved; they are the bearers of the area (Gelinck 2011). The industrial nature is seen as the unique selling point that is distinctive, this forms the basis to which the new qualities of liveliness and creative energy are added (Santen 2012). The program that was formulated in 2004 is still pursued:

- Residential area ±285.000 m^2 (2500-3000 units of various types, i.e. studios, apartments, urban residences and lofts)
- Work and office area: 90.000 m^2
- Commercial and cultural services ±30.000 m^2
- Optional: ±30.000 m^2
- Parking places: 5000

The recent financial crisis has not removed any square meters out of the Masterplan, but the phasing and planning have been subject to change. The risk profile of the different parts is improved by making them smaller because it improves the sale and construction phasing and adapting to the market need. The development of 90,000 m^2 work and office area is spread over the total development time, while the residential development is mainly planned for the end phase (Blauw 2011).
The 27 hectares make Strijp-S one of the largest redevelopment projects of Europe. To make it a successful one, a vastly different approach is used. This is symbolized in one of the main concepts; temporary use. The 'Klokgebouw' is used for events and additionally events organized in proximity were taken to Strijp-S, for example the Dutch Design Week. Crowd pullers such as these promote Strijp-S and are referred to as 'Quartermasters'. Even though

the recent financial crisis has slowed down the pace of development, it is thanks to the 'Quartermasters' that the redevelopment of Strijp-S has been regarded a successful one. This is also because of the slight changes in the vision and because it has been accepted that it takes some time before a profit is made and because they have been taking the time to redevelop the vision through extensive communication (Strijp-S n.d.; Gelinck 2011).

5.10.3 S-mart Strijp-S

In 2013 a high quality, flexible data and communication backbone network was installed as part of the street light network (Light-S). This was done to support the living lab ambitions of encouragement and facilitation of the introduction of ground-breaking innovations. It was designed for a broad range of application to anticipate on future opportunities regarding smart cities. Strijp-S named their project to become a smart city S-mart Strijp-S.
The various stakeholders at Strijp-S asked for a unified vision to position the core activities and this lead to the vision document by Lorna Goulden (2015). Three main development areas have been identified: infrastructure (completing the backbone network to enable the other development areas), platform (both physical and digital as a place to co-create applications), applications (sustainable services and applications to improve the quality of life developed by co-creation in the living lab). This co-creation will be performed by all the stakeholders of Strijp-S. However, at this point it is very hard to define the motivation and willingness to participate in the co-creation by the community. The fact that it is an innovative process and therefore the results are unknown, does not help in the willingness to participate. It is very important for Strijp-S to develop trust in its cooperation with the community, as this is crucial for co-creation to work.

Figure 5-9 Facts Strijp-S (Strijp-S n.d.)

5.11 Results GIS Analysis

In this paragraph, the established neighborhood characteristics are used to determine which neighborhoods in the municipality of Eindhoven are most suited to start a smart city development. To do this, GIS analysis is used. In GIS analysis, spatial and geographical data is captured, manipulated, analyzed and presented (De Smith et al. 2015). In this report MapInfo is used to perform the analysis and the results can be reviewed in Appendices A through C. The most interesting results are discussed below. It must be noted that each neighborhood was given a number, these numbers refer to the list presented in Appendix A. This ensures that the individual results for each neighborhood can be reviewed.

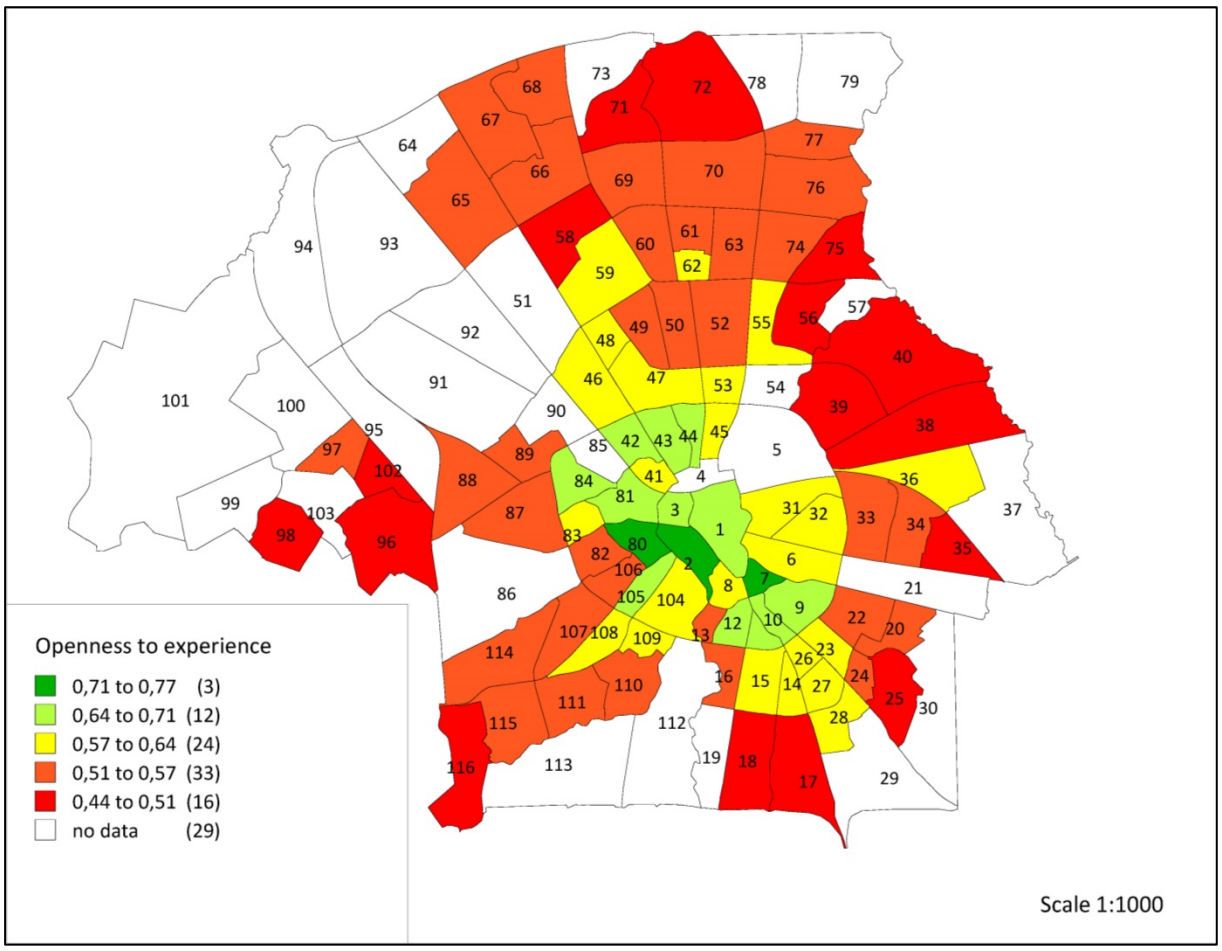

Figure 5-10 Openness to experience calculated with formulas of Table 5-2

The value for openness to experience was calculated by using the correlation values given by Jokela (2015). It is very interesting to see that the map presented in Figure 5-10, shows similar clustering as the referred report by Jokela as can be seen in Figure 5-11. The center of the city has very high values for openness to experience and this decreases as the distance to the city center increases. Very low values of openness to experience are reported at the edge of the city. The consistency with the map by Jokela (2015), gives sufficient proof that the openness to experience is measured and therefore this component is accepted. For the other components verification was not possible and these are therefore is not checked.

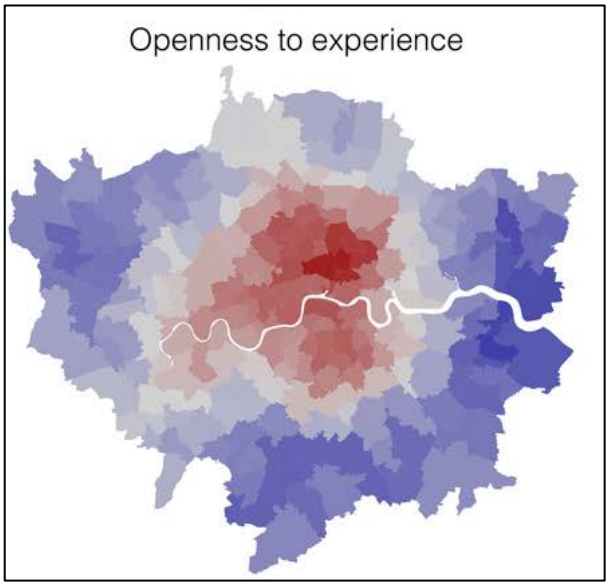

Figure 5-11 Openness to experience as calculated by (Jokela et al. 2015)

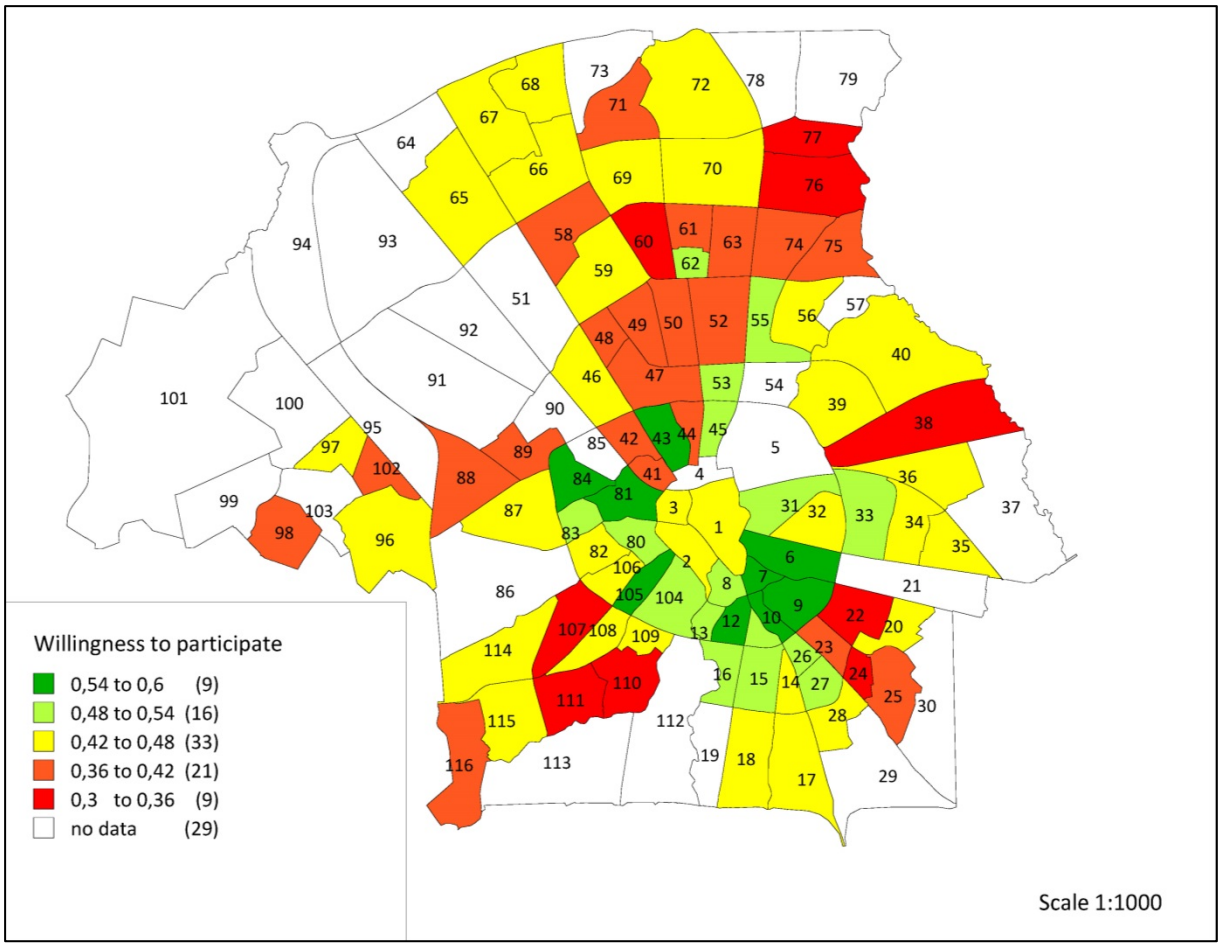

Figure 5-12 The willingness to participate calculated using the formulas of Table 5-2

The willingness to participate is not an exact value that shows how many people would participate, but rather is a rating of a neighborhood on its suitability. For each neighborhood a value was calculated using Table 5-2 and Figure 5-4. By doing so, the neighborhoods can be compared to each other and Figure 5-12 shows the results.

The neighborhoods (7) Rochusbuurt, (12) Looiakkers, and (84) Schoot, have the maximum reported value of 0,60 on willingness to participate. They are therefore regarded as the most suited neighborhoods for the start of a smart city development project by co-creation with citizens. Strijp-S yields number 85 and unfortunately there is not enough data available to calculate the willingness to participate.

However, this analysis is far from perfect. As discussed, only the openness to experience was validated, whereas the other components and their characteristics are only chosen based on theoretical literature. Therefore the statement that the mentioned three neighborhoods are the most suited can be doubted. However, the results of the calculations for the neighborhoods will still be used in the next paragraph, simply because there is no substitute.

5.12 Results System Dynamics

The system described in Paragraph 5.8 and 5.9 is used to simulate different scenarios to learn from the model what the influences of different scenarios will be on the *People participating*. It is of great interest to monitor how variables such as *Progress* and *Media attention* develop over time and influence the *Ownership of projects* and *People participating*. A null scenario will be derived from the model, this scenario will show the most expected scenario in a successful co-creation process. This scenario is developed based on the knowledge obtained in this research as there was no historical data available (Sterman 2000). Furthermore, multiple variables will be adjusted according to different scenarios. Accordingly, the influence can be reviewed on the co-creation process as a whole. The defined two types of participation (word of mouth and media) will be tested on individual effects and impact on the model. Furthermore, different neighborhoods are compared to see what the differences among them are. Additionally, two external variables are tested; *External funding* and *Training and education*. These scenarios will provide insight and understanding in the phenomenon of co-creation and possible ways to influence the process.

5.12.1 Scenario 'null'

The null scenario forms the basis for all analysis. As discussed in Paragraph 5.1, there are limitations for this scenario. The idea was to simulate the process for Strijp-S, but since there is no data available, this is impossible. Therefore an average neighborhood, Schrijversbuurt, is taken. It is calculated that this is an average neighborhood by using the formulas given in Table 5-2 and Figure 5-4. For the null scenario, the system will be simulated using the values mentioned in Appendix D. This scenario provides the graphs presented in Figure 5-13 and Figure 5-14.

At the start the *People participating* slows decreases. This is the result of the assumption that as long as nothing is accomplished, the *People participating* as a result of word of mouth is lower than the turnover rate (people leaving because of reasons other than the project). The *People participating* increases rapidly around 17 months as the result of *Accomplishments* that lead to *Media attention*. Also the frequency of the oscillation is lowered by the increased amount of participants that can do more work and achieve accomplishments faster.

The *Productivity* is delayed by one month and climbs as a result from the increased *Ownership of projects*, however it starts to decrease at 10 months as the *Accomplishments* fail to occur. At 18 months (17+1 delayed month) there is a rapid increase in *Productivity* as the result of increased ownership and more *People participating*, caused by the *Accomplishments*.

It can be concluded that the null scenario reveals that successful co-creation greatly benefits from achievements and that over time the ownership keeps increasing until the maximum value of 1 is reached. At that time the ownership temporarily falls back only if the achievements fail to occur.

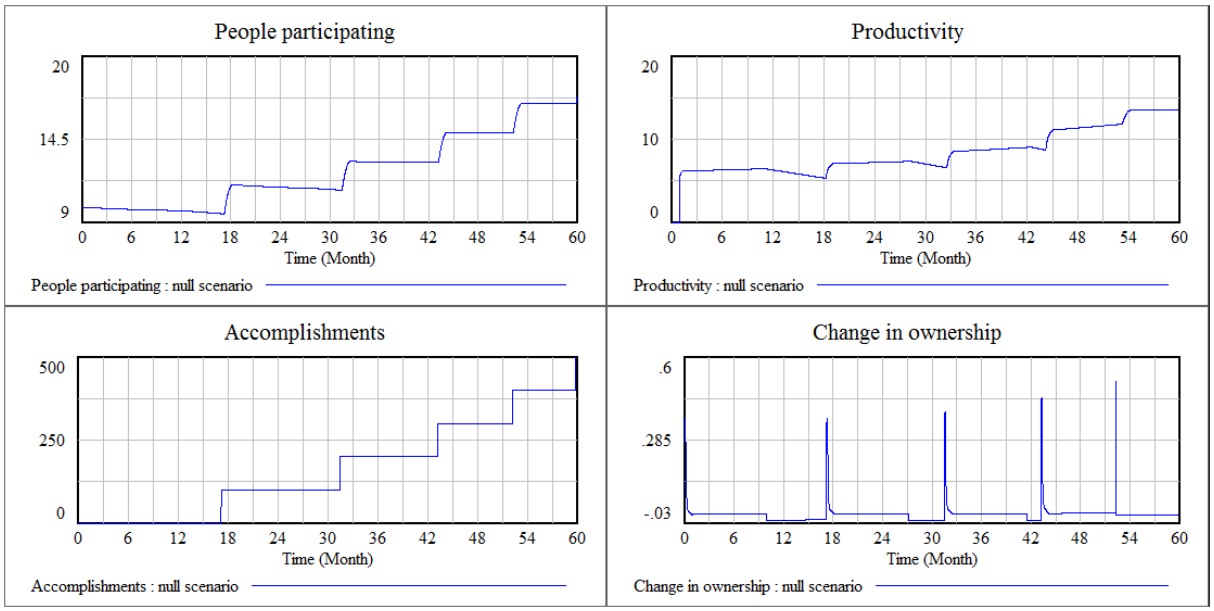

Figure 5-13 Null scenario of *People participating, Productivity, Accomplishing rate, and Change in ownership*

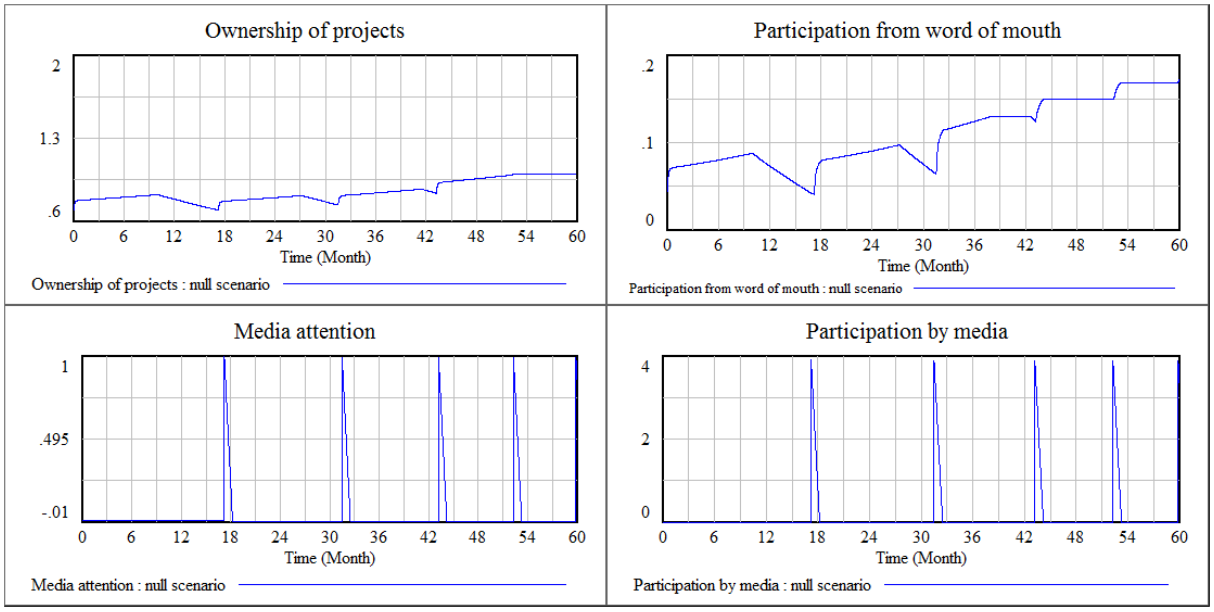

Figure 5-14 Null scenario of *Ownership of projects, Participation from word of mouth, Media attention, and Participation by media*

5.12.2 Scenario I – Participation Types

Looking at the effects of both participations separately is displayed in this scenario. The red line symbolizes the effect of the word of mouth only on the participation, while the green scenario describes the effect of media participation only. The results can be reviewed in Figure 5-15. While the People participating is declining at almost the same pace in both scenarios, it occurs in a different fashion as the result of the media attention. An interesting note can be made while looking at the *Accomplishments*, the first *Accomplishment* occurs later in the scenario of media attention. This is explained by the *People participating*, because in the media scenario the *People participating* decreases faster than the in the word of mouth scenario. The reason behind this is that more people are leaving than joining as opposed to the Word of mouth scenario where the *People joining rate* is similar to the

People leaving rate. This decreases the *Productivity* and therefore the *Work done*, thus it takes more time for achievements to occur.

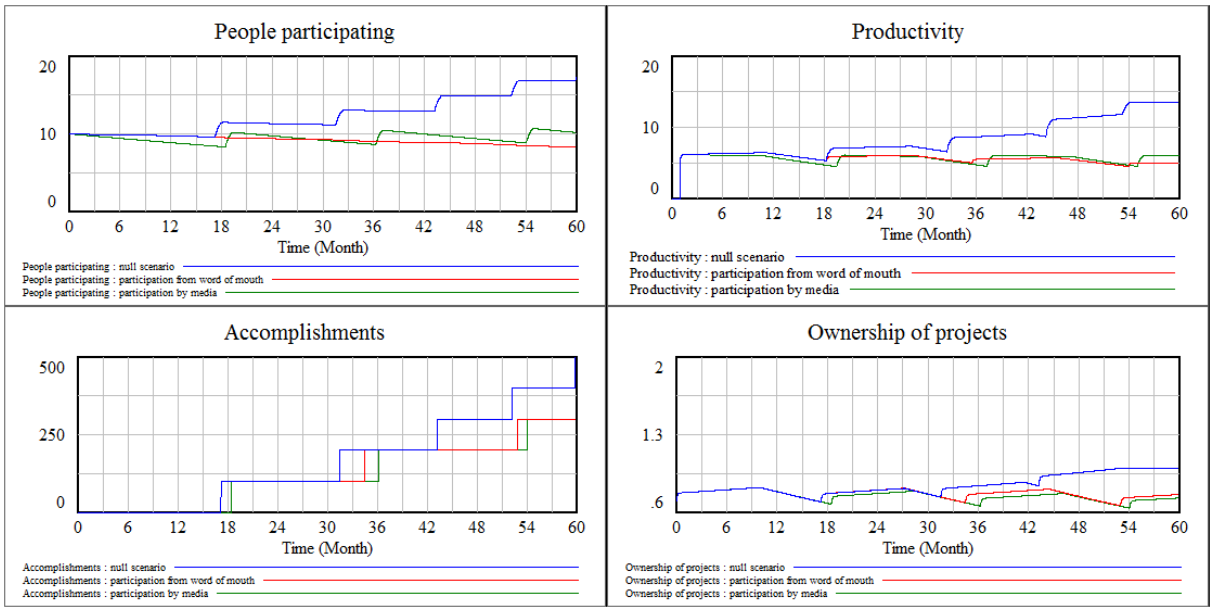

Figure 5-15 Scenario I – Participation types

5.12.3 Scenario II – Participation Impact

The participation types are not the only variable that can be changed. Differentiating with the impact of both participation types is performed in this scenario and the result can be seen in Figure 5-16.

Increasing the impact of *Word of mouth joining per people leaving* has a great effect on the model. Because of the many people joining, the *Productivity* and therefore the amount of *Accomplishments* goes up rapidly. Additionally the *Ownership of projects* hits the maximum value of 1 faster when the *Word of mount joining per people leaving* value is higher. However, the effect between *People participating* and *Ownership of projects* is not very large because when the *Word of mouth joining per people leaving* is 4 times higher, the *Ownership of projects* hits its maximum value barely two times faster. This is due to the *Effect accomplishments on change of ownership* of projects. The same effect is responsible for the short but rapid increase of *Ownership of projects*.

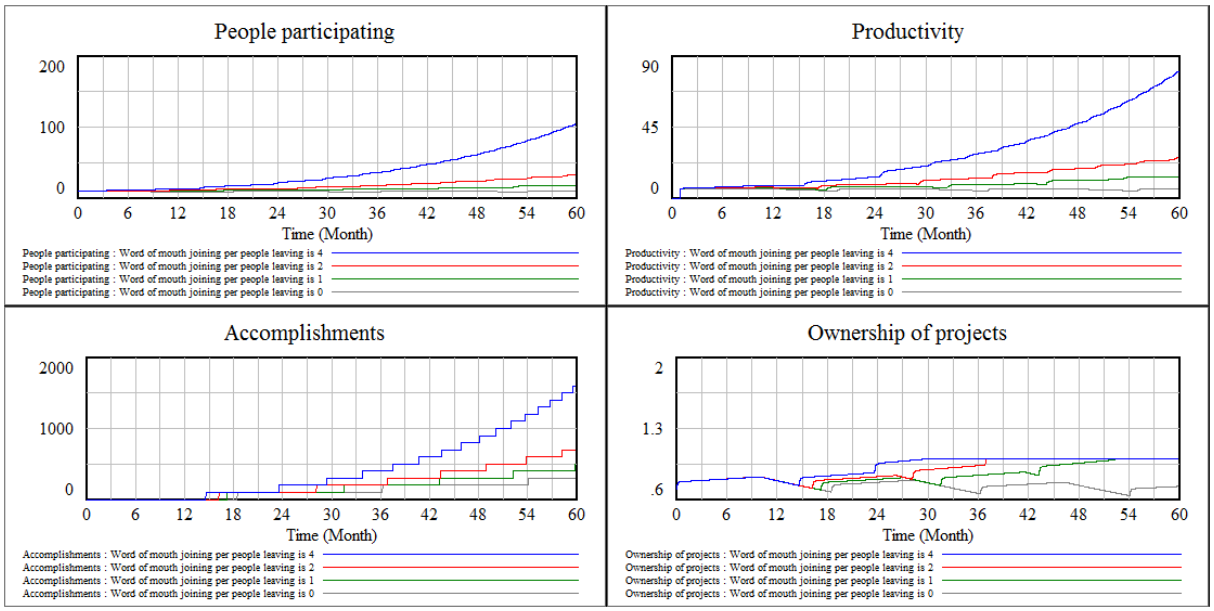

Figure 5-16 Scenario II – *Word of mouth* impact

When the impact from *People joining by media attention* is increased, the *People participating* increases with short bursts. The effects of both types of participation is similar, but it appears that the *Media attention* increases the *People participating* more than the word of mouth. Even though the *People participating* increases more by the media, the maximum value of *Ownership of projects* is reached faster in case in the word of mouth scenario. This is caused by the time at which *Accomplishments* are achieved. In the case of the *Media attention*, the *Accomplishments* are achieved later as was already discussed in Paragraph 5.12.2. In the additional time needed to accomplish, the *Ownership of projects* decreases more in the cases of the media scenario. Such a heavy decrease does not occur in the word of mouth scenario as the *Accomplishments* are achieved faster.

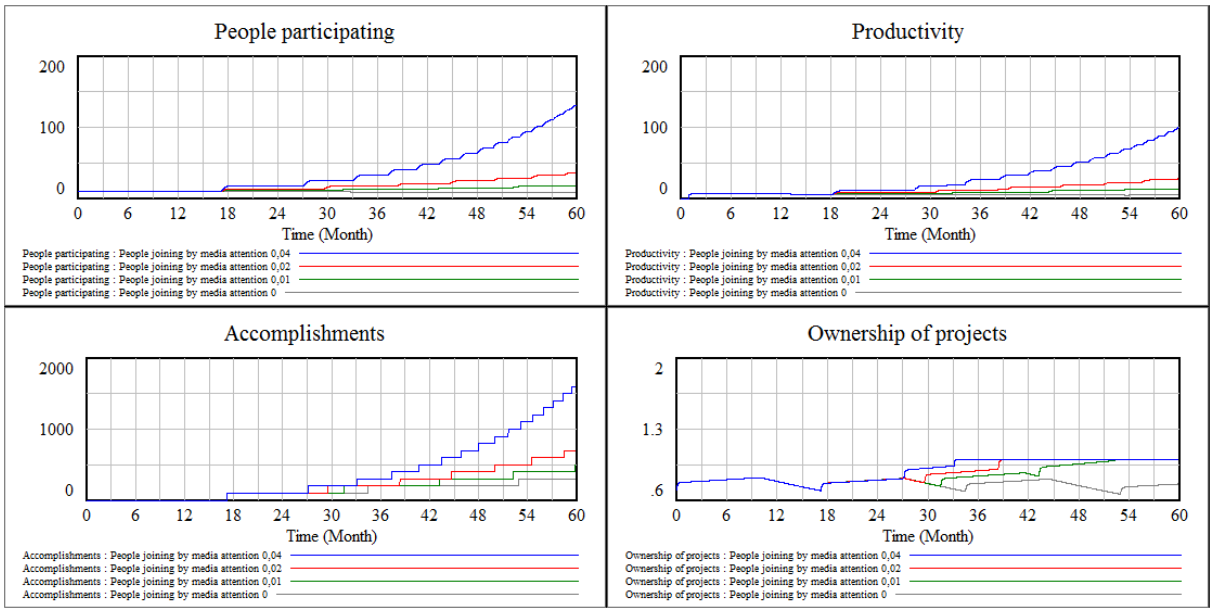

Figure 5-17 Scenario II – *People joining by media attention* impact

Another possible way to measure the impact of participation is to set both types' impact on 0. This scenario can be reviewed in Figure 5-18. It is clear from the *People participating* that

there are no people joining, but the *Productivity* does not decrease in the same way as *People participating*. The cause of this is the *Ownership of projects*. Because *Progress* is still made and *Accomplishments* are still achieved, the *Ownership of projects* increases as long as these *Accomplishments* are finished as expected. But of course the *Accomplishments* start to lag behind as there are too little people joining to perform all necessary *Work done*. This eventually leads to a collapse in the *Ownership of projects* and is followed by a decrease in *Productivity*.

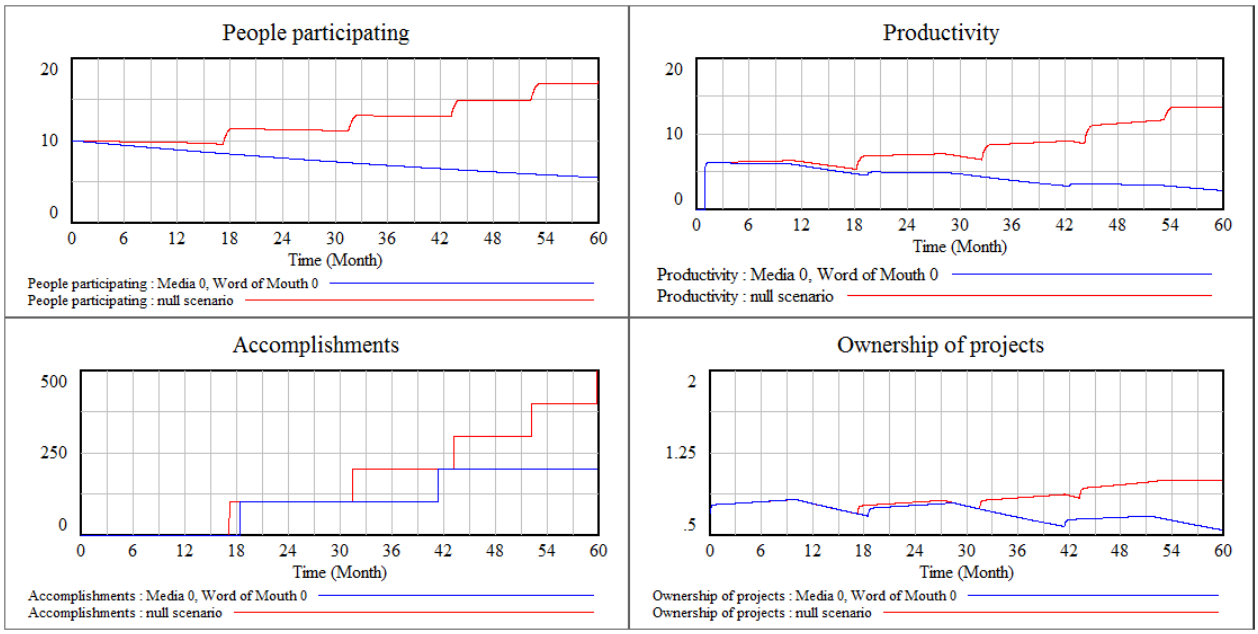

Figure 5-18 Scenario II – No Participation impact

5.12.4 Scenario III – Compare Neighborhoods

The main motivation to use open data as main input source for the model, is that multiple neighborhoods can be compared. Figure 5-19 shows the results of three neighborhoods. The null scenario remains Schrijversbuurt, while the low score neighborhood is Bennekel-West, Gagelbosch and the high score neighborhood is Gerardusplein. A better neighborhood performs better in the picture below, but the reason behind this is not straightforward. A good neighborhood is not only good because of high motivation and ability by its residents. Although this is essential, the *Population* of the neighborhood is of great importance as well. In the model the *Potential participants* are calculated using the *Willingness to participate* (*Ability to participate* and *Motivation to participate*), the *Population* and the amount of people that are currently in *Activities to improve neighborhood*. So a very large neighborhood with an average score, has much more participants than a small neighborhood with a very high score. Although at first sight this seems unreasonable, it is logical. The amount of participants is only a very small fraction of the *Population* and chances of enough people joining in a large neighborhood are larger than in a very small one.

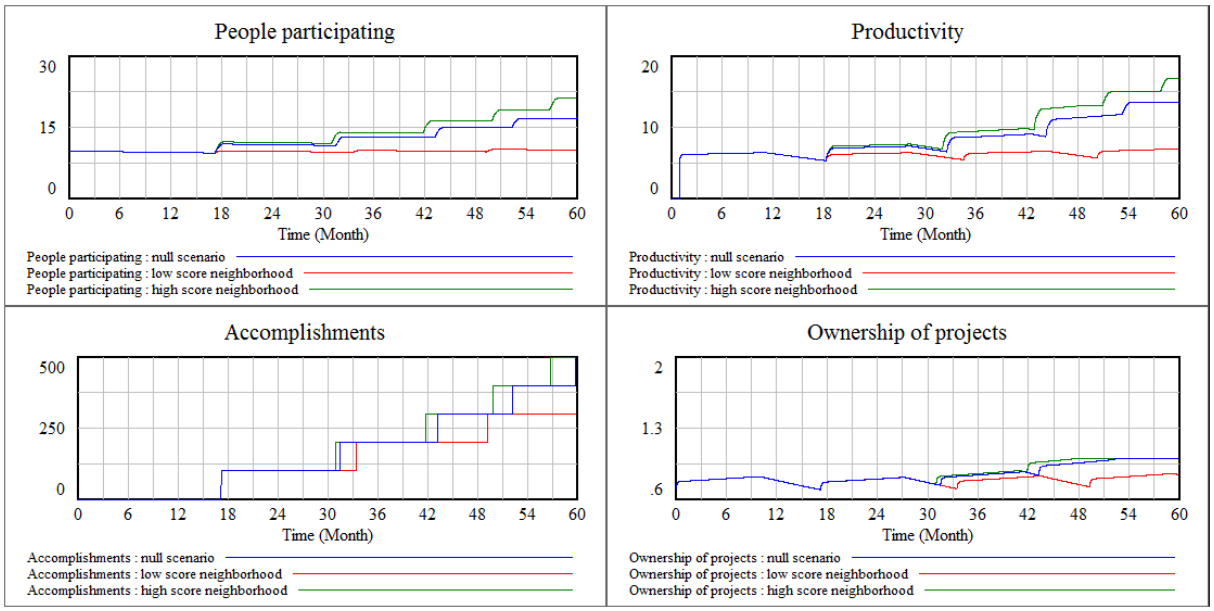

Figure 5-19 Scenario III – *People participating, Productivity, Accomplishing rate, and Ownership of projects*

5.12.5 Scenario IV – External Funding

The concept of *External funding* was already mentioned in Paragraph 5.8. Voorberg (2014) found out that subsidies make municipalities take a director role. In this report it is argued that *External funding* reduced the *Ownership of projects* and the model describes this behavior in this scenario, displayed in Figure 5-20. The first accomplishments are reached earlier, but this is not caused by the *Productivity* of participants. Rather it is the result of faster *Progress rate* caused by the *External funding*. The external funding has the negative feature of decreasing the *Ownership of projects*. So even though the project is successful in terms of *Accomplishments*, it is not as successful as potentially possible due to the decreased *Ownership of participants.*

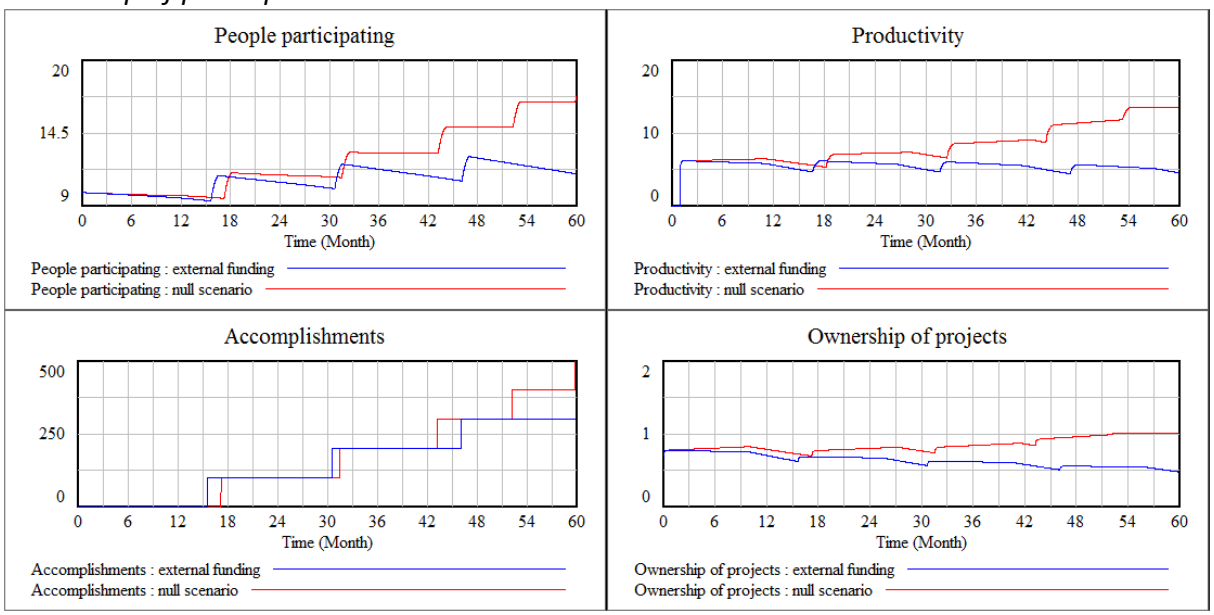

Figure 5-20 Scenario IV - *People participating, Productivity, Accomplishing rate, and Ownership of projects*

5.12.6 Scenario V – Training and Education

Training and education can be regarded as very important to achieve desirable outcomes, this was already discussed in Paragraph 4.3. The null-value for this scenario is 0.8, because it is impossible to prepare the project for 100% as this is an innovative project. The value 1 makes the project almost not exceed its expectations, so *Productivity* and *Ownership of projects* increase rapidly. The value 0.5 has as a result that the *Productivity* remains low. The *Accomplishments* are achieved later and therefore the *Ownership of projects* decreases over time. So it is evident from the model that there is *Training and education* to increase *Productivity of participants* and enable the project to continue for a longer period of time.

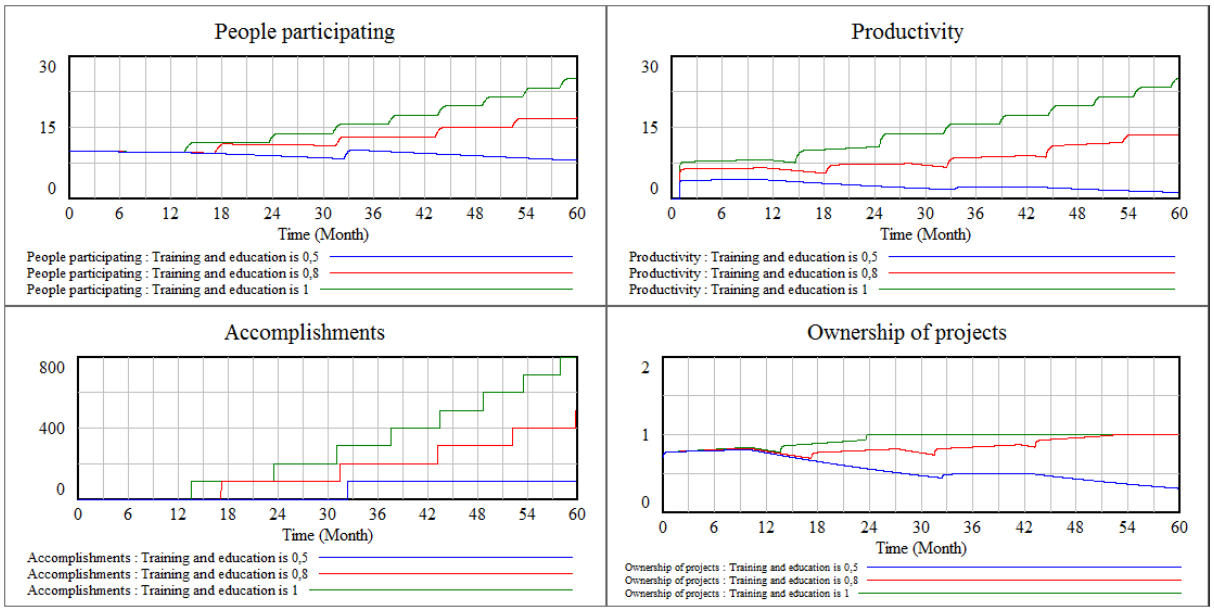

Figure 5-21 Scenario IV – Training and education

5.13 Validation of the Model

The concept of validation has multiple definitions, but there is a general idea behind it. By synthesizing multiple definitions the following definition was created: Validation is the process of determining that a model is consistent with its intended application, that the model is useful, and that it acceptable accurate in its representation of reality (Coyle 1977; Giannanasi et al. 2001; DoD 2002; Sargent 2003).

According to Sterman (2000) no model can ever be validated or verified because all models are wrong. The model represents a simplification of the problem in the real world. The used variables are derived from scientific articles and have been adopted as the truth. Besides these variables, there are also variables that are not mentioned in the literature but might have influence on the problem.

Additionally, it is not possible to validate the model by the author alone because the validation process is social and personal. Mostly, models are used to gain shared understanding and provide insight of complex real world problems. Therefore communication among concerned parties could be seen as the main feature of modelling. As is commonly adopted, human behavior is far from rational, which makes this communication almost impossible to model completely.

The model created in this report is partially qualitative and partially quantitative. Quantitative data forms the foundation for the willingness to participate, however this data is converted by using experience as a qualitative source of input. Additionally the causal

loops of the model are based on literature. This literature uses qualitative methods to acquire the results, such as experience, interviews, and observations. So although quantitative data is used for its input, there is no historical quantitative data available to exactly describe the processes of the model. Therefore the model is mainly qualitative, but with some quantitative input (Luna-Reyes & Andersen 2003).
A comprehensive review of the validation methods for system dynamics modeling is described by Martis (2006). In this report the validation scheme by Forrester & Senge (1980) and Khazanchi (1996) are extensively reviewed. Moreover, various other validation techniques are given. Combination of techniques are commonly used for validating a system dynamics model. The other validation techniques can be used in addition to the validation schemes to increase the credibility of the model (Martis 2006).
The validation scheme proposed by Forrester & Senge (1980) is divided into four phases and with the passing of each phase the confidence in the model increases. It covers the model objective, the model structure, the model behavior and policy implication. This method is used for quantitative and qualitative models.
Khazanchi (1996) proposes a scheme specifically for qualitative models and uses multiple criteria for validating a model. Because the model developed in this report is qualitative, this validation scheme is used. A total of nine criteria are given and immediately discussed with respect to the model developed in this report.

Plausibility is the first criterion. It is argued that the model is plausible if it has face-validity. Face validity means to check whether the model structure and the used parameters make sense. It mostly takes place automatically, since it is a natural thing to do. Face validity is mainly useful when expanding the model. It provides clarity and provides better understanding of complex models. This model is deducted from research and theories that describe the co-creation process as well as participation behavior. Therefore it is concluded that this model is plausible.
The second criterion is feasibility. This criterion dictates that the model must be *"workable or operationalizable"*. In other words, the concept should be able to be put into graphs, mathematics, illustrations, etc. In this report the basic ideas generated from theories are used to create formulas and make the model work. It is argued that this makes the model feasible.
Thirdly, the effectiveness. The main question is how effective the model is in its description of the phenomenon. This reflects the model has the potential of serving scientific purposes as well as giving implications for further research. Paragraph 6.2 gives a complete description of further research and guides to other scientific inquiries with the model as starting point. The model is thus regarded as effective.
Pragmatism forms the fourth criterion. This dictates that the model should not only restrict itself to previous created models, but also find additional conceptual theories to back its validation. This criterion is completely met by the model, since no previous model of the phenomenon of co-creation could be found. Therefore the knowledge to produce this model was relatively abstract, but logical and this greatly adds to the value of the model.
Fifthly, the empirical content. This concerns the empirically testability of the model. However, the model developed in this research focuses on co-creation of a smart city. This development currently has no direct observation research and therefore this phase is regarded as impossible for this research. It can be said that this model is more a logical

conceptual development, in the future this model can be reviewed to test empirically. Only then the model can be validated empirically.
The sixth criterion seeks to answer the question whether the model can predict observed facts. For the same reason as for the sixth criterion, this criterion cannot fully be met. But the model demonstrates that expected phenomena occur in Paragraph 5.12. So the model is partially predictive.
The model must be intersubjectively certifiable as seventh criterion. This means that the model should be tested by different investigators with differing stances. Only they can verify that the model is true in its description of the phenomena by observation, logical evaluation and experimentation. The model fails to meet this criterion because of the absence of valuation by other investigators than the author himself.
Finally, the model should be intermethodologically certifiable. The investigators mentioned in the seventh criterion should use different methodologies to verify that the model represents the phenomenon correctly. This criterion is not met and performing this check by investigators would greatly increase the validity of the model.

It is clear that complete validation is impossible, because of the lacking empirical evidence. Additionally this model is not completely validated as multiple investigators have not used multiple methodologies to check whether the model is correctly describing the phenomenon of co-creation a smart city. According to Ford (2009), who agrees with Sterman (2000), one should wonder if the model is useful instead of valid. The users of the model should make better decisions by using the best available model. And instead of trying to validate the model, the focus should be on the limitations of the model so that these can be improved. This is discussed in the next paragraph.

5.14 Discussion

This chapter attempts to find an answer to the question: *"How to influence smart city development?"* by using system dynamics. The process of smart city development by co-creation is described in Paragraphs 5.5, 5.7, 5.8, and 5.9. The results presented in Paragraph 5.12 give some interesting answers to the research question. However, as all models are wrong, an exhaustive discussion on the model and the results is necessary to find out what the valuable outcomes of this research are. Accordingly this paragraph gives shortfalls of the system and lessons learned.

5.14.1 Shortfalls of the system

The system displayed in Figure 5-6 has some shortfalls. While critically reviewing the model, several aspects can be pointed out that are not in accordance with the reality. The main reason is that these aspects are simplified in order to keep the model comprehensible and on-target. These aspects are discussed in this section.
The Stock and Flow Model is aimed to understand how the process of co-creation in smart city development can be influenced. Several contextual factors are left behind as the focus is on how the process can be influenced to become successful.
The system starts with 10 participants, so this means that some people have to join regardless of any accomplishments. While literature describes ways to increase the participation, there is of course no certainty that people will participate. In this participation process reputation and marketing performed by the city is very important. Also it must be noted that the costs of training, education, supervision and time it takes to bring a group

together are not considered in this model. These can also determine the success and failure of a project and are therefore considered a major shortfall.
The model is fairly abstract as it attempts to describe different forms of co-creation in one model. Therefore internal group dynamics are not considered. This is also a shortfall as group dynamics are of influence to the progress in a project. However, it is argued that with the right supervision by experts, the negative influences of group dynamics can be prevented. These experts also have a great responsibility in managing the cooperation with various stakeholders. This is always a very difficult phenomenon to manage and is also not modeled.
Expert involvement also yields negative influences as it can decrease the level of ownership of the project by participants. There is an optimum in the expert and stakeholder involvement as Goulden (2015) describes. However, it is very hard to explore this optimum in this model, because every project requires a different amount of supervision. More complex projects have to be supervised more and this is accepted easier by participants. But when relatively simple projects are intensively supervised, the ownership by participants is much lower. This topic requires further research and will greatly benefit from empirical evidence to be understood.
There are also external factors that are unaccounted for that can negatively influence the progress. For example: results of technological development fail to materialize, very negative media attention, change of politics, disasters, and problems with regulation on the highest level. While it is very hard to incorporate these factors into the model due to randomness, it must be said that it can therefore never be sure that a project will be a success.
When a project is a success and a new solution is developed, there is the possibility of business development. This topic is not considered in the model. Business development can positively influence the progress of co-creation, because it results in a very high level of ownership. The professional relationship with such a project then greatly increases, which has the opportunity to result in sustained co-creation as the success for business is then also proven.
Another shortfall of the model is in the calculation of the potential participants. The population is used to calculate this factor, but this means that low resident count neighborhoods will almost never be considered successful by the model. A low score very large neighborhood has much higher chances of sustaining than a small neighborhood with a great score. This may be considered logical, because with 10 times as many people living in a neighborhood, chances of it becoming a success are much higher. But you only need a few people to make the process a success, so this model only works good if the neighborhood exceeds a minimum size of approximately 2000 residents. A way to solve this is to combine multiple neighborhoods. Their characteristics are known, so it should be possible to perform analysis on which neighborhoods to combine in a smart city development. This is another recommendation for further research.

5.14.2 Lessons learned

Although there seem to be a lot of shortfalls for the model, there are also a lot of lessons that can be taken away from this research. The so-called added value includes the differentiation between participation types, the behavioral aspects of participants as a result of the ownership, the influence of the accomplishments on the ownership, the influence of external funding, and the model itself.

The differentiation between participation types is often neglected by existing literature. Part of the past research only considers media attention as only influential source of participation. However, the distinction between media and word of mouth participation, as happens in practice, made it clear that both participation types have important influences.
The behavioral aspects of participants as a results of ownership is assumed in the model. Because it is one a very important and sometimes forgotten aspect of a project, this phenomenon should be subject to further research.
Also the effect of accomplishments on the ownership of projects should not be underestimated. While accomplishments are mostly reviewed from the positive viewpoint of giving media attention, it has been made clear that it has a positive effect on the Ownership of projects as well.
The negative influence of external funding is mentioned in literature and the model shows behavior in line with this. It is a clear case of bounded rationality since at first it looks like the project is performing well. But at the same time the ownership by participants is declining and therefore after some time, the progress rate declines rapidly as a result. This conclusion should be made clear to municipalities as their tendency to take control is very high. While they only tend to improve the project with their control, they are actually limiting the possibilities for a successful sustainable development.
One of the major contributions of the model is the model itself. The phenomenon of co-creation has not been modeled by system dynamics before and therefore greatly contributes to the understanding of this phenomenon from a scientific perspective. Though the process of co-creation is relatively new, it is growing in popularity and to effectively use it, it must be completely understood. It is entirely logical that more research in this field must be conducted, but it can be said that this model gives a good foundation for that research.
The model is created with the hook model as a base. This model is gaining popularity, because of the successfulness of the book by Eyal (2014). The behavioral theory that is being used has also never been modeled before. Therefore the structure of this model can also be used for other phenomena that use the hook model as a baseline.
At last the model is predicting the successfulness of a co-creation project to a small extent. Although many external variables remain unconsidered, it gives a broad idea whether a neighborhood is suited for co-creation with citizens. The model is far from perfect and empirical evidence is necessary to make the model completely usable in a real life context. But for now it gives an idea of how the process of co-creation works from a citizen perspective. This model is a first step towards the creation of a smart city by co-creation with citizens.

5.15 Recommendations Case Study S-mart Strijp-S

Strijp-S wants to become S-mart Strijp-S. The developed vision document (Goulden 2015) contains three main development areas: infrastructure, platform, applications. The recommendations that follow on the research of this paper are in line with these development areas, but there are also new findings.

The first recommendation is more a confirmation of expected results. The co-creation that Strijp-S wants to achieve builds on the participation of citizens. Unfortunately the willingness to participate could not be calculated due to lack of data, but the components of the willingness can be evaluated on the Strijp-S case. Strijp-S can be seen as a community. The people who live at Strijp-S are located very closely together and have also started a

neighborhood watch, showing that there is social motivation. Additionally, many entrepreneurs live at Strijp-S because this is being stimulated by having workplaces, studios and a community for entrepreneurs (TRUDO 2015). The assumption is therefore made that the openness to experience is also relatively high. So the willingness to participate at Strijp-S is regarded to be average to high. This means that compared to other neighborhoods, Strijp-S is seen as a good neighborhood to start smart city development from a citizen perspective. But there is more, as Strijp-S has one organization responsible for the whole neighborhood. This is where Strijp-S distinguishes itself from other neighborhoods in the likelihood that a smart city can be built. Additionally this organization (Park Strijp Beheer) has partnerships with technology companies, the university, and the municipality. The quadruple helix is fully available at this location, so Strijp-S can be seen as an outstanding neighborhood to start a smart city development. Thus Strijp-S should continue its development on smart cities as the unique possibility that presents itself should not be wasted.

The second recommendation is that more interaction with other neighborhoods should be sought. The successfulness of the System Dynamics model was to a large extent determined by the population that was addressed. Strijp-S can greatly increase its chances when also people from nearby neighborhoods help in the development of S-mart Strijp-S. Strijp-S can then become a center of smart city development. This also helps to overcome another shortfall of the current development. Strijp-S is no ordinary neighborhood. It has unique historical buildings and new buildings. The solutions developed in S-mart Strijp-S can have the downside of not being scalable, because the solutions are developed for a neighborhood that is unique. By seeking interaction with nearby neighborhoods that are less unique it is likely that solutions will be developed that can be used in the whole of Eindhoven. One could argue that Strijp-S is seeking partnerships with other cities in Europe and therefore the need to work together within Eindhoven is low. However, every city is different and there are many barriers to the repeated implementation of a working solution. Eindhoven is known ground and the positive brand of Strijp-S can help to implement solutions more easily and more successfully. According to the analysis of Paragraph 5.11, the nearby neighborhood Schoot is a recommended neighborhood to seek interaction with.

The final recommendation applies to the process of co-creation itself. In the model the main ways to influence the process are researched. It is important for the development of a smart city by co-creation that this process is not hindered by negative influences. Therefore the process should be influenced by: education and training, increasing control by participants to ensure ownership of projects, enabling accomplishments to be achieved, and encouraging media to have attention for accomplishments. It is important that external funding is avoided, because this may take away the ownership by participants. But it is very helpful that experts from technology companies as well as urban developers assist the citizens in the process of co-creation.

5.16 Conclusion

In this chapter the hook model was translated to smart city development by co-creation with citizens. This formed the basis for the components social motivation, material motivation, openness to experience, ability to participate, and at last willingness to participate. This knowledge was used to create a model in System Dynamics that takes neighborhood data as an input. Also the Strijp-S case was discussed.

One sub question asked in this chapter is: *"Where to start a smart city?"*. The map in Figure 5-12 shows which neighborhoods are most suited for starting a smart city development. However, there are more factors that influence a smart city development such as the technological infrastructure that is present in a neighborhood. Also the presence of technology companies in a certain neighborhood can contribute to its suitability.

The neighborhoods (7) Rochusbuurt, (12) Looiakkers, and (84) Schoot, have the maximum reported value of 0,60 on willingness to participate. They are therefore regarded as the most suited neighborhoods for the start of a smart city development project by co-creation with citizens. Strijp-S yields number 85 and unfortunately there is not enough data available to calculate the willingness to participate. Many factors are left unconsidered, but from the participation by people perspective these neighborhoods are regarded most suited for co-creation of a smart city.

The topic of co-creation has proven to be hard to examine and analyze because of its complexity. Despite the efforts to reduce the problem to its fundamentals by using System Dynamics, the problem of complexity persists. The method of SD has been very useful to abstract the problem, but the many assumptions that needed to be made kept the author from reaching a very clear and complete answer to the sub question: *"How to influence smart city development?"*. However, the modelling effort resulted in the first SD model on co-creation and the first SD model that takes the hook model as a foundation. Additionally some concepts that were pointed out by literature are also described by the model. The main ways to influence the project in a positive way are: education and training, increasing control by participants to ensure ownership of projects, enabling accomplishments to be achieved, and encouraging media to have attention for accomplishments. This model can hereby help policy makers in the field of co-creation, social innovation, citizen participation, and smart city development understand how complex the process of co-creation is and that it contains bounded rationality. The research encourages that more practical examples of co-creation will take place to ensure that future models can be validated and the process of co-creation can be fully understood.

From the Strijp-S case it is clear that the willingness to participate is essential, but also very hard to determine. Additionally, it describes that at first technology partners were attracted to create a technological infrastructure. Three recommendations for Strijp-S are given. Firstly, Strijp-S should continue its development on smart cities as the unique possibility that presents itself should not be wasted. Secondly, more interaction with other neighborhoods should be sought to increase the potential participants and to create more scalable solutions. Schoot is recommended as a neighborhood to cooperate with. Finally, the project should follow the main ways to positively influence co-creation discussed above.

PART 4 – CONCLUSION

6 CONCLUSION

The conclusion is split up in three parts that each show relevance for a specific field. The relevance is explained by using answers to the sub questions of this research.

6.1 Societal relevance

This research has some very valuable conclusions for society as a whole. Especially the answers to the first sub question: *"Why a smart city?".* Evidence is presented that demographic transition and urbanization are trends that can be influenced by the smart city. The smart city is efficient with resources and can provide thorough analysis that help solve the problems related to these trends. Additionally, the quality of life and economic performance can be enhanced by a smart city. The services themselves can enhance the quality of life by solving needs that are currently not fully addressed. While the development process of these services has the potential enhance economic performance by creating new opportunities.

This research gives an extensive description on these four reasons behind the smart city. The descriptions themselves are very relevant and a timely issue. Understanding how the smart city can influence these trends is also very important for society, since cities like a smart city will inevitably arise in the future. So an answer is given in this report why a smart city development is something that everyone should want.

Additionally the concept of co-creation will most likely be used more in the future. Therefore the impact society can have on its environment increases and it is important that society understand this trend.

6.2 Scientific Relevance

This report provides an extensive literature review on the smart city and co-creation and related topics to these two. The conceptual model of Figure 3-2 gives answers to the second research question: *"What is a smart city?"*. This model was designed based on the findings of literature and contributes to the understanding of the concept of smart cities. Three topics are found to be closely related in smart cities: cities, technology, and citizens. Combining these major topics leads to certain concepts that have been referred to in this chapter. Citizens are more and more included in development processes with technology companies and cities and are co-creating solutions. Technology is advancing quickly and the digitalization trend discussed in this chapter reflects this. Cities are also advancing, but this relates to a currently more problematic trend of urbanization. The general idea behind this report is that technology should not be leading, as it will advance nonetheless and is a means to an end. The real end is addressing the needs of end-users, citizens in the case of smart city development.

The hook model by Eyal (2013) was translated to smart city development by co-creation with citizens. This formed the basis for the components social motivation, material motivation, openness to experience, ability to participate, and at last willingness to participate. This knowledge was used to create a model in System Dynamics that takes neighborhood data as an input. Also the Strijp-S case was discussed.

The fourth sub question is: *"Where to start a smart city?".* The map in Figure 5-12 shows which neighborhoods are most suited for starting a smart city development. However, there are more factors that influence a smart city development such as the technological

infrastructure that is present in a neighborhood. Also the presence of technology companies in a certain neighborhood can contribute to its suitability.
The neighborhoods (7) Rochusbuurt, (12) Looiakkers, and (84) Schoot, have the maximum reported value of 0,60 on willingness to participate. They are therefore regarded as the most suited neighborhoods for the start of a smart city development project by co-creation with citizens. Strijp-S yields number 85, but unfortunately there is not enough data available to calculate the willingness to participate. Many factors are left unconsidered, but from the participation by people perspective the neighborhoods are regarded most suited for co-creation of a smart city.
The topic of co-creation has proven to be hard to examine and analyze because of its complexity. Despite the efforts to reduce the problem to its fundamentals by using System Dynamics, the problem of complexity persists. The method of SD has been very useful to abstract the problem, but the many assumptions that needed to be made kept the author from reaching a very clear and complete answer to the sub question: *"How to influence smart city development?".* However, the modelling effort resulted in the first SD model on co-creation and the first SD model that takes the hook model as a foundation. Additionally some concepts that were pointed out by literature are also described by the model. The main ways to influence the project in a positive way are: education and training, increasing control by participants to ensure ownership of projects, enabling accomplishments to be achieved, and encouraging media to have attention for accomplishments. This model can hereby help policy makers in the field of co-creation, social innovation, citizen participation, and smart city development understand how complex the process of co-creation is and that it contains bounded rationality. The research encourages that more practical examples of co-creation will take place to ensure that future models can be validated and the process of co-creation can be fully understood.
From the Strijp-S case it is clear that the willingness to participate is essential, but also very hard to determine. Additionally, it describes that at first technology partners were attracted to create a technological infrastructure. Three recommendations for Strijp-S are given. Firstly, Strijp-S should continue its development on smart cities as the unique possibility that presents itself should not be wasted. Secondly, more interaction with other neighborhoods should be sought to increase the potential participants and to create more scalable solutions. Schoot is recommended as a neighborhood to cooperate with. Finally, the project should follow the main ways to positively influence co-creation discussed above.
Now the main question can be answered as well: *"How to create a smart city?".* The subtitle gives a short but complete answer to the main question: *"Co-creation of a smart city with citizens."* How to exactly create it is impossible to answer, because every city is different and constantly changing. Therefore the smart city must be built with the help of those people who are the experts, the citizens. A neighborhood that scores well on the willingness to participate score is preferred and actual initiatives in the area or an organization that is developing the area is considered very helpful. With the new advances in technology, citizens can interact more with their environment. They can more and more communicate with each other, but also with the public sector and even with objects in the public space. Cities have always been smart thanks to its citizens, and this will not change. The only thing that is changing is that the smart people will now have the opportunity to use that smartness to smarten up their city.

6.3 Beneficiary relevance

The developers at Strijp-S can learn from the recommendations given in this report. Additionally, the developed model can help policy makers in the field of co-creation, social innovation, citizen participation, and smart city development understand how complex the process of co-creation is and that it contains bounded rationality. The research encourages that more practical examples of co-creation will take place to ensure that future models can be validated and the process of co-creation can be fully understood.

The report can also be very helpful for urban developers, as they will also encounter smart cities in their work. The comprehensiveness of this report can greatly contribute to their knowledge on this concept.

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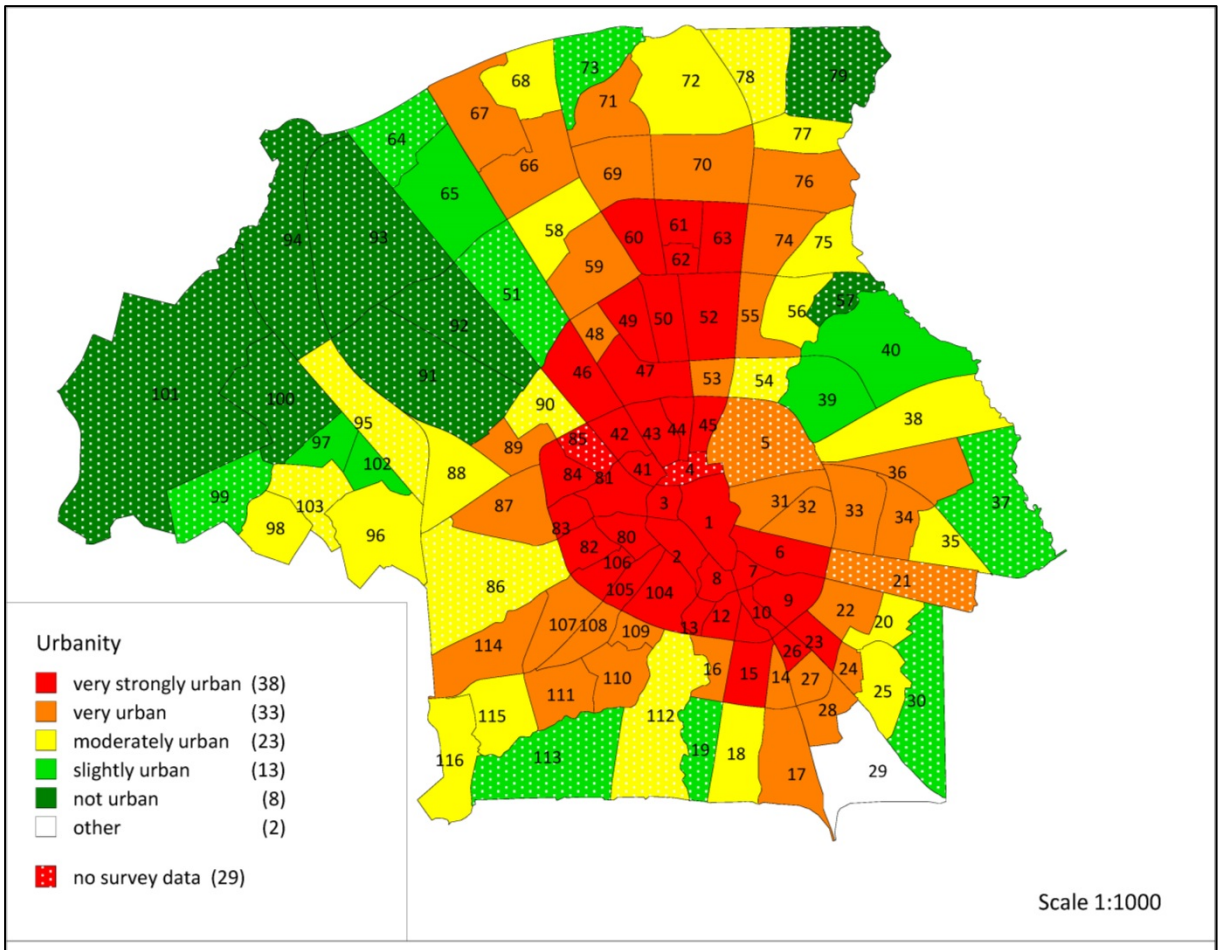
APPENDICES

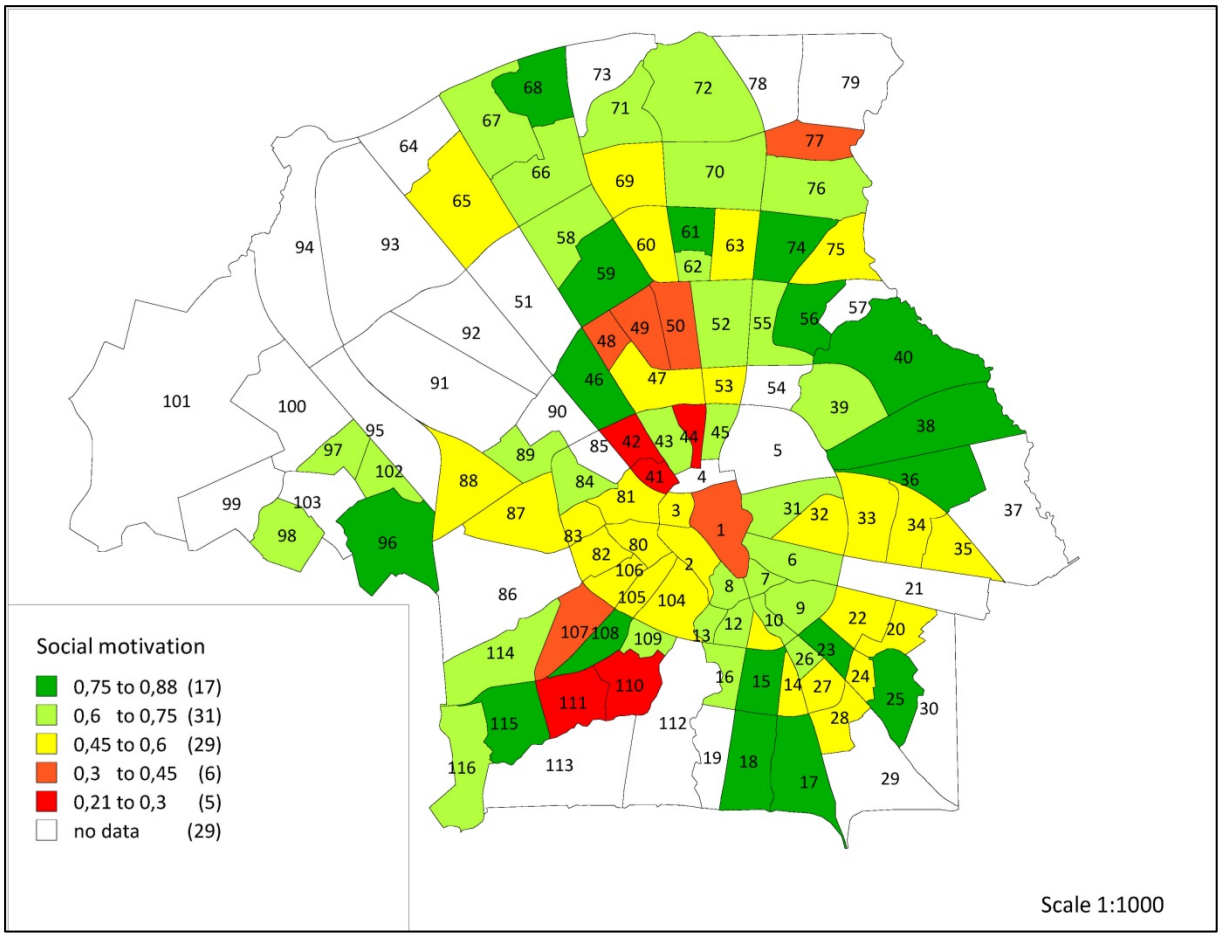
A: Urbanity and Neighborhood Numbers
B: Social Motivation and Functional Motivation
C: Motivation to Participate and Ability to Participate
D: Table Variables SFM
E: Results Calculation Components Willingness to Participate

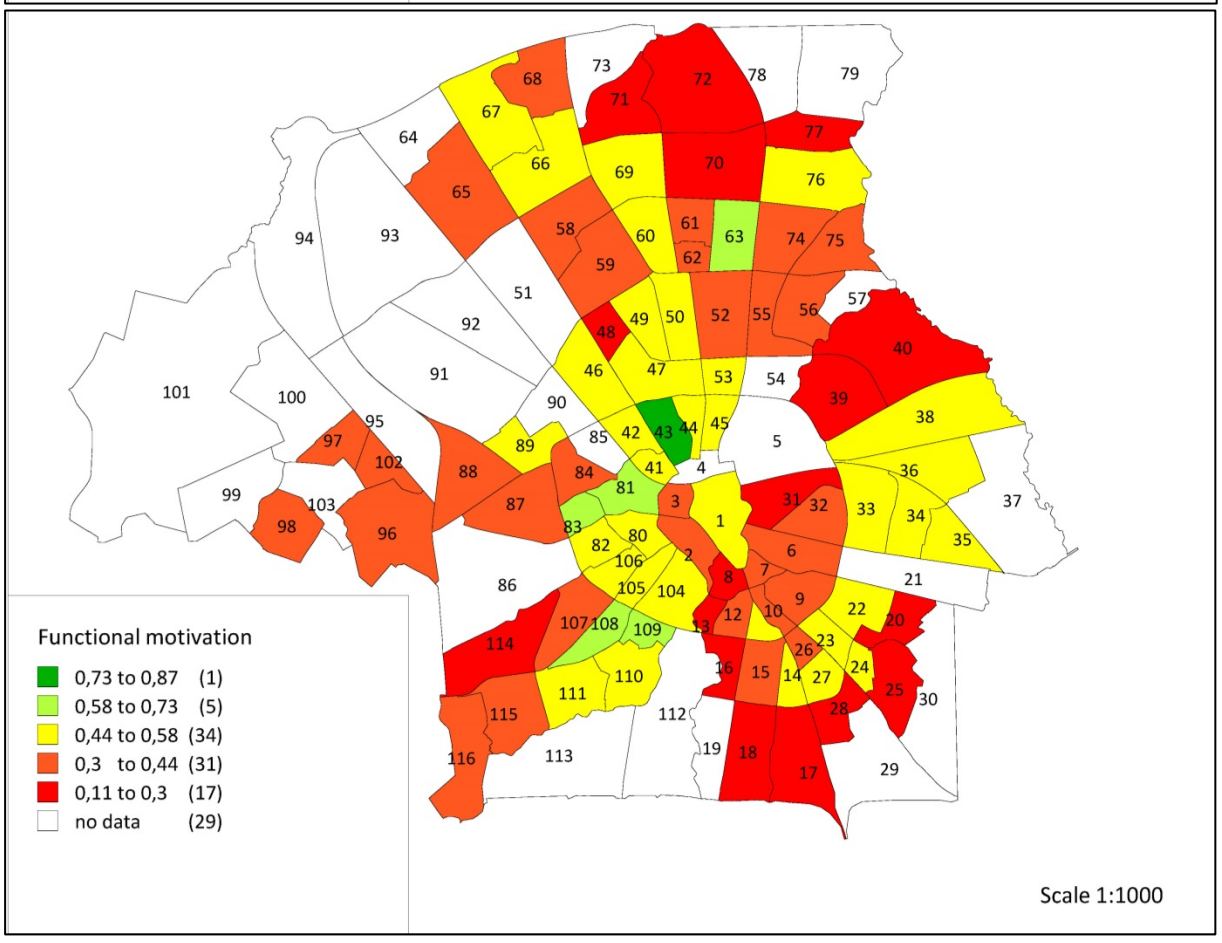
APPENDIX A



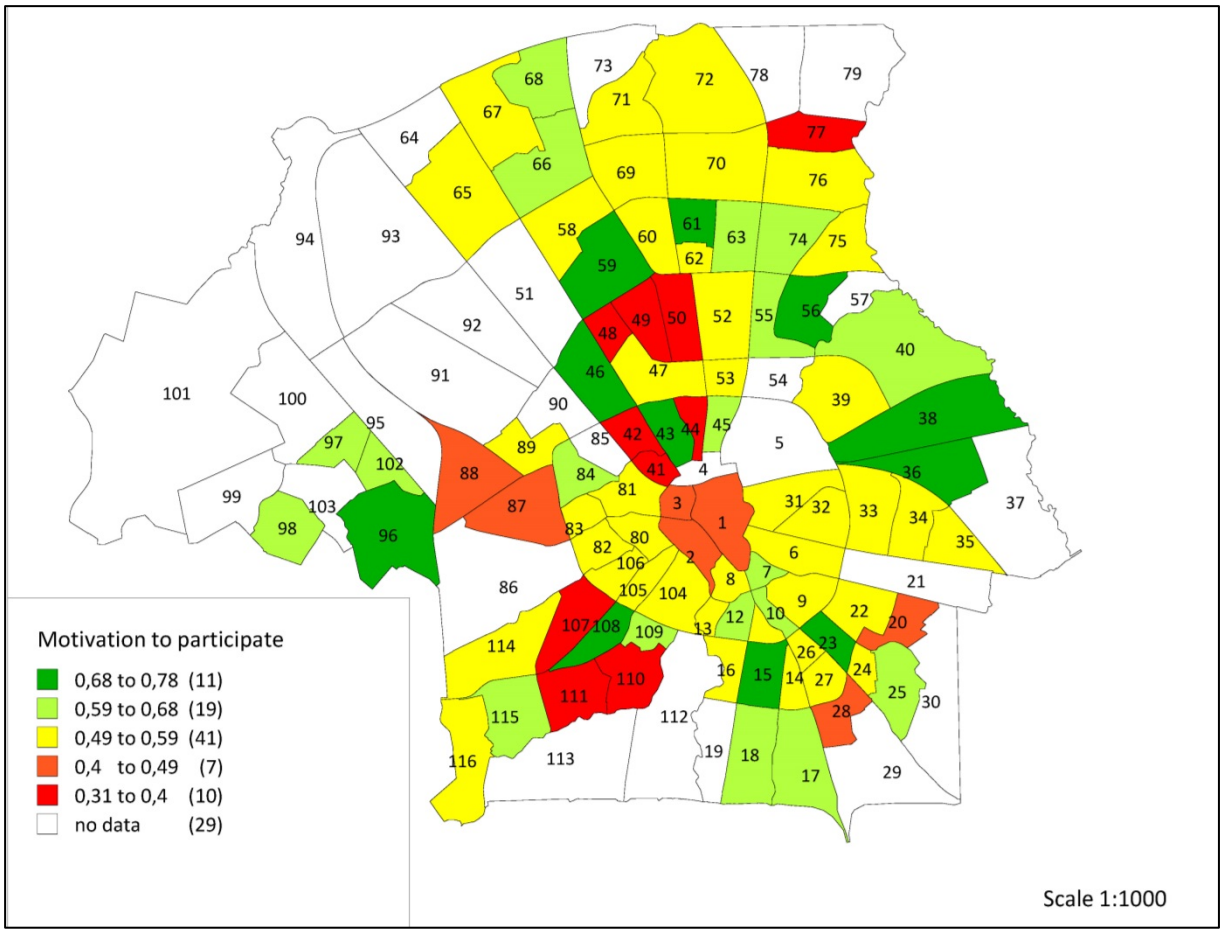
1	Binnenstad	40	Koudenhoven	79	Bokt
2	Bergen	41	Limbeek-Zuid	80	Eliasterrein, Vonderkwartier
3	Witte Dame	42	Limbeek-Noord	81	Philipsdorp
4	Fellenoord	43	Hemelrijken	82	Engelsbergen
5	TU-terrein	44	Gildebuurt	83	Schouwbroek
6	Irisbuurt	45	Woenselse Watermolen	84	Schoot
7	Rochusbuurt	46	Woensel-West	85	Strijp S
8	Elzent-Noord	47	Kronehoef	86	Hurk
9	Tuindorp	48	Barrier	87	Het Ven
10	Joriskwartier	49	Mensfort	88	Lievendaal
11	Bloemenplein	50	Rapenland	89	Drents Dorp
12	Looiakkers	51	Vredeoord	90	Zwaanstraat
13	Elzent-Zuid	52	Generalenbuurt	91	Wielewaal
14	Kerstroosplein	53	Oude Toren	92	Herdgang
15	Gerardusplein	54	Hondsheuvels	93	Mispelhoef
16	Genneperzijde	55	Oude Gracht-West	94	BeA2
17	Roosten	56	Oude Gracht-Oost	95	Meerbos
18	Eikenburg	57	Eckartdal	96	Grasrijk
19	Sportpark Aalsterweg	58	Driehoeksbos	97	Zandrijk
20	Puttense Dreef	59	Prinsejagt	98	Waterrijk
21	Poeijers	60	Jagershoef	99	Park Forum
22	Burghplan	61	't Hool	100	Flight Forum
23	Sintenbuurt	62	Winkelcentrum	101	Eindhoven Airport
24	Tivoli	63	Vlokhoven	102	Bosrijk
25	Gijzenrooi	64	Kapelbeemd	103	Meerrijk
26	Nieuwe Erven	65	Kerkdorp Acht	104	Schrijversbuurt
27	Kruidenbuurt	66	Achtse Barrier-Gunterslaer	105	Oude Spoorbaan
28	Schuttersbosch	67	Achtse Barrier-Spaaihoef	106	Hagenkamp
29	Leenderheide	68	Achtse Barrier-Hoeven	107	Genderdal
30	Riel	69	Woenselse Heide	108	Blaarthem
31	Villapark	70	Tempel	109	Rapelenburg
32	Lakerlopen	71	Blixembosch-West	110	Bennekel-Oost
33	Doornakkers-West	72	Blixembosch-Oost	111	Bennekel-West,Gagelbosch
34	Doornakkers-Oost	73	Castiliëlaan	112	Gennep
35	Tongelresche Akkers	74	Eckart	113	Beemden
36	Muschberg,Geestenberg	75	Luytelaer	114	Genderbeemd
37	Urkhoven	76	Vaartbroek	115	Hanevoet
38	't Hofke	77	Heesterakker	116	Ooievaarsnest
39	Karpen	78	Esp		

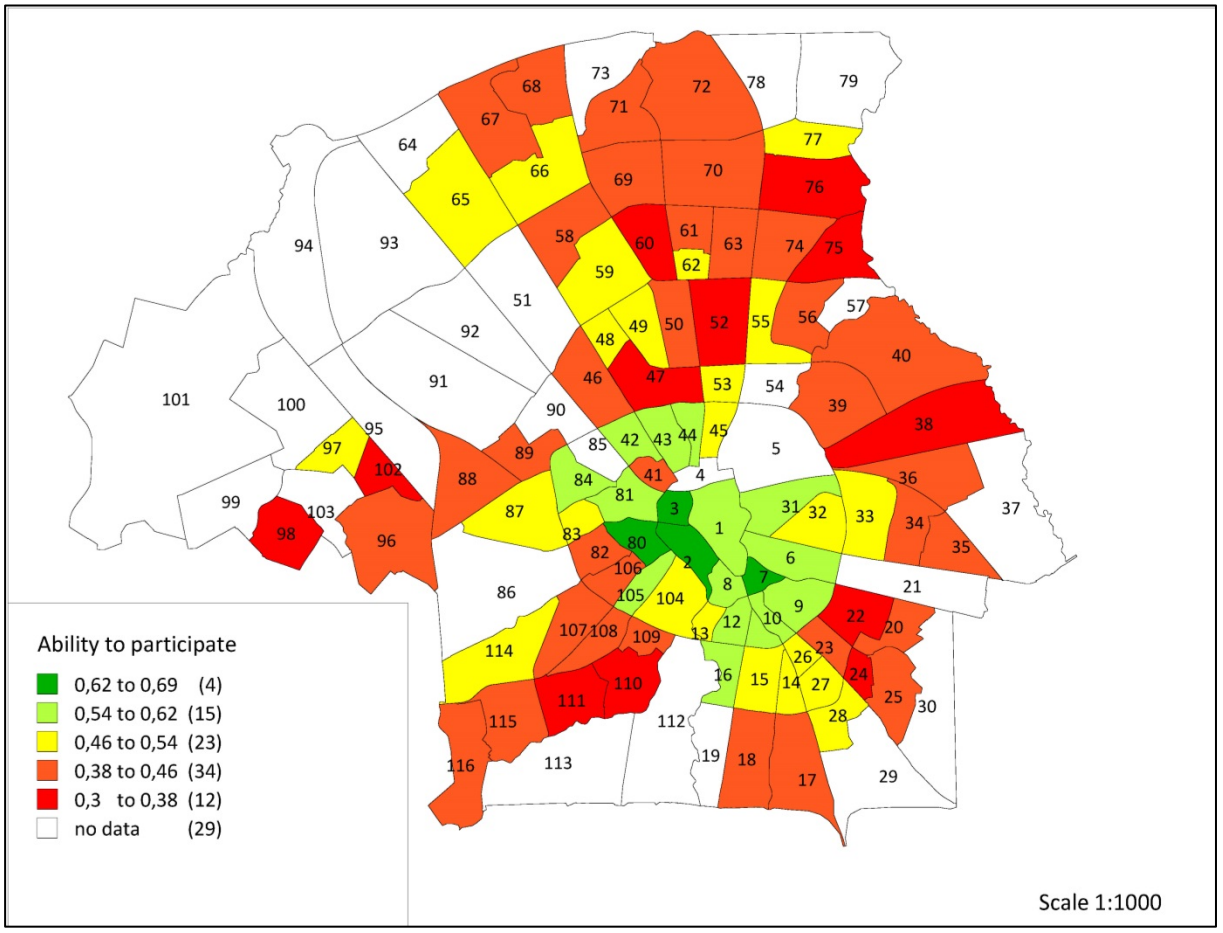
APPENDIX B


Social motivation
0,75 to 0,88 (17)
0,6 to 0,75 (31)
0,45 to 0,6 (29)
0,3 to 0,45 (6)
0,21 to 0,3 (5)
no data (29)
Scale 1:1000


Functional motivation
0,73 to 0,87 (1)
0,58 to 0,73 (5)
0,44 to 0,58 (34)
0,3 to 0,44 (31)
0,11 to 0,3 (17)
no data (29)
Scale 1:1000

APPENDIX C


Motivation to participate
0,68 to 0,78 (11)
0,59 to 0,68 (19)
0,49 to 0,59 (41)
0,4 to 0,49 (7)
0,31 to 0,4 (10)
no data (29)
Scale 1:1000


Ability to participate
0,62 to 0,69 (4)
0,54 to 0,62 (15)
0,46 to 0,54 (23)
0,38 to 0,46 (34)
0,3 to 0,38 (12)
no data (29)
Scale 1:1000

APPENDIX D

VARIABLE	EQUATION	TYPE	INITIAL VALUE	SOURCE
(1) Voluntary work	-	Constant	51	(Buurtmonitor Eindhoven 2015)
(2) Activities to improve neighborhood	-	Constant	30	(Buurtmonitor Eindhoven 2015)
(3) Social cohesion	-	Constant	7.2	(Buurtmonitor Eindhoven 2015)
(4) Neighborhood initiatives	-	Constant	0	(Buurtpreventie Eindhoven 2015)
Social motivation	MIN(1,((((1) Voluntary work-21) / (56-21)) + (((2) Activities to improve neighborhood-10) / (36-10)) + (((3) Social cohesion-4.2) / (7.2-4.2)) + (4) Neighborhood initiatives * 0.2) /3)	Normal	-	Table 5-2
(5) Criminality increase	-	Constant	15	(Buurtmonitor Eindhoven 2015)
(6) Safety	-	Constant	7	(Buurtmonitor Eindhoven 2015)
(7) Physical quality facilities	-	Constant	6.6	(Buurtmonitor Eindhoven 2015)
(8) Quality housing	-	Constant	75	(Buurtmonitor Eindhoven 2015)
(9) Parking nuisance	-	Constant	34	(Buurtmonitor Eindhoven 2015)
(10) Traffic nuisance	-	Constant	34.2	(Buurtmonitor Eindhoven 2015)
Functional motivation	((((5) Criminality increase-7) / (27-7))+ 1- (((6) Safety-5.6) / (7.5-5.6)) + 1- (((7) Physical quality facilities-5.6) / (7-5.6)) + 1- (((8) Quality housing-45) / (94-45)) + (((9) Parking nuisance-9) / (58-9)) + (((10) Traffic nuisance-16) / (51-16)))/9	Normal	-	Table 5-2
Motivation to participate	(2*Social motivation + Functional motivation)/3	Normal	-	Table 5-2
(11) Older people (65+)	-	Constant	9.7	(Buurtmonitor Eindhoven 2015)
(12) Couple households with children	-	Constant	34	(Buurtmonitor Eindhoven 2015)
(13) Population density	-	Constant	6865	(Buurtmonitor Eindhoven 2015)
(14) White ethnic background	-	Constant	11.2	(Buurtmonitor Eindhoven 2015)
(15) Total crime rate	-	Constant	48.3	(Buurtmonitor Eindhoven 2015)
(16) Income	-	Constant	22.8	(Buurtmonitor Eindhoven 2015)
(17) Employment rate	-	Constant	4.5	(CBS 2014a)
Openness to experience	((1-(((11) Older people (65+)-1.2) / (76.3-1.2))) * 58 + (1-(((12) Couples households with children-0) / (58-0))) * 68 + (((13) Population density-282) / (11340-282)) * 61 + (1-(((14) White ethnic background-1.8) / (37.2-1.8))) * 31 + (((15) Total crime rate-18.6) / (227.6-18.6)) * 34 + (1-(((16) Income-9.9) / (62.1-9.9))) * 34 + (1-(((17) Employment rate-0) / (17.5-0))) * 44)/330	Normal	-	Table 5-2
(18) Struggling to get by	-	Constant	10	(Buurtmonitor Eindhoven 2015)
Ability to participate	Openness to experience-((18) Struggling to get by/100)	Normal	-	Table 5-2

VARIABLE	EQUATION	TYPE	INITIAL VALUE	SOURCE
Accomplishing rate	IF THEN ELSE(Work done>Work done to accomplish,Work done to accomplish/TIME STEP,0)	Normal	-	-
Accomplishment time	Accomplishment time change	Level	0	-
Accomplishment time change	IF THEN ELSE(Accomplishing rate>0,(Time-Accomplishment time)/TIME STEP,0)	Normal	-	-
Accomplishments	Accomplishing rate	Level	0	-
Calculate time to accomplish	IF THEN ELSE(Accomplishing rate>0,Work done to accomplish/People participating,0)	Normal	-	-
Change in ownership	IF THEN ELSE (Ownership of projects<1, ((((Progress rate-10*External funding)/People participating)-Effect accomplishments on change of ownership)*Ownership of projects*TIME STEP) ,0)	Normal	-	-
Effect accomplishments on change of ownership	(Expected accomplishments*Impact accomplishment on change of ownership)-(50*Short term effect accomplishments on change of ownership)	Normal	-	-
Effect media attention on participation	MIN(100,Media attention)	Lookup	-	Assumption
Effect ownership on participation	Ownership of projects	Lookup	-	Assumption
Expected accomplishments	IF THEN ELSE((Time-Accomplishment time)>Time to accomplish,1,0)	Normal	-	-
External funding	-	Constant	0	(Voorberg et al. 2014)
Forget time to accomplish	IF THEN ELSE(Accomplishing rate>0,Time to accomplish,0)	Normal	-	-
Impact accomplishment on change of ownership	-	Constant	3	Assumption
Media attention	Media building rate-Media declining rate	Level	0	-
Media building rate	IF THEN ELSE (Accomplishing rate>0,Accomplishing rate/Work done to accomplish,0)	Normal	-	-
Media declining rate	IF THEN ELSE(Media attention>0,1/(Work done to accomplish*TIME STEP),0)	Normal	-	-
Motivation to participate	(2*Social motivation + Functional motivation)/3	Normal	-	Table 5-2
Ownership of projects	Change in ownership	Level	0.7	Assumption
Participation by media	IF THEN ELSE (Potential participants>People participating,People joining by media attention*Potential participants*Effect media attention on participation,0)	Normal	-	-
Participation from word of mouth	People leaving rate*Effect ownership on participation*Word of mouth joining per people leaving	Normal	-	-
People joining rate	Participation from word of mouth + Participation by media	Normal	-	-
People leaving rate	Percentage of people leaving*TIME STEP*People participating	Normal		
People participating	People joining rate-People leaving rate	Level	10	Assumption
Percentage of people leaving	-	Constant	1	Assumption
Potential participants	Population*Willingness to participate*("(2) Activities to improve neighborhood"/100)	Normal	-	-
Productivity	DELAY FIXED(People participating*Ownership of projects*Training and education,Productivity delay,0)	Normal	-	-
Productivity delay	-	Constant	1	Assumption
Progress rate	Productivity+External funding	Normal	-	-
Short term effect accomplishments on change of ownership	IF THEN ELSE((Time-Accomplishment time)<1,Time-Accomplishment time,1)	Lookup	-	(Hill et al. 2006)

VARIABLE	EQUATION	TYPE	INITIAL VALUE	SOURCE
Time to accomplish	Calculate time to accomplish-Forget time to accomplish	Level	Work done to accomplish /People participating	-
Training and education	-	Constant	0.8	(Goulden 2015)
Willingness to participate	MIN(Ability to participate,Motivation to participate)	Normal	-	-
Word of mouth joining per people leaving	-	Constant	1	Assumption
Work done	Progress rate-Accomplishing rate	Level	0	-
Work done to accomplish	-	Constant	100	Assumption

APPENDIX E

NEIGHBORHOODS OF EINDHOVEN	FUNCTIONAL MOTIVATION	SOCIAL MOTIVATION	MOTIVATION TO PARTICIPATE	OPENNESS TO EXPERIENCE	ABILITY TO PARTICIPATE	WILLINGNESS TO PARTICIPATE
Binnenstad	0,53	0,44	0,47	0,69	0,56	0,47
Bergen	0,42	0,45	0,44	0,73	0,69	0,44
Witte Dame	0,42	0,45	0,44	0,67	0,63	0,44
Fellenoord						
TU-terrein						
Irisbuurt	0,40	0,64	0,56	0,63	0,54	0,54
Rochusbuurt	0,42	0,69	0,60	0,77	0,67	0,60
Elzent-Noord	0,23	0,67	0,53	0,60	0,59	0,53
Tuindorp	0,40	0,64	0,56	0,64	0,55	0,55
Joriskwartier	0,42	0,69	0,60	0,67	0,57	0,57
Bloemenplein	0,57	0,50	0,53	0,70	0,55	0,53
Looiakkers	0,42	0,69	0,60	0,70	0,60	0,60
Elzent-Zuid	0,23	0,67	0,53	0,53	0,52	0,52
Kerstroosplein	0,57	0,50	0,53	0,62	0,47	0,47
Gerardusplein	0,40	0,88	0,72	0,61	0,51	0,51
Genneperzijde	0,23	0,67	0,53	0,56	0,55	0,53
Roosten	0,11	0,85	0,60	0,46	0,42	0,42
Eikenburg	0,11	0,85	0,60	0,49	0,45	0,45
Sportpark Aalsterweg						
Puttense Dreef	0,23	0,59	0,47	0,53	0,43	0,43
Poeijers						
Burghplan	0,57	0,55	0,56	0,53	0,33	0,33
Sintenbuurt	0,57	0,75	0,69	0,58	0,38	0,38
Tivoli	0,57	0,55	0,56	0,52	0,32	0,32
Gijzenrooi	0,23	0,79	0,61	0,49	0,39	0,39
Nieuwe Erven	0,40	0,64	0,56	0,62	0,53	0,53
Kruidenbuurt	0,48	0,57	0,54	0,60	0,53	0,53
Schuttersbosch	0,23	0,59	0,47	0,62	0,52	0,47
Leenderheide						
Riel						
Villapark	0,26	0,67	0,53	0,60	0,57	0,53
Lakerlopen	0,38	0,59	0,52	0,60	0,47	0,47
Doornakkers-West	0,56	0,46	0,50	0,56	0,49	0,49
Doornakkers-Oost	0,56	0,46	0,50	0,52	0,45	0,45
Tongelresche Akkers	0,56	0,46	0,50	0,50	0,43	0,43
Muschberg,Geestenberg	0,45	0,79	0,68	0,57	0,43	0,43
Urkhoven						
't Hofke	0,45	0,79	0,68	0,46	0,32	0,32
Karpen	0,26	0,67	0,53	0,45	0,42	0,42
Koudenhoven	0,26	0,87	0,66	0,48	0,45	0,45
Limbeek-Zuid	0,56	0,26	0,36	0,57	0,45	0,36
Limbeek-Noord	0,56	0,26	0,36	0,67	0,55	0,36
Hemelrijken	0,87	0,64	0,71	0,64	0,55	0,55
Gildebuurt	0,56	0,26	0,36	0,66	0,54	0,36
Woenselse Watermolen	0,46	0,71	0,63	0,58	0,50	0,50
Woensel-West	0,55	0,78	0,70	0,57	0,43	0,43
Kronehoef	0,48	0,51	0,50	0,57	0,36	0,36
Barrier	0,29	0,41	0,37	0,59	0,52	0,37
Mensfort	0,54	0,32	0,39	0,55	0,47	0,39
Rapenland	0,54	0,32	0,39	0,53	0,45	0,39
Vredeoord						
Generalenbuurt	0,35	0,68	0,57	0,56	0,37	0,37
Oude Toren	0,46	0,51	0,50	0,59	0,51	0,50
Hondsheuvels						
Oude Gracht-West	0,42	0,67	0,59	0,59	0,52	0,52
Oude Gracht-Oost	0,42	0,87	0,72	0,49	0,42	0,42
Eckartdal						
Driehoeksbos	0,33	0,68	0,57	0,49	0,39	0,39
Prinsejagt	0,33	0,88	0,70	0,57	0,47	0,47
Jagershoef	0,47	0,55	0,52	0,52	0,30	0,30

NEIGHBORHOODS OF EINDHOVEN	FUNCTIONAL MOTIVATION	SOCIAL MOTIVATION	MOTIVATION TO PARTICIPATE	OPENNESS TO EXPERIENCE	ABILITY TO PARTICIPATE	WILLINGNESS TO PARTICIPATE
't Hool	0,31	0,87	0,69	0,51	0,40	0,40
Winkelcentrum	0,31	0,67	0,55	0,61	0,50	0,50
Vlokhoven	0,65	0,58	0,60	0,53	0,40	0,40
Kapelbeemd						
Kerkdorp Acht	0,36	0,59	0,51	0,51	0,46	0,46
Achtse Barrier-Gunterslaer	0,54	0,70	0,64	0,52	0,47	0,47
Achtse Barrier-Spaaihoef	0,44	0,63	0,57	0,53	0,45	0,45
Achtse Barrier-Hoeven	0,38	0,75	0,63	0,54	0,45	0,45
Woenselse Heide	0,47	0,59	0,55	0,53	0,43	0,43
Tempel	0,20	0,63	0,49	0,51	0,42	0,42
Blixembosch-West	0,24	0,69	0,54	0,46	0,41	0,41
Blixembosch-Oost	0,24	0,69	0,54	0,48	0,43	0,43
Castiliëlaan						
Eckart	0,42	0,79	0,67	0,51	0,40	0,40
Luytelaer	0,42	0,59	0,53	0,48	0,37	0,37
Vaartbroek	0,46	0,60	0,56	0,51	0,32	0,32
Heesterakker	0,29	0,33	0,32	0,54	0,51	0,32
Esp						
Bokt						
Eliasterrein, Vonderkwartier	0,45	0,56	0,53	0,73	0,63	0,53
Philipsdorp	0,62	0,54	0,56	0,67	0,55	0,55
Engelsbergen	0,45	0,56	0,53	0,55	0,45	0,45
Schouwbroek	0,62	0,54	0,56	0,61	0,49	0,49
Schoot	0,42	0,70	0,61	0,65	0,60	0,60
Strijp S						
Hurk						
Het Ven	0,42	0,50	0,47	0,56	0,51	0,47
Lievendaal	0,31	0,49	0,43	0,51	0,40	0,40
Drents Dorp	0,46	0,64	0,58	0,52	0,39	0,39
Zwaanstraat						
Wielewaal						
Herdgang						
Mispelhoef						
BeA2						
Meerbos						
Grasrijk	0,43	0,87	0,72	0,50	0,42	0,42
Zandrijk	0,43	0,67	0,59	0,55	0,47	0,47
Waterrijk	0,43	0,67	0,59	0,44	0,36	0,36
Park Forum						
Flight Forum						
Eindhoven Airport						
Bosrijk	0,43	0,67	0,59	0,45	0,37	0,37
Meerrijk						
Schrijversbuurt	0,46	0,58	0,54	0,63	0,50	0,50
Oude Spoorbaan	0,46	0,58	0,54	0,67	0,54	0,54
Hagenkamp	0,46	0,58	0,54	0,55	0,42	0,42
Genderdal	0,32	0,35	0,34	0,51	0,41	0,34
Blaarthem	0,64	0,85	0,78	0,58	0,42	0,42
Rapelenburg	0,64	0,65	0,65	0,61	0,45	0,45
Bennekel-Oost	0,53	0,21	0,31	0,55	0,35	0,31
Bennekel-West,Gagelbosch	0,53	0,21	0,31	0,53	0,33	0,31
Gennep						
Beemden						
Genderbeemd	0,26	0,62	0,50	0,55	0,46	0,46
Hanevoet	0,32	0,84	0,67	0,51	0,44	0,44
Ooievaarsnest	0,32	0,64	0,54	0,47	0,40	0,40
MIN	0,11	0,21	0,31	0,44	0,30	0,30
MAX	0,87	0,88	0,78	0,77	0,69	0,60