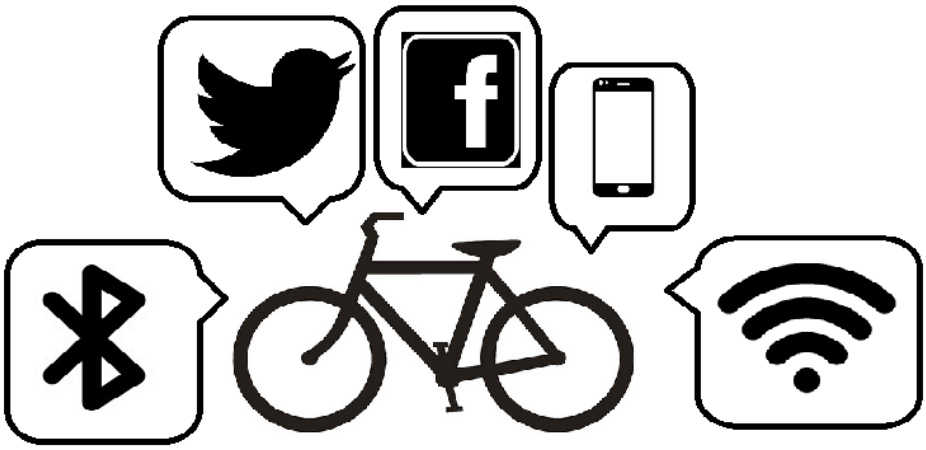
Can smart innovations pave the way for the bicycle?

The potential of smart bicycle system innovations to affect motivational factors of modal choice



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Abstract

Recently, innovations in the auto mobility system gained a lot of attention in the media. However, innovations in the cycling system, which make use of information and communication technologies, remain underexposed. It remains unclear which smart bike innovations are in development, and which smart bike innovations will have a disruptive impact on the bike system. This thesis analyses the potential disruptiveness of the smart bike innovations which are being made available to society. First, by applying a desktop research method, recent smart bike innovations are collected and listed. The resulting sixty-three smart bike innovations are divided into 17 smart bike innovation categories. The Delphi method is used to measure the potential degree of disruptiveness. The three categories of smart e-bike, package logistic on bike and bike nudging apps and websites are deemed as most disruptive innovations according to the respondents involved in the Smart Cycling Futures (SCF) project. A second Delphi round is implemented to analyse the extent of the impact the most disruptive innovations have on motivational factors on travel behavior. From this research it becomes clear that these categories have an impact on motivational factors that help explain modal choice, although no consensus is reached regarding the extent of the impact on the motivational factors.

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Preface

In front of you lies the Master's thesis 'Can smart innovations pave the way for the bicycle? The potential of smart bicycle system innovations to affect motivational factors of modal choice'. It has been written to fulfil the graduation requirements of the Master Urban and Regional Planning. From February up to and including August 2016 I have been working on this thesis. In this thesis I have focused on the potential level of disruptiveness of smart bike innovations. I have chosen the subject of smart bike innovations, because I always have been fascinated by the number of e-bikes overtaking me in my daily commute to the University of Amsterdam, as well as seeing many food delivery services switching to the bike in order to deliver their products. This has sparked my interest for these innovations within the cycling system. At request of my supervisor Marco te Brömmelstroet, I did not only focus on these bike innovations, but instead I chose to discover the whole range of smart bike innovations which are taking place.

I would like to thank the people without whom I could not have realized this thesis. First, I would like to thank Marco te Brömmelstroet for helping me find a suitable project, for guiding me through the process of writing a thesis and for the critical questions and remarks during this process. The multiple feedback sessions were very helpful and enjoyable because of the lively discussions in these sessions. Second, I would like thank the different respondents participating in the Smart Cycling Futures (SCF) project. Despite their busy schedules they still were able to find time to answer my questions. Last, I would like to thank my fellow students, my family, my partner and my friends for their support. Writing a master thesis can be a very difficult process, but thanks to their support, I was able to write this thesis of which I am very proud.

I hope you enjoy reading this thesis.

Bart Wijnands Bsc,
Amsterdam, August 12, 2016

1. Introduction

The car is the 'iron cage' of modernity according to Urry (2004). While this is a very dramatic description, social researchers agree that the car plays an important role in the twenty-first century even though the car imposes negative effects on the environment and the urban landscape (Urry, 2004; Schwanen *et al.,* 2011). Because of these negative effects, there is a growing demand to break with the current system of auto mobility (Urry, 2004; Makinen *et al*., 2015). Cities as Madrid, Paris, Brussel and Amsterdam are discussing new legislation with regard to the car (Kruyswijk, 2015). In the Netherlands, this break from the car system does not seem to happen soon according to Jeekel (2013). He argues that the use of the car and the dependency on it has increased in the period between 1995 and 2007 and he expects this trend to continue until 2040 (Jeekel, 2013).

Regarding the increasing usage of the car and its effects on cities and the environment, urban planners are faced with a difficult dilemma. They have to keep into account the essential role of mobility in enhancing cities' welfare and well-being (Bertolini, 2012), while at the same time breaking with the current car system and move to a different pattern (Bertolini, 2012; Geels, 2012; Makinen *et al*., 2015).

One possible solution to solve this dilemma may be found in the smart discourse. Dutch cities are on the eve of a revolution because of the smart innovations developing in the mobility system (Raven, 2016). The smart innovations in the auto mobility system receive a lot of attention from the mass media (van Ammelrooy, 2016; van Lieshout, 2016) and from researchers (Bodhani (2012; Narla, 2013). However, it remains vague which smart innovations are taking place in the bike system. Additionally, the impact of these smart innovations on the larger cycling system has yet to be studied systematically. The studies that look at the field of cycling mostly focused on the long-term effects of cycling policies, the social and geographical determinants of cycling and its environmental impacts (Heinen *et al.,* 2010; Pucher, 2010). As a consequence, a wave of smart bike innovations is being made available to society, while little information is available to society that helps explain what these smart bike innovations are and what they can mean for society.

Several innovations in the bike system are in development which may have a certain level of disruptiveness to potentially break with the unsustainable car system by addressing the motivational mechanisms that explain the modal choice of individuals. A thorough understanding of the motivational factors that help explain the modal choice is needed to know to which extent smart bike innovations could have an impact on these factors. By conducting a research that analyses the extent of the impact that smart bike innovations have on motivational mechanisms of modal choice, it may become clear which innovations are expected to be disruptive and have the potential to help break away from the auto mobility system.

This research aims to gain insight in the wave of smart bike innovations which are being made available to society in the light of the increasing car usage in the Netherlands. This will be done by applying a mixed methods research addressing the research question: *"To what extent can disruptive innovations in the cycling system affect motivational mechanisms of modal choice?"*

The structure of this thesis is as follows. First, the different theories that are used in the research question will be conceptualized in chapter 2. Second, in chapter 3 it is explained how the different theories are operationalized and researched in this thesis. Chapter 4 presents the smart bike

innovation categories. In chapter 5, the potential degree of disruptiveness of these smart bike innovation categories is being researched. Chapter 6 analyses the extent of the impact the most disruptive bike innovation categories have on motivational factors of modal choice. Finally, the conclusion links the findings back to the theoretical framework and the research question. Additionally, the limitations of this research are discussed and suggestions for further research are provided.

2. Theoretical embedding

This chapter focuses on the different theories of which the research question consists. These parts are discussed in order to explain which theories are used to conduct the research and how these theories are conceptualized and operationalized in the literature.

2.1 Innovations in the bike system

The focus of this thesis is on smart innovations in the bike system. The concepts of 'innovation', 'smart' and 'bike system' are conceptualized in the literature. An innovation is the process of making changes to something established by introducing something new that adds value to the users and/or society. This can either be incremental or radical (O'Sullivan & Dooley, 2008). A smart innovation is operationalized as an innovation which incorporates information and communication technologies (Hollands, 2008; Verbong *et al*., 2013). These developments make it possible to create a better functioning mobility system by using new technologies such as apps, sensors and real time data in existing systems (te Brömmelstroet *et al.*, 2015). The bike system is operationalized as a 'sociotechnical system' in which technology and the social and cultural context have a reciprocally influence (te Brömmelstroet et al., 2015).

With regard to the bike innovations that add value to the bike system, research has mainly focused on three groups of bike innovations, namely the bike sharing innovations (DeMaio, 2009; Midgley, 2009; Wang *et al*., 2010; Mäkinen *et al*., 2015), the bike infrastructure (Bendiks & Degros, 2013, p. 163) and the bike nudging apps and websites (Tertoolen *et al.*, 2015). Internationally, the bike sharing innovations are deemed a success because of their impact on the bike system in cities such as Paris, Lyon and Barcelona (Wang *et al.,* 2010). Bendiks and Degros (2013) conclude that innovations in the bike infrastructure can have an impact on the bike system because of their effectiveness, but also because of their function as a landmark in the region. On the other hand, the impact of smart bike infrastructure innovations on the bike system remains unclear. This is because most smart bike infrastructure innovations that are discussed in the book were in concept at the time of publishing. Therefore, it could only be speculated what their impact on the bike system will be (Bendiks & Degros, 2013). The research focused on the category of bike nudging apps and websites concludes that the setting up and carrying out of bike nudging is an ongoing process. The goal of bike nudging is twofold: first people have to recognize and experience the bike as an alternative, and then people need to have confirmation that the bike is indeed an alternative mode of transport (Tertoolen *et al*, 2015).

While some research has been done that analyses the impact of several smart bike innovations on the bike system, very little scientific research has been carried out with regard to other smart bike innovations. As a result, it remains unknown to what extent the bike system is impacted by the broad range of bike innovations that make use of information and communication technologies. Some expectations are expressed by Sijmons (2014), who indicates that the traditional bike will go through new developments with new forms of electrical pedal support systems coupled with smartphone applications. These developments are expected to contribute to a stronger bike system because they give the bike a greater reach and will relieve the user from typical small user discomforts such as cycling uphill (Sijmons, 2014, p. 180). Sijmons suggests that the bike system will start the transition towards more sustainable modes of transportation in the Netherlands, because the smart innovations that are in development offer a practical solution to problems on the short

term (Sijmons, 2014, p. 184). However, this statement is just a vision based on recent developments and cannot be supported by facts.

Smart is a concept which is used in different research fields. In the scientific transportation field, the smart discourse has become a topic which gained an increasing interest from researchers. Here, an interesting discrepancy concerning the optimism that surrounds the smart innovations becomes clear when studying the scientific literature. Bodhani (2012) and Narla (2013) frame smart transportation innovations as the cure to reduce greenhouse gasses, to manage traffic congestion, and they analyse how new technologies can be used in private automobiles to let them communicate with other vehicles and infrastructure (Narla, 2013). The goal of these smart technologies is to enhance the safety and convenience and to optimize traffic flows (Narla, 2013), but cities also use these smart systems as a way to attract, retain and target businesses and residents through enhanced mobility and economic competitiveness (Bodhani, 2012).

Le Vine, Zolfaghari and Polak (2015) put this positive view on smart innovations in perspective as they analyse potential threats of driverless transportation. Many transport experts anticipate that the occupants of autonomous cars are able to perform a wide range of productive or leisure activities and that roadway capacity will increase due to shorter headway between vehicles and control of traffic streams. Yet, in some circumstances, there will be some tension between the two anticipated benefits of productive use of travel time and increased network capacity (Le Vine *et al*., 2015).

Raven (2016) acknowledges both the downside and the upside of the smart discourse in the transportation field. He acknowledges that the smart discourse has several downsides, but these smart technologies are still in development, thereby increasing the potential possibilities of these innovations in solving urban challenges such as congestion (Raven, 2016).

The concept of smart is also applied on a city level. Many Western cities have been increasingly influenced by discussions of incorporating smart technologies in all aspects of the cities. Even in the Dutch public debate and in policy documents, the smart city is a discourse which cannot be missed (Ministerie van Infrastructuur en Milieu, 2014; van Noort, 2016). Yet, despite the increasing popularity of this discourse, surprisingly little is known in terms of what the discourse reveals as well as hides (Hollands, 2008). While there is no clear definition of a smart city, it often refers to the application of information and communication technology to solve urban complexities (Raven, 2016). The problem with this definition is that it can be mistaken for another city discourse such as intelligent, digital or creative, since it appears that these discourses all link together technological informational transformations with political, economic and socio cultural change (Hollands, 2008; de Jong *et al*., 2015).

Following the argumentation of Hollands (2008), Raven (2016) notes that there are some downsides to the way the discourse is used in the Dutch debates and documents. First, the discourse is being characterized by a naïve optimism in technology. Smart technology is thought of as the new medicine that will cure all the problems that cities are facing. The advantages and opportunities are being highlighted, but the risks involved remain underexposed (Raven, 2016). Second, sustainability is often thought of as a result of making cities smart. However, this relationship is not very clear as it is the question whether the increasing smartness of cities actually leads to the system changes which are necessary for a sustainable development (Raven, 2016). Finally, the smart city discourse deems the interests of private companies more important as the interests of public interests.

Governments, Raven (2016) argues, become dependent of the choices technology companies and their software algorithms make, because they prescribe which information is of importance in a certain area and which information is left out.

It is, arguably, Adam Greenfield who is the least positive about the smart city discourse. In his book 'Against the smart city' he visualizes a dark dystopia in which the smart city will not, and cannot, serve the interests of the people who live in it (Greenfield, 2013). Nevertheless, despite the critiques on the smart city discourse, it is a promising discourse, since many technologies are in development that may have the potential to help overcome urban challenges (Raven, 2016).

2.2 Disruptive innovations

A disruptive innovation transforms the way we live and provides an opening to upset the established order by creating a new market and eventually disrupting an existing market (Gilbert, 2003; Manyika *et al*., 2013). It is important to make clear which category of disruptive innovation is discussed, since lumping all categories together has serious implications on the study of disruptive innovations (Markides, 2006). This thesis focuses on potentially disruptive innovations. Disruptive innovations are an important and powerful means for developing and broadening new markets. Despite the importance of disruptive innovations, relatively little academic research has been done on this innovation characteristic (Daneels, 2004; Govindarajan & Kopalle, 2006a). The main reasons for the dearth of such research may be because there is no appropriate measure for the disruptiveness of innovations (Govindarajan & Kopalle, 2006b) or because of the difficulty of making ex ante predictions given the ex post nature of the disruptiveness (Govindarajan & Kopalle, 2006a). Moreover, academic research fails to properly categorize disruptive innovations, making the concept of disruptive innovations more confusing (Markides, 2006). Markides (2006) tries to make a beginning with categorizing disruptive innovations by defining two distinct phenomena, namely a disruptive business model innovation and a disruptive product innovation. These two categories arise in different ways and have different competitive effects. A disruptive business model innovation is the discovery of a fundamentally different business model in an existing business. It redefines what an existing product is and how it is provided to the customer (Markides, 2006). A second type of innovation that tends to be disruptive to the established competitors is the disruptive innovation, which creates new-to-the-world products. These innovations result from a supply-push process originating from those responsible for developing new technologies. Innovations are disruptive when they introduce products that disturb prevailing consumer habits and behaviors in a major way (Markides, 2006).

Despite the relatively little academic research performed, the topic of disruptive innovations is of interest for a lot of companies and industries since it shakes up the markets and creates new opportunities. In their rapport published in 2012, Deloitte (2012) analyses how Australian companies and the economy as a whole are being disrupted by digital innovations. The innovations which are disrupting the economy are captured in Deloitte's digital disruption map to identify how sensitive each industry is for disruptive innovations. The digital disruption map is build up with the use of two variables. The first is the scale of the residual impact, referred to as the bang. The bang is the expected change in percentage terms that a company will experience because of a disruptive innovation. Companies that will experience a fifteen or more percent change in their metrics, such as revenue, will experience a big bang. Below fifteen percent companies feel a small bang (Deloitte, 2012). The second variable, the length of the fuse, shows how soon each industry will be affected. If

an industry will experience changes within three years, it is assumed to have a short fuse. Those that can expect major change in four to ten years are on a long fuse (Deloitte, 2012). Based on these two variables, four categories can be identified which show in what time frame and with what impact each industry will be affected (Deloitte, 2012). These categories are:

1. Short fuse, big bang;
2. Long fuse, big bang;
3. Short fuse, small bang;
4. Long fuse, small bang.

The most pressing category, which indicates that the potential level of disruption is high and will happen within three years, is the category of 'short fuse, big bang' (Deloitte, 2012). For industries or businesses that are placed in this category, there is very little time to adapt to the changes that are going to happen. This category is relevant for this thesis, because this category indicates the most disruptive innovations that are going to be studied further.

The operationalization of Deloitte is used in this thesis since it offers a clear and effective conceptualization how to measure whether an innovation can be deemed disruptive. However, as Deloitte (2014) recognizes, the approach of the digital disruption map is not precise and perfect, because this model is mostly based on expert opinions. Its purpose is to look at the innovations in a granular way and not in a precise way (Deloitte, 2012).

2.3 Motivational mechanisms of modal choice

The impact of the potentially disruptive smart bike system innovation categories are being researched in the light of the motivational factors that influence the modality choice. Impact is operationalized as an end in itself and is expected to be the long term effect of a measure, intervention or innovation (OECD, 2002). The auto mobility system is the dominant form of quasi private mobility (Urry, 2004). A thorough understanding of the motives for modality choice of people is needed to know to which extent smart bike system innovations could have an impact on these motivational factors that lead to a certain choice of modality. Jeekel (2013) argues that the decision to use the car for a movement is being made in a society which stimulates the frequent use of the car, but the decision remains driven by individual motives. So, to understand the factors that lead to car usage and how bike system innovations can impact this, it is important to analyse the individual motives for travel behavior. The discipline of psychology offers a perspective in which the motives of modality choices can be studied because this perspective looks to the motivational factors that influence travel behavior (Dijst *et al*., 2013).

Within the motivational factor, three lines of research are distinguished and operationalized that focus on different types of individual motivation to help explain travel behavior. These three lines of research are not mutually exclusive, as behavior is likely to result from multiple motivations (Dijst *et al*., 2013).

The first motivational factor is perceived costs and benefits, and starts with the assumption that individuals make reasoned choices and choose alternatives with the highest benefits against the lowest costs. This could either be expressed in terms of money, effort or social approval (Dijst *et al*., 2013).

The second individual motivational factor is moral and normative concerns, which looks at how travel behavior is shaped by the norms of individuals. People will probably only reduce their car

use when they value the environment and when they are concerned with the problems caused by car use (Dijst *et* al., 2013).

Affection is the final individual motivational factor and assumes that travel behavior is also motivated by affective outcomes. An affective outcome may be that driving to work is more fun than taking the bus (Dijst *et al*., 2013).

The field of psychology has several shortcomings. First, there is discussion among researchers about the importance of each of the motivational factors on modal choice. For example, the perceived costs and benefits argument assumes that car users make reasoned choices and behave rationally (Steg *et al.,* 2001). However, such motives from cognitive reasoned behavior choices do not seem to give sufficient explanations of car use. The affective function of the car plays an important role as well (Steg *et al.,* 2001). For this reason, the three lines of research that together form the psychology perspective are all taken into account when assessing to what extent the smart bike innovation categories affect the motivational mechanisms on modal choice.

The second shortcoming is that the field of psychology neglects habits with regards to travel behavior (Dijst *et al*., 2013). Habits refer to the way behavioral choices are made. Habitual behavior may involve misperceptions and selective attention. People tend to focus on information that confirms their choices and neglect information that is not in line with their habitual behavior (Dijst *et al*., 2013). This shortcoming is neutralized by taking into account the individual motive of habit as it is operationalized by Jeekel (2013). Habit is operationalized as an automatism of people to choose a certain mode of transport over and over again because it performed good during previous similar situations (Jeekel, 2013).

Last of all, travel behavior does not depend on motivation alone. Many contextual factors may facilitate or constrain travel behavior. For example, the quality of public transport can strongly affect travel behavior (Dijst *et al.,* 2013).

2.4 Summary

Each section in this chapter discussed several concepts in order to operationalize the concepts for this thesis. The result is the conceptual model as can be seen in Figure 1. First, the smart discourse is conceptualized to show the wider discussion in which these smart bike innovations can be placed and to distinguish the smart bike innovations from the 'non-smart' bike innovations. It is researched whether a bike innovation meets the criteria of a smart bike innovation, that is whether an innovation makes use of apps, sensors and real time data.

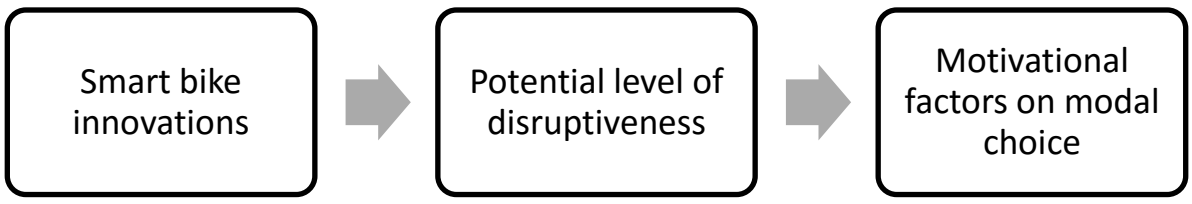

Figure 1: The conceptual scheme of this thesis

Second, the potential degree of disruptiveness of the smart bike categories is researched, since it is unknown which smart bike innovations are expected to have a big impact on the bike system. This is done by conceptualizing how soon the smart innovations will have an impact, and how big the impact of the smart innovations will be on the bike system. This will be operationalized by looking at the fuse and the bang of each smart bike innovation category as used by Deloitte (2012). Their operationalization is used since it is deemed a successful practical tool to analyse disruptive innovations in practice.

The categories which are placed in the 'short fuse, big bang' quadrant can be deemed as most disruptive, meaning these smart bike innovation categories have the greatest potential to upset and disrupt the established order (Manyika *et al*., 2013). According to Urry (2004), the established order within the mobility system is the system of auto mobility. So, in order to verify the potential level of disruptiveness, it is analysed whether these smart bike innovation categories have the potential to break with the car system by looking to what extent the innovation categories have an impact on the motivational factors that help explain the modal choice. The three motivational factors that are discussed by Dijst *et al*. (2013) are used because the motivational mechanisms on modal choice are clearly operationalized. The fourth motivational factor of habit is added since it offers a more complete view of how the smart bike innovation categories address the motivational factors on modal choice. The operationalization by Jeekel (2013) is used since his peer-reviewed book 'De auto-afhankelijke samenleving' (translated: 'The car dependent society') clearly operationalizes the motivational factor of habit.

3. Methodology

In the previous chapter, the different theories that will be used in this thesis were conceptualized and operationalized to explain what will be researched in this thesis. In this chapter, it will be shown how these concepts will be researched by explaining which research and data analysis methods will be used to measure and analyse these concepts. To be able to answer the main research question of this thesis, multiple subquestions are introduced. These all explain a part of the main research question and are listed below:

1. Which smart bicycle system innovations are taking place?
2. What is the potential level of disruption of each innovation?
3. To what extent does the most disruptive bike system innovations have an impact on key psychological motivational mechanisms of modal choice?

For every subquestion, the research design, research and data analysis method are explained in the following sections.

3.1 Which smart bicycle system innovations are taking place?

The first subquestion has the research design of a desk research study. The goal of this research question is to map the bike innovations which can be deemed smart. The first reason to use the desk research method is the relative ease of access to many sources of secondary data since these are published online. The second reason is that the desk research method can be used as a starting point to explore the topic of smart bike innovations.

The documents that are used to list the smart bike innovations can primarily be found online by using the research terms ‘Smart Cycling Futures’ or ‘Bike System Innovations’. From these sources, more information is gathered by using the snowballing technique. The source on which information is found is scanned on references to other sources which present a smart bike innovation. The snowballing technique is applied because this method offers benefits for studies which seek to access difficult to reach or hidden research subjects (Atkinson & Flint, 2001). The source on which a bike system innovation is found is further scanned on other smart bike system innovations that are mentioned in that document.

The innovations derived from the desk research are mapped in a document. The list has been published on Twitter, Facebook and LinkedIn in order to be completed with insights from experts or people involved in the field of mobility. Using these sources, they have been asked whether they were missing some innovations in the document. The list has been updated until a certain level of saturation was reached, that is when innovations were repeated by several experts.

These social media sources are used because they have the potential to reach many experts and therefore generate many reactions. Furthermore, experts involved in the Smart Cycling Futures (SCF) project are consulted for bike system innovations. The SCF experts have been involved because the aim of the SCF project is to investigate how smart cycling innovations – including ICT enabled cycling innovations, infrastructure, and social innovations like new business models – contribute to more resilient and livable Dutch urban regions by creating labs in which actors from different sectors are involved. The SCF project is part of the Smart Urban Regions of the Future (SURF) project, which is funded by the ‘Nederlandse Organisatie voor Wetenschappelijk Onderzoek’ (Dutch Organization for Scientific Research).

This subquestion lists all the innovations that are found through several information resources and mentioned by the mobility experts in one document. Smart bike innovations are mapped together based on their shared characteristics. Although the information with regard to the characteristics of the innovations is derived from the internet pages on which the smart bike innovation have been found, the categorizing of the innovations can be deemed as a subjective matter. Therefore, the meaning of every category is explained here, as well as the innovations that are placed in that category. Some innovations can be placed in multiple categories since these innovations are a combination of several innovations. For example, the VanMoof electric bike is not only an e-bike, but it also has a bluetooth smartphone lock. Therefore, this innovation is placed within multiple categories that fit the description of the innovation.

The smart bike system innovations are listed in Appendix 10.1. First, the name of the innovation is listed. Second, the company and/or the municipalities behind the innovation are listed in order to know who developed the innovation. The description of the innovation is added thereafter to make clear what the innovation is about and why it can be deemed a smart bike innovation.

After listing the innovations, the 'non-smart' innovations are filtered out of the list by evaluating whether the innovation meets the requirements of a smart innovation, that is whether an innovation incorporates information and communication technologies. The 'non-smart' innovations are listed in Appendix 10.2. Here, the description of each innovation is added to make clear why the innovation cannot be deemed a smart bike innovation.

3.2 What is the potential level of disruption of each category?

The second subquestion has the research design of a comparative case study. It compares the scores of all smart bike innovations on the variables of disruptiveness to analyse which innovations are deemed as the most disruptive. The goal is to find the smart bike innovation categories deemed the most disruptive by the SCF experts.

For this question information is gathered using the Delphi method. The Delphi method is a process to collect and distill the anonymous judgments of experts using a series of data collection and analysis techniques interspersed with feedback (Okoli & Pawlowski, 2004; Skulmoski *et al.,* 2007). A Delphi study can be seen as a virtual panel of experts gathered to arrive at an answer to a difficult question (Okoli & Pawlowski, 2004). The size of the Delphi group for this subquestion consists of twelve experts, since ten to fifteen experts may yield sufficient results using the Delphi method (Skulmoski *et al*., 2007). The participants of the first round and the following feedback questionnaire of the Delphi method are the SCF experts who are listed in Appendix 10.3. The Delphi method is used because the method can be used as a judgment tool to problems that could benefit from the subjective judgment of individuals on a collective basis (Skulmoski *et al*., 2007). In this thesis there is incomplete knowledge about the potential level of disruptiveness of the smart bike system innovations and therefore the Delphi method will be used.

An online self-completion questionnaire is used for this subquestion, because it is more convenient for the respondents. They can answer the questionnaire when they want and at the speed they want to go (Bryman, 2008). Second, one of the goals of the Delphi method is to research whether there is consensus between the respondents. The data from the questionnaire can be easily quantified which is efficient in comparing the various reactions on the list by the experts and to see

whether there is consensus among the experts in this Delphi group by calculating the standard deviation of the answers.

The experts are asked how disruptive each innovation is by using an online questionnaire with questions about the two variables of disruptiveness, the length of the fuse and the size of the bang. For each innovation, the experts indicate what the length of the fuse and the size of the bang is. The description of each category is added in the questionnaire, as well as an example of an innovation in that category, in order to make clear what every smart bike innovation category is about. The experts also have the possibility to add a smart innovation category which they think is missing in the list but should be incorporated. The online survey is displayed in Appendix 10.4. A reminder to fill in the survey has been send to the experts who did not react within one week.

The scale of the residual impact, referred to as the bang, is the first variable in the survey. The bang is the expected impact of the innovation category on the bike system. For this indication, the experts are asked to grade each innovation category using a Likert scale with five possible answers ranging from a very big impact to a very small impact. They also have the ability to indicate that they do not have an opinion with regard to a smart bike innovation category.

The length of the fuse indicates how soon the innovation category will have reached the impact on the bike system. In the questionnaire the experts are asked to grade each innovation category using a Likert scale with five possible answers ranging from a very short period of time to a very long period of time. They also have the ability to indicate that they do not have an opinion with regard to a smart bike innovation category.

After analysing the resulting data, the feedback moment of the first Delphi round takes place. The goal of this round is to clarify conflicting views among the members of the group and to see whether consensus among the SCF experts can be reached. The SCF experts can clarify or change the answers given in the first round with regard to the smart bike system innovation categories that have a standard deviation higher than 0.5 on one of the two variables of disruptiveness. This score indicates that there is no consensus on the mean group answer because 0.5 is the difference between one of the five possible answers. Categories that score above the standard deviation for one of the two variables can be judged again on that variable by reacting on the outcomes that have been send to the experts by mail.

The answers from the first questionnaire are coded before the analysis. The coding list of the variable of the bang is shown in Table 1 and the coding list of the fuse is displayed in Table 2.

Extend of the impact	**Coding**
Very big	1
Big	0.5
Neutral	0
Small	-0.5
Very small	-1

Table 1: The coding of the variable of the bang.

Extend of period of time	Coding
Very Short	1
Short	0.5
Middel	0
Long	-0.5
Very Long	-1

Table 2: The coding of the variable of the fuse.

The answer is not taken into account when an expert has not provided an answer on the fuse or the bang because they did not know it or had no opinion about it. In these cases the average score is calculated by adding all the responses minus the responses without answers. All the average scores are still valid, since the minimum of ten Delphi responses is reached after taking into account the experts who have not provided an answer.

The codes are analysed by using an univariate analysis method. The univariate analysis method analyses one variable at the time. The univariate analysis method analyses the two variables of disruptiveness, the length of the fuse and the size of the bang. Based on the average score of the innovations on the two variables of disruptiveness, the univariate analysis helps to analyse whether an innovation can be placed in one of the four groups of potential disruption and which categories are deemed as the most disruptive by the experts. A smart innovation category can be placed in one of the four categories of disruptiveness depending on the scores of the two variables.

1. '*Short fuse, big bang'*: innovations are placed in this category if the fuse is higher than the average score of all innovations on this variable and if the bang is higher than the average score of all innovations on this variable;
2. *'Long fuse, big bang'*: innovations are placed in this category if the fuse is lower than the average score of all innovations on this variable and if the bang is higher than the average score of all innovations on this variable;
3. *'Short fuse, small bang'*: innovations are placed in this category if the fuse is higher than the average score of all innovations on this variable and if the bang is lower than the average score of all innovations on this variable;
4. *'Long fuse, small bang'*: innovations are placed in this category if the fuse is lower than the average score of all innovations on this variable and if the bang is lower than the average score of all innovations on this variable.

Despite the quantitative nature of this subquestion by using codes to analyse the answer, this subquestion only gives an indication of the potential disruptiveness of each category. The main goal of this subquestion is to look at where one innovation category stands from another on their potential level of disruptiveness. Therefore, the x-axis and y-axis of the resulting disruption map are placed on the average score of both the variables of disruptiveness. The results are displayed in the resulting disruption map in chapter 5.2. The disruption map shows which bike system innovation categories can be placed in which quadrant of disruption.

The standard deviation is also calculated by using an univariate analysis method. The standard deviation is measured to look at the consensus between the SCF experts with regard to the fuse and the bang of each innovation category. There is no consensus on a smart innovation category if a smart innovation category has a higher standard deviation than the average standard deviation on the fuse or the bang.

In the feedback round, the answers on the fuse and the bang are analysed the same way as the first round of the Delphi method is analysed. The resulting answers replace the answers given in the first round. The answers are coded by using the coding list of the variable of the bang in Table 1 and the coding list of the fuse in Table 2.

The feedback round offers the SCF experts the possibility to react on the results of the first round. The experts are given the opportunity to clarify their answers or react on the average scores of the group. These reactions are analysed by using a thematic analysis method. The thematic analysis method is used because key themes in the argumentation of the experts can be identified (Bryman, 2008, p. 556), which allows to gain insight into why the SCF experts indicated a certain bang or fuse. The themes that are used to analyse the answers are the fuse and the bang of the smart bike innovation categories with a standard deviation of 0.5 or more. The answers that fit to the theme of the fuse or the bang of an innovation category are placed in that category to gain insight in the different opinions regarding the impact of a smart bike innovation on the bike system. The reactions on the fuse and the bang are listed per bike innovation category and can be found in Appendix 10.5.

The smart bike system categories which are placed in the quadrant of the 'short fuse, big bang' are deemed as the relatively most disruptive innovation categories and are further discussed in this thesis. This category is the most relevant for this thesis, because the potentially most disruptive innovation categories are found in this quadrant of the disruption map.

3.3 To what extent does the most disruptive bike system innovation categories have an impact on key psychological motivational mechanisms of modal choice?

The third subquestion has the design of a multiple case study because it studies how the units of analysis, the most disruptive bike system innovations, have an impact on the variables of the psychological motivational mechanisms that help explain modal choice.

Information is gathered by using the second round of the Delphi method, in which surveys by telephone are held with the experts involved in the SCF project. The experts who have participated in the second round of the Delphi method can be found in Appendix 10.6. The second step of the Delphi method builds further on the first step in which the most disruptive bike system innovations were identified. This step in the Delphi method analyses to what extent the disruptive innovations have an impact on the motivational factors that help explain modal choice as listed by Dijst et al. (2013) and completed by Jeekel (2013). The size of the Delphi group for this subquestion consists of ten experts, since ten to fifteen experts may yield sufficient results using the Delphi method (Skulmoski et al., 2007).

Data is collected through a questionnaire by telephone, because this method can take place within a short amount of time and because the replies can be aggregated reliably (Bryman, 2008, p. 193). The questionnaire begins with a description of the disruptive smart innovation categories and the motivational factors on modal choice. Thereafter, the scaled questions are asked. It is asked to what extent the most disruptive bike system innovation categories have an impact on each of the four motivational factors of modal choice. The experts can indicate whether a smart bike innovation category has no impact, a small impact, a medium impact or a big impact on each motivational factor on modal choice. They also have the option to say that they do not know the answer. Thereafter, the experts are asked to explain why they have choosen a certain impact. This question

is asked since the argumentation can help understand the conflicting views with regard to the extent of the impact of the disruptive innovations on motivational factors that explain modal choice. The survey can be found in Appendix 10.7.

After the questionnaires are held, the answers are written out and send back to the interviewed experts. They can verify their classification and argumentation of the extent of the impact the disruptive innovations have on each psychological motivational factor of car usage. Furthermore, the experts gain insight in the argumentation of the other experts. This round of feedback allows the interviewed participants to change or expand their answers given in the interview.

The questionnaires in the second round of the Delphi method are analysed by using an univariate analysis method. This method is chosen to analyse the data, since the univariate analysis method can show how many experts indicate a certain impact on the four motivational factors on travel behavior. For each motivational factor on modal choice, it is first listed how many experts indicate whether the most disruptive smart bike system innovation categories will have an impact or not. The respondents that indicate that there will be an impact are then divided into the categories of a small impact, a medium impact or a big impact of the smart bike innovation category on the motivational factors on modal choice.

The reason that each expert gives to justify his answers are analysed by using a thematic analysis method. The thematic analysis method is used because key themes in the argumentation of the experts can be identified (Bryman, 2008, p. 556), which allows to gain insight into why the SCF experts indicated a certain impact on the motivational factors on modal choice. The themes that are used to analyse the answers are the estimated extent of the impact the most disruptive smart bike innovations have on each motivational factor on modal choice. The arguments are listed per estimated impact per smart bike innovation category and can be found in Appendix 10.8 up to and including 10.11. This way, the arguments used to support the estimated impacts can be analysed and compared to show the conflicting views.

The same methods as in round two of the Delphi method are used in the feedback round to analyse the data. The extent of the impact is analysed by using an univariate analysis method and the arguments used to support the extent of the impact are analysed using a thematic analysis method.

3.4 Conceptual framework

First, the smart bike system innovations are listed per smart innovation category by using a desk research method. Second, the smart bike innovations are tested on their potential degree of disruptiveness by looking at the bang and the fuse to indicate which innovation is deemed as most disruptive by the SCF experts. Data is gathered via an online questionnaire and is analysed using an univariate analysis method and a thematic analysis method. Thereafter, it is being researched to what extent the most disruptive innovation address the key psychological motivation factors of car usage to analyse whether these smart bike innovation categories have the potential to break with the car system. Data is collected through a questionnaire by telephone. The data is analysed by using an univariate analysis method and a thematic analysis method.

4. Innovations in the cycling system

The old, humble bicycle of the year 1890 which was made of steel with a chain, brakes and two wheels set the standard for today's bikes. Today, many innovators take this standard as the starting point for their innovation, trying to reinvent its main components, from the tires to the frame. But is not only the bike itself in which innovators are interested. In all components of the bike system, such as the infrastructure or the bike policy arena, innovations are in concept or in practice. This chapter looks at these innovations by researching the following subquestion: *"Which smart bicycle system innovations are taking place?"*

4.1 Smart bicycle system innovations

Seventy-nine bike system innovations were found by using the desktop study as described in section 3.1. Seventeen distinct smart bike innovation categories are identified based on the sixty-three smart bike system innovations. These smart bike innovations are listed in Appendix 10.1. The smart bike innovation categories and subcategories are described below:

1. *The smart bike*: the focus of this category is on upgrading the bike by using new technologies such as solar power wheels which charge the motor of the e-bike or use technology to connect the bike to the internet and the smartphone. This category consists of three sub categories. The difference between the three categories lies in the speed the bike support.

1.1 *e-bike*: the first category of the smart bike system innovations is the e-bike. The e-bike is a bike with an electrical engine that goes up to 25 km/h and which uses technology to connect the bike to the internet and the smartphone. Sensors in the bike indicate whether the cyclist is pedaling and thus whether the motor should support the cyclist. Moreover, the sensors also indicate whether the cyclist is in a potentially dangerous situation by vibrating handlebars. The innovations in this category are the e-bike produced for example by Gazelle and Sparta, VanMoof electric and the 'Slimme fiets' (Smart Bike) by TNO. The S-Bike is also included in this list, because it has a speed limit up to 25 km/h but it charges its motor by using solar panels placed on the wheels.

1.2 *Speed pedelec*: innovation category where the innovations have a speed limit that goes up to 45 km/h. Sensors in the frame determine the amount of support the bike must give to the cyclist in order to reach the speed that the cyclist indicates. A display is attached to the steering wheel which provides the cyclist information about the speed or the altitude and the display allows cyclists to adjust the degree of brightness of the bike lights. The innovation in this category is the Speed Pedelec which is produced by Sparta and Gazelle.

1.3 *Bike to e-bike transformators*: the final category focuses on upgrading the two-wheeler. This subcategory covers the innovations that, because of new technological developments, can turn a regular bike into an e-bike by adding an electric motor on the bike. By using an application on the smartphone, the energy level of the plug-on motor can be viewed and the settings of the motor can be changed. Innovations in this category are FlyKLySmartWheel and go e-Onwheel.

2. *Smart bike ride information & tracker system*: this category includes applications on smartphones and devices that are sold separately and that track the bike ride using GPS. These smart innovations show information of the bike ride such as speed and altitude

during or afterwards the bike ride. Innovations in this category are Bicycle Buddy App, Garmin Varia Vision, Ring a Bell!, Dero Zap, Strava and the SmartHaloBike.

3. *On bike communication*: on bike communication covers smart bike system innovations that focus on communication applications between cyclists in traffic. This can either be a jacket or a bag which communicates the direction of travel to other cyclists using the combination of a GPS tracker with an application on the smartphone that is connected to the jacket or the bag by bluetooth. But it can also be infrastructure on which messages to other cyclist can be displayed or a backlight on the bike which shows certain messages. Smart Jacket, Social Light, Seil Bag and Pleasant Pass are the innovations that together form this category.
4. *Smart bike locks*: innovations that are placed in this category have in common that they are bike locks which can be unlocked by using an application or bluetooth on the smartphone to unlock the bike. The locks also have to function to trace your bike back with the help of a smartphone and using GPS or bluetooth. This way the owner knows where the bike is parked or whether it is moving. The innovations that are placed in this category are Lock8, LINKA, Mobilock, Bitlock, VanMoof electric and SmartHaloBike.
5. *Smart bike sharing*: innovations in the field of bike sharing that make use of technological systems to support the bike sharing. This can either be an internet page on which bikes are offered or a social media platform on which people can place their bike to be rented for a certain period of time. This category consists of two subcategories.

5.1 *People 2 people bike sharing*: innovations in the form of online social platforms on which people place their bike to be shared. Examples are Spinlister, Yellow Backie and Airdonkey.

5.2 *Company 2 people bike sharing*: this category of smart bike innovations has the shared characteristic that companies develop applications for the smartphone or internet pages which make it possible to rent a bike. Gobike, Self Service Electric bikes, DonkeyBike, Hopperpoint, Studentbike and Swapfiets are the innovations that together make up this subcategory.

6. *Personalised green wave*: this category has the shared characteristic of using sensors an applications to influence the traffic light system. Innovations use new communication technologies to connect the smartphone of a cyclist with the traffic lights by using bluetooth or to show when the traffic lights turn to green by using light sensors which reckon whether a cyclist is approaching and indicate how fast this cyclist should be biking in order to catch the green light. This category is not placed in the infrastructure category because there are many smart innovations taking place which are specifically aimed at traffic lights. Evergreen, Traffic Lights, The Light Companion and SiBike app make up this category.
7. *Smart bike infrastructure*: this is the category which includes the most smart bike system innovations found by using the desk research method, namely Pleasant Pass, verwarmd fietspad, GoLightAvenue, Re-Light, SolaRoad, Tvilight Intelligent Lighting and Bike Scout. The shared characteristic of these innovations is that they use technology to enhance the bike infrastructure and make it more effective and fun to ride it, for example to provide heated bike paths in the winter or bike paths that have solar panels within them to generate electricity for the bike path lighting. In addition, motion sensors are implemented in the infrastructure which in turn cause the streetlights to adjust their brightness based on the presence of cyclists.

8. *Smart bike park systems*: the shared characteristic of this category is the technical innovations focused on increasing the efficiency of the process of finding a parking space and parking your bike. For instance, sensors can be placed in parking spots to indicate how many free parking spaces are left in a bicycle storage. The sensor system can also send a message to your mobile phone to let you know whether there is any free space. The innovations in this category are Cloud Fietsenstalling, P-Route Bike, Linked&Locked and Automated Cycle Storage.
9. *Smart bike logistics*: this category focuses on certain services which make use of the bike in the transport phase and are accessible by applications and websites. This category consists of three sub categories which focus on different products or even tourists to be transported on the bike.

9.1 *Food logistics on bike*: the first sub category under smart bike logistics. People can order food by certain companies, thereby making use of an application on their smartphone to order the food, which is brought to them by a courier who uses the bike for the transportation phase. Innovations in this subcategory are Deliveroo, Foodora and TringTring.

9.2 *Tourist logistics on bike*: the focus is on companies which, through an online platform, stimulate tourists to take the e-bike to visit the tourist attractions outside Amsterdam, such as the Zaanse Schans. On the website and on the tablet mounted on the bike, the tourists can find information how to reach several tourist attractions by bike. Fietsy is an innovation which can be placed in this category.

9.3 *Package logistics on bike*: the innovations in this category, UberRush and Parkcycle, are online platforms accessible by an application on the smartphone and website. The application of UberRush functions as a platform for the transportation of goods on bikes in and around New York, but is planning to expand to Amsterdam. Parkcycle is an initiative by DHL to deliver packages in different cities on the e-bike, thereby offering the package to be followed online by a track-and-trace code.

10. *Bike nudging apps and websites*: in this category, the innovations all share the characteristic of using websites and applications to stimulate the usage of the bike by developing an online platform on which cyclists, employers and health insurance companies can connect. The stimulation happens in various ways. Some applications and websites stimulate the use of the bike by developing a competition in which several schools in the provinces of Zeeland and Noord-Brabant compete with another to see which school can travel the most kilometers on their bikes. Other applications and websites reward people for kilometers traveled on the bike by awarding the cyclists with financial incentives received through their health insurance and their employer. The innovations that together form this category are B-Riders, Burn fat not fuel, Trappen scoort, Toury, ByCycling, RingRing and the Doorgeeffiets.
11. *Technology for supporting and creating bike policy*: the innovations in this category are all aimed at increasing the effectiveness of bike polices. This can either be through smart innovations which visualize bike data into different traffic models or visualizing the effects of bike policies on the number of cyclists by providing new software in combination with a virtual reality glass. Innovations within category are Bike Print, Virtual Reality cycling simulator, Hightech 3D Engineeringstool and SKOPEI Cycling.

12. *Smart bike safety innovations*: this category consists of two innovations. Innovations within this category are specifically aimed at increasing the safety of cyclists by using new technologies. The two innovations use sensors to detect whether there is danger, the Hovding airbag inflates itself when the cyclists falls or crashes and the Slimme fiets from TNO has vibrating handlebars to signal the driver when a potentially dangerous situation is taking place.

What becomes clear by looking at the different bike system innovation categories is that most innovations focus on the bike infrastructure and the bike nudging apps and websites, but there are also many innovations which focus on the bike itself (Slimme Fiets, e-bike, S-Bike, VanMoof electric). Another development which becomes clear by looking at the list is that there are many corporations which focus on innovating the bike lock (Lock8, MobiLock, Bitlock, Linked&Locked) by using new technologies such as applications on the telephone which need to be used in order to lock or unlock your bicycle.

Furthermore, innovations in the field of bike sharing are very popular. Many reactions of the list on social media have mentioned Airdonkey, DonkeyBike, Hopperpoint and GoBike as innovations which needed to be included on the list. This is partly because of the importance of these innovations in the bike system, but also because of the involvement of several experts in these innovations.

Not only the individual experts who are involved in some of the innovations have mentioned their projects, also corporations have reacted on the list on social media by adding their innovations. JCDecaux for example, have mentioned their self-service electrical bicycle share system and Springlab has reacted on the list by adding the Light Companion in the reaction section. The corporations in the list are very diversified. Some are big companies such as Heijmans, while a lot of bike system innovations come from startups.

Not all smart innovations are launched. Several innovations are still in concept or are tested in pilots. Examples of smart innovations that are tested in pilots are the ‘verwarmd fietspad’ and the ‘Slimme fiets’ by TNO.

4.2 Conclusion

This chapter discussed the subquestion*: “Which smart bicycle system innovations are taking place?”*. Many bike innovations are in development or have been launched. Based on the research conducted for this thesis, seventy-nine bike system innovations are found. Not all these innovations can be qualified as a smart innovation, as they do not incorporate information or communication technologies. Applying the criteria of a smart bike system innovation, sixty-three smart bicycle system innovations are found that are in development or launched. These innovations take place within different parts of the bike system. The most smart bike innovations are found in the field of bike infrastructure and bike nudging apps and websites. Seven smart innovations are found in these categories. Also interesting to point out are the smart innovations that can be placed in several categories. The electrified S by Vanmoof is placed in both the categories of the smart e-bike and the smart bike locks. The list of the smart bike system innovations that are found through the desk research method are listed in Appendix 10.1.

The different smart bike innovation categories and the list of smart bike innovations that is displayed in Appendix 10.1 offer a clear view into the wave of smart bike innovations that is available to the public or will become available in the near future.

5. The potential level of disruption of the innovations

This chapter focuses on the potential level of disruption of the smart bike system innovations found in the previous chapter by discussing the following research subquestion: *"What is the potential level of disruption of each innovation?"*. The first paragraph discusses the first round of the Delphi method, the second paragraph shows the results of the feedback round.

5.1 The fuse and the bang in the first Delphi round

In this section, the smart bike system innovations which were grouped together into categories in section 4.1 are tested on their potential degree of disruptiveness within the current bike system. The results of the first round of the Delphi method with regard to the potential degree of disruptiveness are displayed in Figure 2.

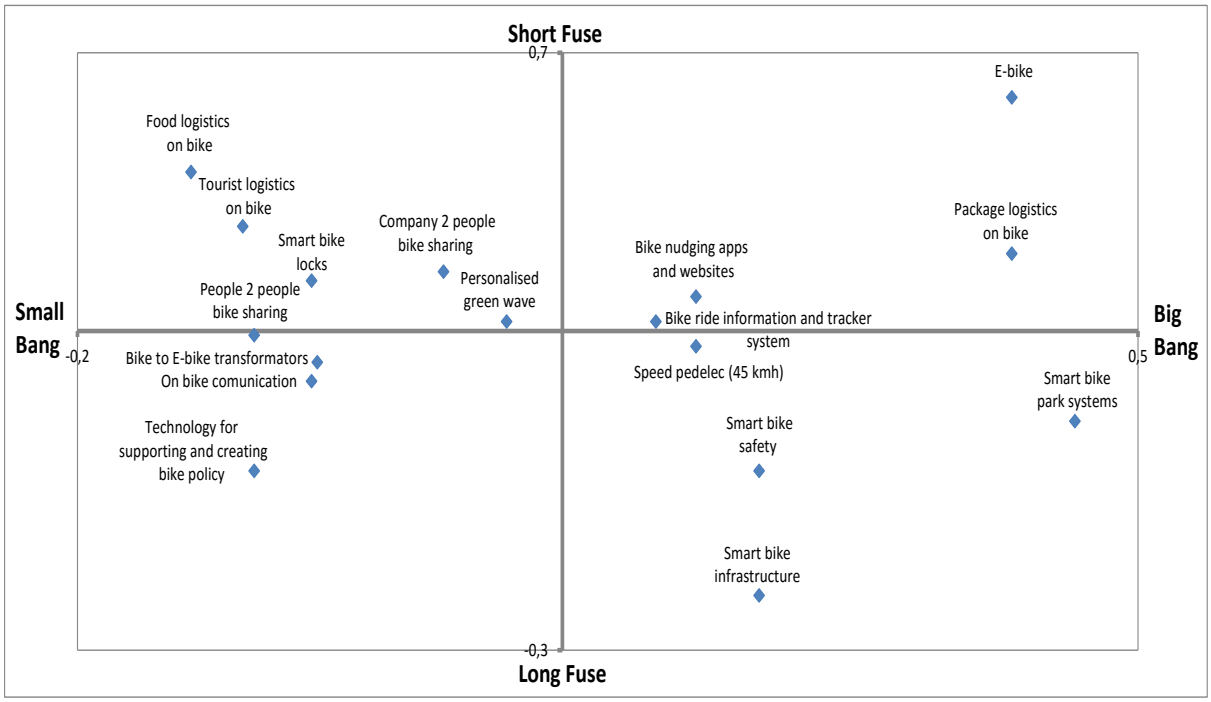

Figure 2: The disruption map of the first round

Four quadrants can be identified with regards to the potential degree of disruptiveness.

1. *Long fuse, small bang*: innovation categories in this quadrant are deemed as the least disruptive categories by the SCF experts. They are the least disruptive because the categories need a long time before they have little impact on the bike system. The four categories that are deemed least disruptive by the SCF experts are the people 2 people bike sharing, bike to e-bike transformators, on bike communication and technology for supporting and creating bike policy.
2. *Short fuse, small bang*: innovations that are listed in this quadrant are expected to have a small impact on the bike system, but the time that this impact will be realized is deemed as short. Two of the three logistics categories are placed in this category, namely food and tourist logistics on bike. The other categories are smart bike locks, company 2 people bike sharing and finally personalised green wave.

3. *Long fuse, big bang*: this quadrant is expected to have a big impact on the bike system, but this impact is expected to take a long time before it is realized. Four categories can be placed in this quadrant based on the responses given by the SCF experts. The speed pedelec, smart bike park systems, the smart bike safety and smart bike infrastructure are estimated to have a big impact on the bike system, which will be realized on the relatively long term.
4. *Short fuse, big bang*: the categories in this quadrant have a big impact on the bike system and this impact is expected to realize relatively quick in comparison with the categories which have a longer fuse. In this quadrant the most disruptive bike system innovations can be found which have the biggest impact on the bike system. These are the e-bike, package logistics on bike, bike nudging apps and websites and bike ride information and tracker system.

The placing of the smart bike innovation categories is not the definitive placement, since some categories have a standard deviation higher than 0.5 on one of the two variables of disruptiveness. The categories in Table 3 have a standard deviation of 0.5 or higher. These categories are further researched into the feedback round.

Smart bike categories	**St. dev. on the bang**	**St. dev. on the fuse**
Bike to e-bike transformators	0.52	-
Bike ride information and tracker system	0.51	-
On bike communication	0.58	0.51
People 2 people bike sharing	0.51	0.52
Personalised green wave	0.60	-
Smart bike infrastructure	0.50	0.54
Smart bike park systems	0.62	0.60
Food logistics on bike	0.61	-
Tourist logistics on bike	0.58	-
Technology for supporting and creating bike policy	0.52	-
Smart bike safety	-	0.62

Table 3: Categories with a standard deviation higher than 0.5 on one of the two variables of disruptiveness.

5.2 The fuse and the bang in the feedback round

After comparing the group answers on the bang and the fuse with their own perspectives, some changes have been made regarding the fuse and the bang of the categories with a standard deviation of 0.5 or higher. The changes in the four quadrants of disruptiveness are displayed in Figure 3. The standard deviation decreased for some categories on either the bang or the fuse, yet no full consensus was reached. These changes can be seen in Table 4, in which the standard deviation of the first round is compared with the results after the feedback round. In addition, some experts explained why they expected a certain bang or fuse. This clarified some of the conflicting views that caused the standard deviation of certain categories to be 0.5 or higher.

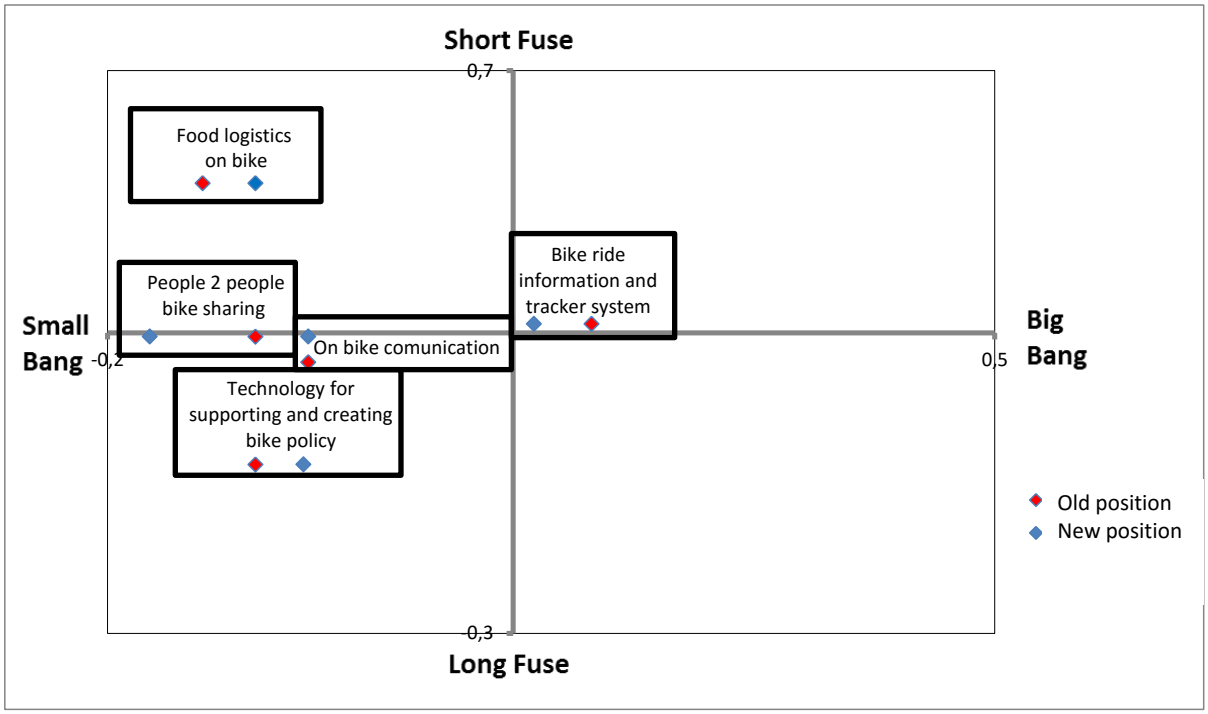

Figure 3: The changes that are made in the feedback round.

Smart bike categories	St. dev. on the bang first round / feedback round	St. dev. on the fuse first round / feedback round
Bike to e-bike transformators	0.52/ 0.52	-
Bike ride information and tracker system	0.51/ 0.50	-
On bike communication	0.58/ 0.58	0.51/ 0.47
People 2 people bike sharing	0.51/ 0.49	0.52/ 0.52
Personalised green wave	0.60/ 0.60	-
Smart bike infrastructure	0.50/ 0.50	0.54/ 0.54
Smart bike park systems	0.62/ 0.62	0.60/ 0.60
Food logistics on bike	0.61/ 0.56	-
Tourist logistics on bike	0.58/ 0.58	-
Technology for supporting and creating bike policy	0.52/ 0.47	-
Smart bike safety	-	0.62/ 0.62

Table 4: Comparing the standard deviation of the first round with the feedback round.

The bike to e-bike transformators category is a category on which the experts have very conflicting views regarding the impact on the bike system. Some state that the category has a potentially small impact on the bike system because they do not believe in the technology, or because the innovation is deemed an expensive ad-on: "*I don't believe that this technology will have a big impact; this will not be sold that much*" or "*I expect most cyclists just want a good bike, and won't invest in expensive ad-ons on the bike*" (SCF3 and SCF4, see Appendix 10.5). On the contrary, one expert expects that this category will have a big impact on the bike system because it is an affordable innovation which can be mounted on the bike relatively simple: "*A relatively cheap do it yourself operation and then I think it can have a big impact*" (SCF11, see Appendix 10.5). These conflicting opinions make clear

that the category is differently interpreted by the SCF experts and therefore has a standard deviation of 0.52 on the size of the bang.

The bike ride information and tracker system is one of the four categories placed in the quadrant of 'short fuse and big bang', which indicates that the category is deemed as the most disruptive by the SCF experts. But this category has a standard deviation of 0.51, thereby indicating that there is no consensus among the SCF experts on the impact of this category on the bike system. The conflicting views are expressed in the feedback round. Two experts explain the potentially big impact on the bike system: "*I see the future in intermodal movements, this technology can support this"* (SCF3, see Appendix 10.5) and *"Because it can help support the adoption of e-bikes*" (SCF7, see Appendix 10.5). However, one expert has changed his mind about the impact of the category on the bike system: *"Change from 'Big' to 'Neutral'"*(SCF9, see Appendix 10.5). Finally, one expert mentions that he could not estimate the impact on the bike system: "*I cannot give an answer, I don't know enough about this innovation*" (SCF10, see Appendix 10.5). As a result, the conflicting views about the potential disruptiveness of this category is decreased since one expert has changed his answer with regard to the potential bang of the impact. However, still no consensus has been reached about the potential degree of disruptiveness of this innovation category, because the standard deviation of the bang still is 0.5.

More conflicting views are expressed on the impact of the on bike communication category. Two experts explain their reasons why they think the category will have a big impact on the bike system: *"I see the future in intermodal movements, this technology can support this"* (SCF3, see Appendix 10.5) and *"Biking becomes an integrated transport system"* (SCF9, see Appendix 10.5). On the opposite, two other expectations are shared by experts who explain their choice for a small impact of the category on the bike system: "*I expect it to be a small impact because the degree of penetration will be small"* and "*I don't think this will lead to any significant change in behavior"* (SCF7 and SCF10, see Appendix 10.5). The answers regarding the potential impact on the bike system has remained the same, but the period of time that this bang would be reached has been changed. As a consequence, the standard deviation decreases which means that the estimations given by the experts are closer to one another as in the first round.

On the category of people 2 people bike sharing, the group answers are less divided after the feedback round, since the standard deviation decreases from 0.51 to 0.49 after one expert has indicated that the impact he estimated should be changed to a small bang: "*I change my estimation, for P2P I see a small impact"* (SCF3, see Appendix 10.5). Although a small bang is estimated for this category, one expert has indicated why he thinks it will have a big bang: "*Something like people 2 people bike sharing connects very well to what might be interesting to a lot of cyclists. Renting a bike if you need one, like UBER*" (SCF4, see Appendix 10.5).

Personalised green wave is a smart bike innovation category in which several conflicting views are expressed. Some experts argue it will have a big impact on the bike system: "*The green wave meets the 'normal cyclist' without to many difficult adaptation on the facts itself*" and "*Because it would sufficiently increase the 'flow' experience and with that the attraction of cycling*" (SCF4 and SCF7, see Appendix 10.5). On the contrary, one experts thinks it will have a small impact: "*I don't believe in this*" (SCF3, see Appendix 10.5). Finally, one expert acknowledges both the upsides and downsides of this innovation category: "*This will make biking more comfortable and the (crossroad) resistance will decrease, but it won't have any shocking consequence in the sense of modal shift or a strong growth of bike traffic*" (SCF9, see Appendix 10.5).

The standard deviation of the smart bike infrastructure for both the bang and the fuse remains unchanged. One expert argues that the smart bike infrastructure is expected to have a big impact on the bike system because it stimulates to use of the bike on longer distances: "*Bikes shall be used more on the longer distances*" (SCF9, see Appendix 10.5). However, several experts expect that this innovation category has a long fuse since the construction of new infrastructure takes a lot of time: "*Infra just takes long*" and "*Adaptations of infrastructure just is a lengthy process, depending on the scale you're watching. Partly dependent on management and replacement demand. Locally it could go quick, but overall it will take some time*" (SCF3 and SCF10, see Appendix 10.5).

The fuse and the bang of the smart bike park systems remains unchanged as well. This category is expected to have the biggest impact on the bike system, although not every expert agrees with this indication. This is because some experts approach the question from a different perspective: "*Special that the impact is deemed 'big'. I think mainly in terms of increasing comfort and less in system impact*" (SCF10, see Appendix 10.5). These different perspectives may explain the high standard deviation of 0.62 on the variable of the bang. This category also has a high standard deviation on the variable of the fuse, although no conflicting arguments are expressed by the experts.

The group answers are less divided after the feedback round with regard to the category of food logistics on bike. One expert has changed his estimated impact: "*Beautiful initiatives like TringTring and Foodora, and you see it grow fast, so maybe I am too pessimistic in my estimation*" (SCF10, see Appendix 10.5). However, the standard deviation remains above the 0.5, thereby indicating that the group still can reach no consensus with regard to the impact on the bike system.

The tourist logistics on bike category is placed in the least disruptive quadrant. Two experts explain why they indicate that this innovation category will have a small bang: "*I don't expect it to go that fast, too many stays out*" and "*Maybe locally, like in Amsterdam, but on the whole the impact is negligible*" (SCF7 and SCF10, see Appendix 10.5).

Although some experts remain skeptic about the impact of the smart bike category technology for supporting and creating bike policy ("*Seeing is believing*", SCF10, see Appendix 10.5), the standard deviation decreases in comparison with the first Delphi round. This is because one expert has changed his impact estimation to neutral: "*Technology for bike policy is very limited, I see it as something on which there are a lot of chances, especially with tools like Bikeprint etc. So therefore my impact estimation can be best changed to neutral" (*SCF4, see Appendix 10.5).

Smart bike safety is the final category on which the experts could react. This category had a standard deviation of 0.62 on the fuse which remains unchanged despite the feedback round. Two conflicting arguments are expressed. One expert explains why he expects an impact on the middle term: *"It is dependent of the replacement degree of penetration of smart bikes and smart bike infra"* (SCF10, see Appendix 10.5). This argument is in contrast with the argument expressed by another SCF expert, who states that this innovation has not been started yet: "*We still have to start with this…*" (SCF3, see Appendix 10.5).

The disruption map after the feedback round of the Delphi method is shown in Figure 4. Despite the feedback round, no smart bike category has been placed in another quadrant. Based on the answers given by the SCF experts in the first Delphi round and the feedback round, the disruption map shows which smart bike categories can be placed in which of the four quadrants of disruptiveness. Four categories are placed in the most disruptive quadrant. Three of the four categories in this quadrant

have a standard deviation which is lower than 0.5, and therefore there is consensus among the SCF experts about the bang and the fuse of these categories. These categories are deemed as the most disruptive smart bike innovation categories, based on the estimations given by the SCF experts on the variables of the fuse and the bang in both Delphi rounds. However, the smart innovation category of bike ride information and tracker system has a standard deviation of 0.5 on the variable of the bang. This means that the group has not reached consensus about the impact of the category on the bike system. Thus, this category will therefore not be taken into account in the next subquestion of this thesis.

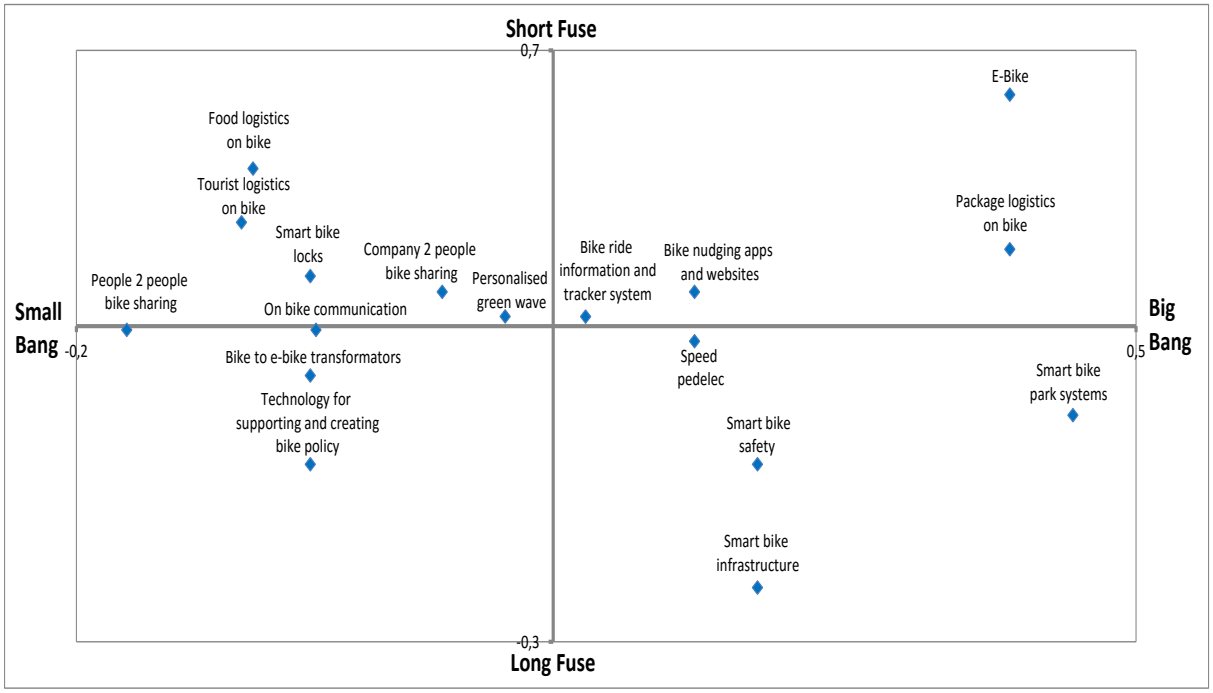

Figure 4: The disruption map after the feedback round.

5.3 Conclusion

The subquestion *"What is the potential level of disruption of each innovation?"* was addressed in this chapter. Four quadrants are identified that indicate the potential level of disruptiveness of each innovation category. People 2 people bike sharing, on bike communication, bike to e-bike transformators and technology for supporting and creating bike policy are placed in the quadrant of the 'long fuse, small bang', thereby indicating that these innovation categories have the lowest potential level of disruptiveness. These innovation categories all have a standard deviation of 0.5 or above. This indicates that the experts cannot reach consensus about the impact of these innovation categories on the bike system, despite the feedback round in which each expert had insight into the answers given by the group. However, as is the case for the people 2 people bike sharing, on bike communication and technology for supporting and creating bike policy, the standard deviation has decreased. This means that several experts have changed their answers based on the insights derived from the group answers.

The quadrant of 'short fuse, small bang' and the quadrant of 'Long fuse, big bang' have a higher potential level of disruptiveness since either their impact on the bike system is estimated to be higher or the impact is expected to take place relatively soon. The speed pedelec, smart bike park systems, smart bike safety and smart bike infrastructure are estimated to have a big impact on the

cycling system. But because this big impact is estimated to take a long time before it will be realized, the innovations within this quadrant do not have the highest potential level of disruptiveness. All innovations in this category except for the speed pedelec have a standard deviation of 0.5 or higher for one of the two variables of disruptiveness. This means that there are conflicting views in the group regarding the impact of the categories on the bike system. These conflicting views have not decreased in the feedback round, since no answers have been changed in the feedback round.

The five categories of food logistics on bike, tourist logistics on bike, smart bike locks, company 2 people bike sharing and the personalized green wave do not have the highest potential degree of disruptiveness since they are placed in the category of 'short fuse, small bang'. The impact of these innovations will be realized relatively soon but this impact is deemed small. Within this quadrant, the experts had conflicting views regarding the impact of categories of food logistics on bike, tourist logistics on bike and personalized green wave on the bike system. The conflicting views have decreased for the category of food logistics although the SCF experts still have not been able to reach consensus on the impact of this category on the bike system. The standard deviation on the bang decreased from 0.61 to 0.56.

The three smart bike innovation categories that are placed in the 'short fuse, big bang' quadrant and thus have the highest potential degree of disruptiveness are the smart e-bike, bike nudging applications and websites and package logistics on bike. The SCF experts have come to a consensus with regard to the impact of the innovation categories on the bike system, since the standard deviation of these categories is lower than 0.5. The bike ride tracker and information systems is placed in this quadrant as well. However, the standard deviation of this category on the size of the bang is more than 0.5, which means that it is uncertain whether this innovation category can be deemed as most disruptive since it is uncertain whether this category has a big impact on the bike system.

6. The impact on key psychological motivational mechanisms of modal choice

The previous chapter has clear what the most disruptive innovations in the bike system are according to the SCF experts. Here, their disruptiveness is tested by addressing the following subquestion: "*To what extent does the most disruptive bike system innovations have an impact on key psychological motivational mechanisms of modal choice?"*.

In contrast with chapter 5 this chapter presents the results of the second Delphi round and the feedback round at once, because no significant changes were made in the feedback round by the SCF group.

6.1 Impact on the perceived costs and benefits

6.1.1 The smart e-bike

The smart e-bike category is deemed to have an impact on the perceived costs and benefits, since all experts indicate that this smart innovation category will at least have a small impact (see Figure 5). Two experts indicate that the smart e-bike will have a small impact on the perceived costs and benefits. One expert explains that the e-bike will have a small impact because the price of a new e-bike is similar to the price of a second-hand car and therefore there are no real benefits in comparison with the car: "*If people could choose between a secondhand car and an e-bike, that will be difficult, because of the price of an e-bike. This will change when there will be a good functioning second hand market for e-bikes*" (SCF10, see Appendix 10.8.1).

Most experts, however, estimate a medium impact, because the e-bike will decrease travel time ("*A positive impact, because it shortens the travel time with the bike, so in that sense there is a higher benefit*", SCF2, see Appendix 10.8.1), it is more flexible than the car ("*e-bike certainly is an alternative, because of the comfort of reaching your destination, faster, more flexible*", SCF3, see Appendix 10.8.1) and you do not have to pay parking fees. One expert mentions the fun as a benefit that people experience when they travel on their bikes ("*The benefits can as well be fun and ease. And that shows. Research shows that people do choose the e-bike because of this. Not on a large scale, but it happens*", SCF5, see Appendix 10.8.1).

A big impact is estimated by two experts. In comparing the costs and benefits of the car with the smart e-bike, they come to the conclusion that there is a significant difference in the costs and benefits in favor of the smart e-bike: "*If people really notice how little an e-bike costs, then people will recognize that the costs and benefits are more favorable for the e-bike as for the car*"(SCF6, see Appendix 10.8.1).

6.1.2 The package logistics on bike

For this smart bike innovation category, the group is more divided as can be seen in Figure 5. Two experts explain that they cannot see the how the package logistics on bike will have an impact on the perceived costs and benefits. Consequently, they indicate that the smart innovation category will have no impact on the perceived costs and benefits.

Two experts estimate a small impact by approaching it from the perspective of the municipalities that use an environmental zone or gating time. This category could have the benefit to get around these municipal measures and thereby creating benefits for package logistics: "*I think that municipalities make it difficult for diesel engines of the package logistic companies by*

introducing certain measures. In combination with this innovation, it can have an impact" (SCF1, see Appendix 10.8.2).

A medium impact is estimated by three experts, since package logistics on bike are deemed to have an advantage over car logistics in the city centers since it is faster to deliver by bike: "*For the companies using this innovation, I think it is beneficial regarding the costs and benefits, especially within inner-cities because the bike is clearly more efficient here. So this will work*" (SCF10, see Appendix 10.8.2).

Last of all, three experts estimate that package logistics on bike will have a big impact on the perceived costs and benefits, since they approach it from the perspective of the companies involved in the package logistics: "*Big influence, because with many bike couriers, they approach it more rationally as with individuals. So here with the rational costs and benefits, the impact will be bigger*" and "*Because the logistic looks at the finances. In the urban areas the bike is faster as the car, and therefore more cheap*" (SCF4 and SCF5, see Appendix 10.8.2). All three argue that the companies have a rational approach on increasing the benefits and lowering the costs. Thus, in this case, package logistics on bike are expected to have a big impact on the perceived costs and benefits.

6.1.3 The bike nudging apps and websites

One expert expects the bike nudging apps and websites to have no impact on the perceived costs and benefits. However, most experts expect that this smart bike innovation category will have a small impact on the perceived costs and benefits (see Figure 5). Several arguments are given by the experts to support their answer. One mentions the increasing number of applications available to the public as a reason for a small impact but also as a potential threat ("*I do think it has somewhat an effect. But there is proliferation. Too much effort, too many costs for all these people to activate the apps*", SCF1, see Appendix 10.8.3) while others mention RingRing as an example of monetizing bike rides, thereby increasing the benefits of the bike system: "*These are things like RingRing for example, if those apps gain ground, then I think it will have an impact. But it has to be accessible. So there cannot be too much hassle with logging in and such*" (SCF3, see Appendix 10.8.3). One expert coins the term 'game-ification'. By turning cycling into a game through these applications, it can be more fun to cycle: "*Well, for example RingRing, what it does, it monetizes cycling, so it has costs and benefits. So it can have a small impact. But most of the apps make a game out of it, game-ification, and not so much the costs and benefits*" (SCF4, see Appendix 10.8.3). One final reason that the applications and websites are expected to have a small impact is that they offer their users insight into what the costs and benefits of cycling are. This alone will have a small impact on the perceived costs and benefits ("*Maybe a small one. Because people can become aware of the costs and benefits. This way they will have an impact. A small impact*", SCF9, see Appendix 10.8.3).

Two experts indicate a medium impact. One expert argues that these applications and websites make visible what the costs and benefits of cycling are. This function, in combination with the creation of a community, causes a medium impact of the bike nudging apps and websites on the perceived costs and benefits: "*Cyclists can be rewarded for their cycling, these are the benefits. But the participation with these apps will increase the awareness. You learn the benefits through the community that participate. So it will have an impact*" (SCF8, see Appendix 10.8.3).

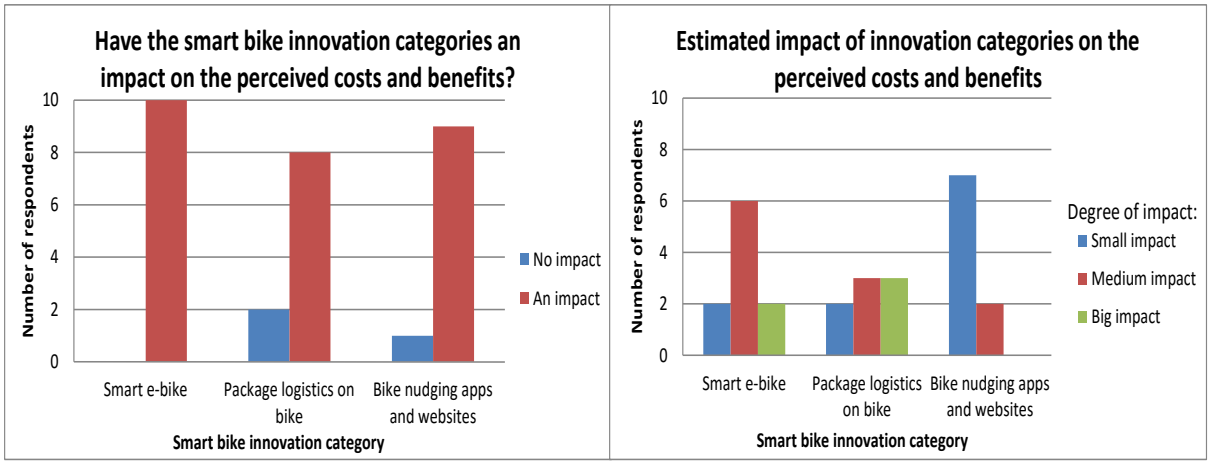

Figure 5: The estimated impact of the most disruptive smart bike innovation categories on the perceived costs and benefits.

6.2 Impact on the moral and normative concerns

6.2.1 The smart e-bike

Contrary with the estimated impact of the smart e-bike on the perceived costs and benefits, four experts indicate that they think the smart e-bike will have no impact on the moral and normative concerns (see Figure 6). Their main reason is that the e-bike will not have an impact on the moral and normative concerns. People who are already concerned with the environment will choose an e-bike. However, those who do not have any concerns about the environment will not be impacted because of the smart e-bike: "*I think the e-bike is a serious alternative for the ones who already neglect the car because of these concerns and take the public transport in regional transport. So I think it is more of a competitor for the public transport as it is for the car*" (SCF10, see Appendix 10.9.1).

Five experts estimate that the smart e-bike will have a small impact on the moral and normative concerns. One expert argues that the smart e-bike can let a small group of people think about the consequences of car use and raise climate awareness ("*Can definitely play a role, but the health factor is more important here. That is the motive to take the bike, but climate awareness also plays a role"*, SCF1, see Appendix 10.9.1), while another expert mentions health concerns as a factor that is impacted by the e-bike: "*Can play a small role, this can be a pull factor, the smart e-bike, but also health concerns play a role to choose the e-bike*" (SCF9, see Appendix 10.9.1).

One expert argues that the smart e-bike will have a big impact on the moral and normative concerns. He argues that people who have a smart e-bike will be more aware of the negative consequence of car use (see Appendix 10.9.1).

6.2.2 The package logistics on bike

Again, the group is divided concerning the impact of the package logistics on bike on this motivational mechanism of modal choice. One argument to indicate that this innovation category will have no impact is because the companies are more concerned with the costs and benefits. Their moral and normative concerns will not be impacted by this, because they only pay attention to their costs and benefits: *"I don't think this is a factor of influence. For those logistic companies the costs and benefits are of more importance as this"* (SCF3, see Appendix 10.9.2).

Three experts estimate a small impact. One expert explains why the the package logistics on bike will have a small impact: "*Small, people are not really busy with it*" (SCF5, see Appendix 10.9.2). This argument is not supported by the experts who indicate that this innovation category will have a

medium impact on the moral and normative concerns. They argue that this innovation will have a medium impact on the customers of those companies with moral and normative concerns. The package logistics on bike can thus be used as a marketing instrument to show their customers they are an environmental friendly company: "*For the companies, such as in Amsterdam, they can make an marketingargument, so it is an stimulation to increase the green image, so indirectly it sure has an impact*" and "*I think this is a way for the companies to show they are social responsibly entrepreneurs*" (SCF4 and SCF10, see Appendix 10.9.2).

This argument is also used by the expert who expects a big impact by the package logistics on the bike on the moral and normative concerns: "*Here, it does play a big role, if you look at it from the marketing perspective of these companies. They show good they are. Customers will see that this company thinks about the environment*" (SCF9, see Appendix 10.9.2). The marketing argument is thus used to support both the medium and big impact.

6.2.3 The bike nudging apps and websites

Last of all, five experts indicate a small impact of the bike nudging applications and websites on the moral and normative concerns, while the other five experts indicate a medium impact. The main argument that the five experts mention is that the applications and websites can raise the awareness of the impact of the different modal choices on the environments and thus influencing their moral and normative concerns: "*Could increase the awareness. Plays a role for fifty percent I think*" and "*This could be, it is a way to become aware of the moral aspects. So I think a small influence, no big one*" (SCF1 and SCF9, see Appendix 10.9.3).

Five experts indicate a medium impact. Two experts argue that the individuals who use these applications and websites form a community that has a significant reach to impact others with regard to their moral and normative concerns: "*This one does, because you can learn from others. You can consider with others, because of this community. So it can have an impact*" and "*I think this one is interesting. People like to be with like-minded, with the same values, in this case the bike. They can form an online community, that can play a positive role*" (SCF8 and SCF10, see Appendix 10.9.3).

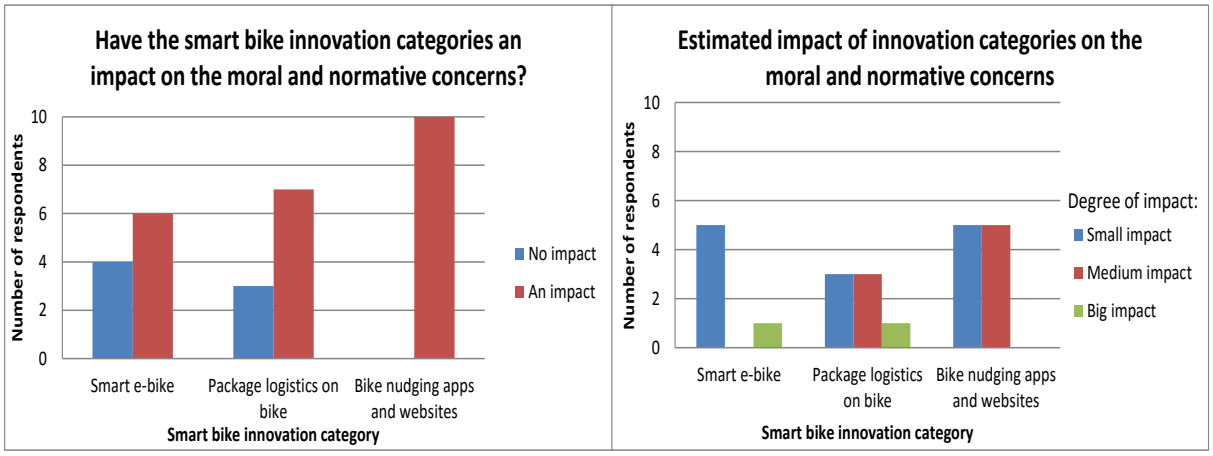

Figure 6: The estimated impact of the most disruptive smart bike innovation categories on the moral and normative concerns.

6.3 Impact on the affection

6.3.1 The smart e-bike

As can be seen in Figure 7, nine experts indicate that they expect an impact of the smart e-bike, while only one expert expects the smart e-bike to have no impact on the motivational factor of affection. His argument is that using the smart e-bike is no more fun as using a regular bike or a car, although he argues that this can change: "*It does not make it more fun as the regular bike or car, but it is faster, because of the feeling of the acceleration. But these associations with the e-bike are about to change I think*" (SCF4, see Appendix 10.10.1).

Three experts indicate a small impact. They expect people to more like biking on a smart e-bike to work instead of taking the car: "*A little bit, because taking the e-bike to work is more fun than taking the regular car or bike to work*" (SCF2, see Appendix 10.10.1). They also argue that the image of the smart e-bike is a factor that can cause an impact of the smart e-bike on the affection. The smart e-bike by VanMoof was mentioned as a positive example of how the smart e-bike can influence affection by creating and branding a bike aimed at a certain lifestyle: "*Car drivers are very hard to convince I think. Unless the lifestyle aspect gets more recognition, like VanMoof does. Those e-bikes do an appeal on certain lifestyle groups through differentiation and branding and by making beautiful bikes*" (SCF10, see Appendix 10.10.1).

The smart e-bike is estimated to have a medium impact on the affection according to four experts. One reason for this answer is because certain groups are sensitive for using new technologies, thus making an impact on the emotions of this group ("*It could certainly have an impact. Especially among people who enjoy technology, they will find this very interesting. That you will have a group of forerunners*", SCF7, see Appendix 10.10.1). The function of coupling the smartphone with the e-bike is also seen as a factor that can lead to an impact on the affection ("*It could have an impact. With the smartphone, you can enlarge the experience or see where you are. The positive impact of the bike can be enlarged and take naïve feelings concerning the bike away*", SCF8, see Appendix 10.10.1).

Two experts indicate that the smart e-bike will have a big impact on the affection. Their main argument is that cycling brings joy and using a smart e-bike will increase this joy even more, because they like the feeling of having the wind in their back.

6.3.2 The package logistics on bike

The main reason for three respondents to indicate that the package logistics will have no impact on the affection is because the experts approach it from the perspective of the companies making use of this technology. They indicate that this category will have no impact because the companies making use of this innovation category only look at the costs and benefits of the modes of transport: "*Here, I am not so convinced. It seems as very handy, practical and cost beneficial. But no emotional value*" and: "*I don't think so. It does not really have an effect on the emotions such as happiness*" (SCF7 and SCF10, see Appendix 10.10.2).

Contrary to the experts who only look at the perspective of the companies, seven experts look at both the supply and demand perspective. Their main reason to estimate a certain degree of impact is because of the demand side. The customers of the logistic companies all will appreciate it if package logistics will be done on bikes: "*Big, especially by clients and customers, the demand side. It seems like the scooter is gone, and I think it has to do with emotions. It has to do with the people who order there and who sign a contract with these companies*", *"I think this has an influence,*

people can feel good because they order the package logistic to be done by bike" and *"Something less, a small impact I guess. Because customers get a good feeling about this, but this effect does not happen on the companies"* (SCF5, SCF2, SCF9, see Appendix 10.10.2). However, despite their shared argument of the customers being impacted by this innovation category, the experts cannot agree to which extent the affection of the customers is impacted by the package logistics on bike. Four experts argue that it will have a small impact, two estimate a medium impact and one estimates that it will have a big impact.

6.3.3 The bike nudging apps and websites

The bike nudging applications and websites are expected to have a small or medium impact on the affection. Several arguments are expressed to support a small impact. The first argument is that few people are interested in these applications and websites and therefore only they are affected ("*Could definitely have an impact, because it triggers you in a way, it steers you. But it has a small impact and on a small group who is interested in these kind of technologies*", SCF9, see Appendix 10.10.3), or because the bike nudging applications and websites create a sort of community which can influence the emotions ("*I don't think that this is very big. The creation of the community could have an impact, but further I don't expect a big impact*", SCF10, see Appendix 10.10.3). Finally, one expert estimates a small impact, despite his stating that he does not expect that much of this category: "*A little bit more positive as I just did, but I still don't expect much of it. Because people are just not busy with it*" (SCF5, see Appendix 10.10.3).

The majority indicates that the bike nudging applications and websites have a medium impact on the affection. Several reasons are given to support this indication. First, one expert mentions that the main goal of these applications is to increase the fun of cycling ("*I do think they have an impact, because this is what they are aimed at to have an impact on*", SCF2, see Appendix 10.10.3). Second, the rewards after biking one hundred kilometers are mentioned as an example why this category can have an impact on the affection. Moreover, the 'game-ification' is brought forward as a reason why the bike nudging applications and websites will have an impact on the motivational factor of affection ("*Could make it more fun, for example through game-ification, that people enjoy it more because of the game element*", SCF4, see Appendix 10.10.3).

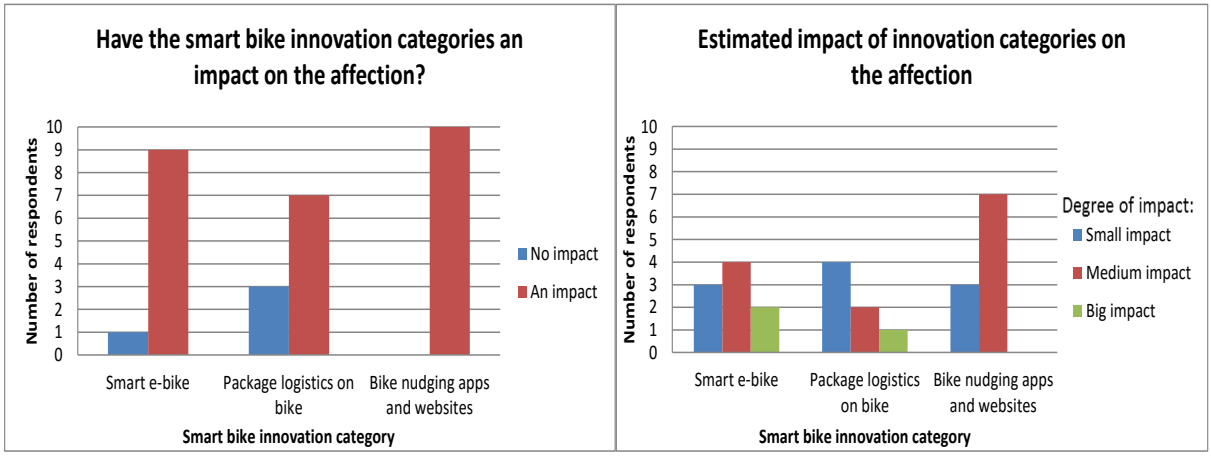

Figure 7: The estimated impact of the most disruptive smart bike innovation categories on the affection.

6.4 Impact on the habit

6.4.1 The smart e-bike

Three experts estimate that the smart e-bike will have no impact on the final motivational factor on modal choice of habit (see Figure 8). The main reason that these experts give is that the habit of modal choice cannot be addressed by a rational alternative as the smart e-bike: "*Barely, or even not at all. Because the habit is just ingrained in those groups that are not motivated to do something about these habits*" and "*No, I don't think this is present. The problem with habits is that a rationally better choice is not being seen. So only the presence of such an smart e-bike does not have an impact on the break of the habit*" (SCF5 and SCF8, see Appendix 10.11.1).

Contrary to this argument, three respondents argue that the smart e-bike will have a small impact. One expert argues it will have a small impact because the confrontation of people with the smart e-bike lets people rethink their habits ("*It does have an small impact, because people are confronted with the e-bike, and they will think about it if it is something for them. Even though they take the care every day*", SCF2, see Appendix 10.11.1).

The argument of the confrontation of a person with the smart e-bike is also used by several experts to indicate why the smart e-bike has a medium impact on the habit ("*I do think the smart e-bike will have an impact on this, on the behavior. You can see it in your social environment, and if you have an e-bike or in your surroundings, that could be a reason to break the habit*", SCF7, see Appendix 10.11.1). Moreover, one expert indicates that the smart e-bike can have a potentially medium impact when a life event takes place, for example when people get a new job: "*Innovations in general play an important role here. But routine can also play a big role when people get a new job. e-bike can be seen as an alternative in these kind of situations. So in that combination it could work*" (SCF1, see Appendix 10.11.1).

6.4.2 The package logistics on bike

As can be seen in Figure 8, four experts think that the package logistics on bike will have no impact on the habit. One expert indicates that it has no impact because companies can be affected through cost or environment arguments, and not through smart bike innovations: "*I don't think this has an impact. There needs to happen something to affect the habit, like costs or environmental reasons. The car is a good modal choice here*" (SCF6, see Appendix 10.11.2).

Two experts indicate a small impact of the package logistics on the bike on the habit. The first argument to support this impact is that certain companies act as a forerunner in using this smart bike innovation, thereby having an impact on the habit of other companies: "*Partly, the companies that can make the switch can function as forerunners here, they will impact the behavior*" (SCF7, see Appendix 10.11.2). The second expert who indicates a small impact mentions the attention the package logistics on bike generate as an impact factor: "*I do think a little bit. The attention that it generates, it can have an impact on the habit*" (SCF2, see Appendix 10.11.2).

A medium impact is estimated by three experts. Here as well, the confrontation of companies with this smart bike innovation can have an impact on the habit of companies. Another argument brought forward by one expert is that package logistics on bike is a quick alternative in the city for the car. Besides by using this innovation, companies can position themselves as societal responsible, thereby impacting the habit of those companies: "*From the company perspective, I do think this has an impact; in overcrowded cities it is a quick alternative for the car. Moreover, it is an efficient way to position yourself as a socially responsible company*" (SCF10, see Appendix 10.11.2).

Finally, one expert argues that the package logistics on bike will have a big impact on the habit because of the increasing traffic flows in the city. As a result, the package logistics on the bike will be recognized as an alternative to deal with the increasing traffic flows in the city: "*I do think this is stronger as with the e-bike. People are aware of the increasing crowdedness in the cities, that auto mobility is becoming more difficult. So yes, it will have an impact, it will become a routine because of the crowdedness*" (SCF3, see Appendix 10.11.2).

6.4.3 The bike nudging apps and websites

Two experts think that the bike nudging applications and websites will have no impact on the habit. One expert argues that this category has no impact because it is not visible on the streets; people have to put in effort to be confronted with it: "*I think that there will be barely an impact, because you don't see it out on the streets. You first have to be interested in cycling, and then you have to search for these apps and such*" (SCF2, see Appendix 10.11.3). The second expert explains that people who do have a habit of taking the car are not affected by this, because they do not look for alternatives: "*Barely, or even not at all. People who have these habits won't be affected by these innovations*" (SCF5, see Appendix 10.11.3).

Only one expert expects a small impact, stating that he does not expect that much from these applications. On the other hand, several experts think it will have a medium impact. One reason for a medium impact is that social media and the smartphone have changed daily life. This impact can therefore as well be expected by these applications and websites on the habit of people: "*Yes they can have an positive impact. It already is a habit of people to look at social media, so with this app you can see how much you have cycled. This contributes to the awareness of cycling, and thus it has an impact on habitual behavior*" and "*Till a certain degree, I do think so. You can see that the smartphone is interwoven with daily activities. These apps and the smartphone completely changed everyday life. So maybe it can have an impact on cycling as well* (SCF3 and SCF4, see Appendix 10.11.3).

A big impact is estimated by three experts. Two experts argue it will have a big impact because the online community on these applications and websites can give its users insight into their habits. Each time an user is confronted with the habits of the community on these applications can be seen as a disruptive moment, thereby having a big impact: "*This will have the most impact, because the community does make habits clear because of the communication with others. So they can have a reasonable big impact*" and "*Big, if people are active on these apps this can be a technology on which the peer group can constantly be seen. These are all disruptive moments*" (SCF8 and SCF10, see Appendix 10.11.3).

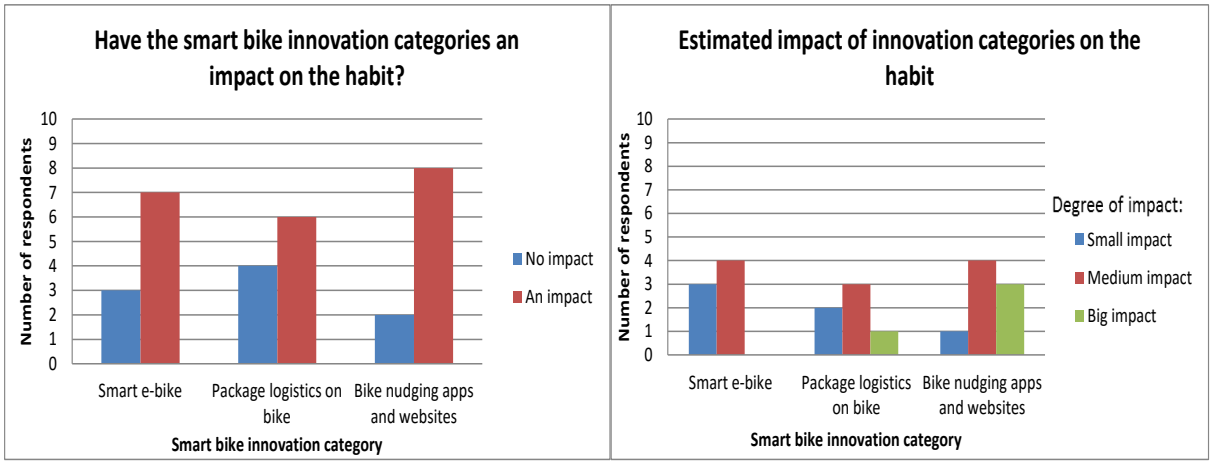

Figure 8: The estimated impact of the most disruptive smart bike innovation categories on the habit

6.5 Conclusion

The following subquestion is analysed in this chapter: *"To what extent does the most disruptive bike system innovations have an impact on key psychological motivational mechanisms of modal choice?".* The majority of the respondents indicate that the smart e-bike, package logistics on bike and bike nudging apps and websites do have an impact on the motivational factors on modal choice. As can be seen in Figure 9, the disruptive smart bike innovation categories mostly do have an impact on the motivational factor of costs and benefits. This is because the experts estimate that the smart bike innovations will have many benefits compared with the car in terms of costs savings, health benefits and fun while making use of the smart bike innovations.

The motivational factor of habit is being impacted the least by these smart bike innovation categories. This is because several SCF experts argue that the problem with habits is that a rationally better choice is not being seen. So the smart bike innovations may be a rationally better choice, but they may not have an impact on the habit since the habitual behavior of taking the car is just ingrained in the lives of people.

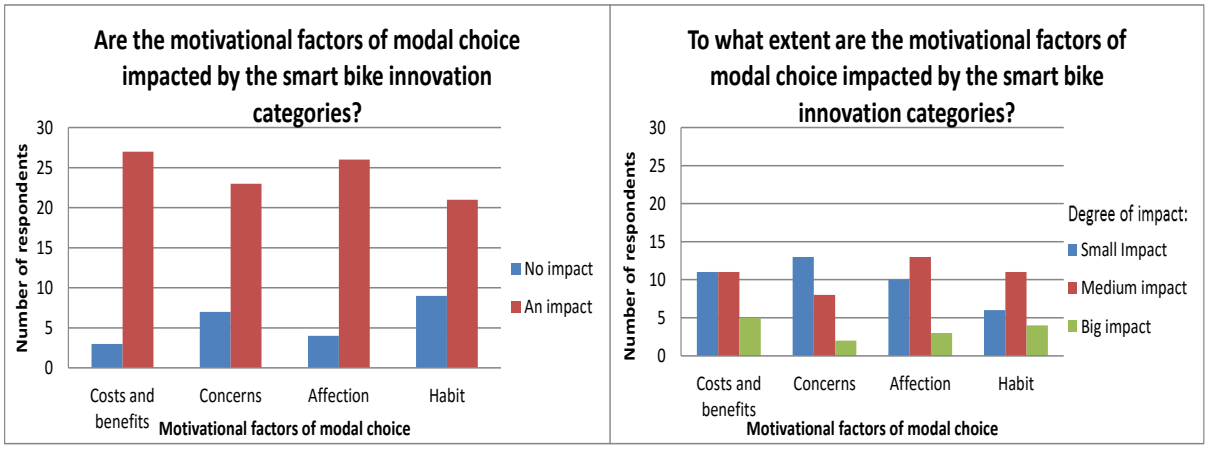

Figure 9: The estimated impact of the most disruptive smart bike innovation categories on the motivational factors of modal choice

The experts who indicate that the smart bike innovation categories will have an impact on each motivational factor of modal choice cannot come to a consensus regarding the extent of the impact. This can partly be explained because of the different approaches that are used by the experts to

estimate the degree of the impact. For example, some experts express the impact on the perceived costs and benefits in terms of money, while other experts express the impact in terms of health or fun. Another example of the varying perspectives that are used by the experts is found in the category of package logistics on bike. Some experts approach the package logistics on bike through a company perspective which is sensitive for costs and benefits, while other experts approach it from the customer perspective which is sensitive for the moral and normative concerns. Because of these different approaches, different arguments are mentioned to explain the varying degree of impact. The different approaches have not been changed in the feedback round, as not one expert has changed his answer. This means that the experts stand behind their argumentation, despite the opportunity to compare their own argumentation with that of the other experts. A majority of the respondents indicate a small to medium impact by the smart e-bike, package logistics on bike and the bike nudging apps and websites on the motivational factors on modal choice.

7. Conclusion

The research question of this thesis was: "*To what extent can disruptive innovations in the cycling system affect motivational mechanisms of modal choice?"*

First, current smart bike innovations are collected and processed. Sixty-three smart bike innovations are listed. These are grouped into 17 categories.

Thereafter, the potential degree of disruptiveness of the smart bike innovations is analysed. The smart bike innovation categories of smart e-bike, package logistics on bike and bike nudging apps and websites are placed in the quadrant of 'Short fuse, big bang'. The SCF experts reached consensus with regard to the impact of these innovation categories on the bike system. This indicates that these bike innovation categories have the highest potential degree of disruptiveness in the bike system. On the contrary, no consensus could is reached regarding the impact of the bike innovation categories of bike to e-bike transformators, bike ride information and tracker system, on bike communication, personalised green wave, smart bike infrastructure, smart bike park systems, food logistics on bike, tourist logistics on bike, technology for supporting and creating bike policy and smart bike safety. Although some experts have changed their indication of the estimated impact of some innovation categories on the bike system, many conflicting views are expressed in the feedback round. An example of a smart bike innovation category on which conflicting views were expressed is the bike to e-bike transformators category. Some stated it is an expensive ad-on, while others think it is an affordable innovation which is mounted on the bike relatively simple. These conflicting views make clear that there is discussion among the experts about the potential level of disruptiveness of the smart bike innovations.

The most disruptive bike innovation categories of smart e-bike, package logistics on bike and bike nudging apps and websites may have the potential to break with the unsustainable car system since they have the potential to disturb prevailing consumer habits and behaviors. Their path breaking potential is researched by analyzing to what extent the motivational mechanisms that explain the modal choice are impacted by the most disruptive innovation categories. It is expected that the most disruptive bike system innovations will have a small to medium impact on the motivational factors on modal choice. However, the exact degree of the impact cannot be estimated precisely since the respondents cannot come to a consensus regarding the extent each motivational factor on modal choice is affected by the smart bike innovations. The main reason for the disparity among the SCF experts are the different approaches used to estimate the impact. The package logistics on bike is an example of a category in which these different approaches are expressed. Some experts approach the package logistics on bike through a company perspective which is sensitive for costs and benefits, while other experts approach it from the customer perspective which is sensitive for the moral and normative concerns

In conclusion, disruptive smart bike innovations in the cycling system can affect motivational mechanisms of modal choice, although this impact is rather small. However, there is uncertainty about the extent of the impact of smart bike innovations on the bike system. In the first round of the Delphi method, the SCF experts cannot reach consensus about the potential degree of disruptiveness of eleven of the seventeen smart bike innovation categories. In the second round of the Delphi method, the group of SCF experts are divided concerning the extent of the impact the smart bike innovation categories have on motivational factors that help explain modal choice. Both

the feedback rounds cannot help overcome these conflicting views. This indicates that the SCF experts who have participated in this research all have different opinions on the potential degree of disruptiveness of the smart bike innovation categories and that they can hardly be convinced by the argumentation of fellow SCF experts.

8. Discussion

The results that are found in this thesis may further contribute to the literature on which this thesis is based. But first, in the light of the contribution of this thesis to the scientific literature, it is important to mention the empirical limitations of results that were found. Several limitations need to be taken into account. The first important reflection point is that there is no clear universally applicable definition of the smart concept. There is little knowledge in terms of what the discourse reveals as well as hides. As a consequence, several of the smart bike innovations may be unclear whether they fit the definition of an smart innovation. The resulting smart bike innovation list could be different if a different operationalization of the smart concept was being used.

The second limitation concerns the operationalization to measure the potential degree of disruptiveness. The research method to gain insight in the potential level of disruptiveness is not precise and perfect, because this model is mostly based on expert opinions. Its purpose is to look at the innovations in a granular way and not in a precise way (Deloitte, 2012). Therefore, the disruption map displayed in figure 4 shows were one category relatively stands from the other categories. Furthermore, experts involved in the Smart Cycling Futures project are involved in both rounds of the Delphi method. While the focus of this project is on smart innovations in the cycling system, the results cannot be generalized since members of this group may have a bias towards certain innovations, or do not understand the meaning of each smart innovation category despite a description of each category given before the questionnaires started.

Finally, it needs to be noted that other factors as well have an impact on the motivational factors on modal choice. Many contextual factors may facilitate or constrain travel behavior. For example, the quality of public transport can strongly affect the modal choice (Dijst *et al*., 2013).

The first contribution to the scientific literature is the collection and presentation of smart bike innovations which are in development. To my knowledge, this is the first academic attempt to create such a holistic overview of this dynamic field. A clear insight into which smart bike innovations are in development or launched contributes to a clear debate about which smart bike innovations are expected to be desirable and are estimated to have an influence on the bike system.

A second contribution to the scientific literature is that scholars must focus on the impact of other smart bike innovations on the bike system. Research mainly focused on the impact of three groups of smart bike innovations, namely the bike sharing innovations (DeMaio, 2009; Midgley, 2009; Wang *et al*., 2010), the smart bike infrastructure (Bendiks & Degros, 2013, p. 163) and the bike nudging apps and websites (Tertoolen *et al.*, 2015). This research shows that other smart bike innovations may be expected to have a big impact on the bike system as well. For example, the statement of Dirk Sijmons (2014) concerning the potential of e-bikes is supported by the results from this thesis. He suggests that the e-bike will have a big impact on the bike system because these smart innovations give the bike a greater reach and will relieve the user from typical small user discomforts such as cycling uphill (Sijmons, 2014, P:180). This suggestions is proven by in this research. According to the SCF experts, the smart e-bike will have a disruptive impact on the bike system. On the other hand, the smart bike sharing innovations are placed in the quadrant with a small bang. This indicates that this innovation category will not have the biggest impact on the bike system. This is in contrast with the scientific literature that discuss the success of smart bike sharing innovations in various cities (DeMaio, 2009; Midgley, 2009; Wang *et al*., 2010).

The third contribution is that the results from this thesis make clear that the smart discourse does not have to be characterized by a naïve optimism in technology. The smart discourse is a promising discourse, since many technologies are in development that may have the potential to help overcome urban challenges (Raven, 2016). Smart technology is thought of as the new medicine that will cure all the problems that cities are facing (Raven, 2016). The SCF experts did not display such naïve optimism. What they made clear, based on their conflicting opinions about the impact of smart bike innovations on the cycling system, is that there are conflicting views about the impact of smart bike innovations. One possible explanation for these conflicting views may be the lack of knowledge regarding the smart discourse, since surprisingly little is known in terms of what the smart discourse reveals as well as hides (Hollands, 2008).

9. Recommendations for further research

Based on the results of this thesis, several research questions might be worth analyzing to further contribute to the knowledge of disruptive smart bike innovations.

First, the method from Deloitte (2012) is used to analyze the potential degree of disruptiveness of the smart bike innovations. This method is a granular way to look at the level of disruptiveness. Other methods to measure the potential degree of disruptiveness might be interesting to look at as well, since the use of different methods to examine the disruptiveness of the smart bike innovations can contribute to the knowledge of which smart bike innovations will have a big impact on the bike system. Also, using other methods to measure the disruptiveness can contribute to a better understanding of the concept of disruptiveness since relatively little academic research has focused on the potential degree of disruptiveness.

Second, only the innovations that were deemed as most disruptive were further analyzed in this thesis on their potential impact on motivational factors on modal choice. It might be interesting to research the potential of the other bike innovation categories since there still is discussion among the experts about the potential degree of disruptiveness of the smart bike innovations. For example, several bike innovations in the category of bike infrastructure were expected to have a big impact on the bike system, but a long fuse. Despite this long fuse, it might be interesting to look at the extent of the impact these innovation categories have on motivational factors on modal choice.

The final recommendation is a more practice oriented research proposal. This thesis analysed the path breaking potential of the most disruptive smart bike innovations to break with the system of auto mobility from a theoretical perspective. The question remains if these smart bike innovations work in practice. What are necessary conditions for a smart bike innovation to realize a concrete effect, and how can these smart bike innovations be further developed? These questions are essential to be dealt with in order to gain more insight in the path breaking potential of the smart bike innovations.

10. Appendices

10.1 The smart bike system innovations

Innovation	Company	Description
S-Bike	Technische Universiteit Eindhoven	A bicycle with electrical support. The battery is recharged via solar cells placed in the wheels
Lock8	Lock8	Bluetooth bike lock with integrated GPS to track the bike in real time on the Lock8 app for smartphone
Ring a Bell!	Blossity	Ring a Bell is a smart bicycle bell, which measures fine dust and colors red when exceeding critical levels. That means both instant feedback to the user and data collection on a big scale. This bell is part of The Internet of Things and so all collected data is illustrated real-time into insightful maps
LINKA	Velasso	Smart Phone lock. By connecting the lock with the smartphone, LINKA will recognize you as you approach the bike and will unlock automatically
FlyKly SmartWheel	FlyKly	Smart wheel which can turn almost any regular bike in an e-bike by adding a motor in the wheel which speed can be adjusted through the application on the smartphone
Smart Jacket	Vodafone & Magic Bullet	The jacket connects with bikers' smartphones. Cyclists map out their route on a map app and then put their phones into a special pocket, which uploads the route and transmits to 300 built-in LEDs. These LEDs direct the traveler along the best route to take while the lights on the back alert drivers around him to where he is heading
go e-Onwheel	DUI	An engine which turns almost any regular bike into an e-bike by adding a motor on the frame which speed can be adjusted through the application on the smartphone
The Social Light	Springlab	A rear light on which short text messages can be displayed
SEIL Bag	Myung Su Lee	Bicycle riders could operate a detachable wireless controller to illustrate traffic signals such as the cruise signal, stop signal and emergency signal directly on the backpack by bluetooth
Hopperpoint	Hopperpoint	Free float bike sharing system. By making use of an app on the telephone, people reserve and unlock a bike. It also displays all the available Hopperpoint bikes
Airdonkey	Erdem Ovacik	A lock and an application on the smartphone that, together, allows bike owners to rent out their bike and allows renters to find and rent a bike by the click of a button
GoLightavenue	Heijmans	Smart bicycle highway. With sensors, automobilists are warned for approaching cyclists. The traffic lights can also register an approaching cyclist, so it

		can provide a 'flow experience'
Evergreen	DTV	Interaction between cyclists and traffic light through sensors in the bike path
BikeScout	Heijmans	Safety system which indicates approaching cyclists at a crossover using LED lights
The light Companion	Springlab	'Personal' traffic lights which indicates, using sensors in the bike path, how fast a cyclists needs to cycle in order to get a green traffic light
Pleasant pass	Public passes	Making infrastructure such as a bicycle underpass or bicycle route attractive through interaction between infrastructure and user and also between users of the bike path. Messages can be written on the website and on the app, which are then displayed on the infrastructure
Fietsy	Grrr	Inspirig tourists to explore the Amsterdam countryside by electric bike. The application offers several routes to explore and functions as a tourguide to provide information about the region
SiBike app	Siemens	Smart traffic light system. By using GPS the position of the cyclist is tracked. If the cyclist passes a trigger point, a signal is send to the traffic lights to turn green or to maintain the green light
VanMoof electric	VanMoof	Smart e-bike. By using an application on the telephone, the bike can be unlocked. It also has a GPS function built in to track the bike
Speed Pedelec	Gazelle, Sparta	Bicycle with an electrical engine that goes up to 45 km/h. The software on the board computer is being continuously updated in order to improve the engine
e-bike	Sparta, Gazelle, Vanmoof	Bicycle with an electrical engine that goes up to 25 km/h
SmartHalo	SmartHaloBike	Device which can be applied on the steering wheel. by linking the SmartHalo with the smartphone, the device can be used as a navigator, anti-theft system and bike lights
Hövding bike airbag 2.0	Hövding	A collar airbag with sensors and microprocessors which inflates itself within one-tenth of a second when a crash happens
Mobilock	Mobilock	Unlock your bike without keys by using an app on the smartphone. With the app you can lock and unlock your bike
Bitlock	Bitlock	Unlock your bike without keys by using an app on the smartphone. With the app you can lock and unlock your bike
Garmin Varia Vision	Garmin	When connected to a smartphone, it will display notifications like incoming calls and text messages. It also displays performance data like speed, heart rate, cadence, turn-by-turn directions with street name, distance to turn, and directional arrows
Strava	Strava	Using GPS and an app on the phone or the bike computer, cyclist can upload their ride on Strava

		and see where they cycled, how fast, the altitude of their ride and of cyclists they are following
Self Service Electric bikes	JCDecaux	Self-service bikes which are made electrical by a light weight portable battery which needs to be rented. Furtermore, riders will have smartphone connectivity. Through the application on the smartphone, riders can see the number of available bikes and they can reserve a bike
Spinlister	Spinlister	People 2 people bikesharing via app and website. On the app or the website, renters select a bike style and bike size they would like to rent, as well as their location
Gobike	Gobike	e-bike sharing system and tablet which displays transit information
Studentbike	StudentBike, Amsterdam	A free bike renting system. Students can rent the bike for free. In exchange, they have to cycle at least ten kilometers per day on a bike with advertisement on the frame. An application on the telephone tracks the students
DonkeyBike	Donkey Republic	An app which allows the users to rent a bike by booking a bike with the app and to unlock the lock with the app
Verwarmd fietspad	Provinces of Overijssel en Gelderland & Thermopath & Wegbeheerders ontmoeten Wegbeheerders	A bicycle path which saves the heath it faces in the summer and uses this heath during the winter by using a smart WKO system which lies underneath the path
Re-Light	ENECO	Bike path lighted by solar and wind power. Lighting sensors are used to adjust the strength of the lights
Cloud fietsenstalling	HR Group/Brimos	System which makes use of sensors to indicate where there is place for the bike to be parked
Automated Cycle Storage	Eco Storage	An automatic system which stores multiple bikes below or above the ground, with a retrieval time of just thirteen seconds
Tvilight Intelligent Lighting	TVILIGHT B.V	Outdoor smart sensors, wireless lighting controls, and connected lighting management software for street lights, the lamps adjust their brightness based on the presence of pedestrians, cyclists or cars
P-Route Bike	Municipality of Utrecht & Lumiguide	System which indicates which public transport stations and parking garages in the city center have available parking spaces. A map shows the cyclists how to reach these parking spots. The availability of the parking spaces is measured by sensors in the bike racks
EasyPath	EasyPath	Coupled precast concrete elements with sensors to measure infrastructure quality
TringTring	TringTring	Open bike messenger platform
Deliveroo	Deliveroo	Bike messenger food delivery

Foodora	Foodora	Bike messenger food delivery
B-Riders	Ministerie van Infrastructuur en Milieu & Provincie Noord-Brabant	The B-Riders application on the smartphone registers the bike ride for people living in the Province of Noord-Brabant. Based on the kilometers cycled, it gives the cyclists feedback and rewards him or her with discounts in local shops
Burn fat not fuel	eCarConnect BV	A special box is mounted on the bike which registers the rides. A receiver at the employer and an application on the smartphone registers all these rides. Based on the kilometers cycled from and to work, you receive points and coaching. What distuingishes this innovation from the others is the focus on the employer to encourage his employees to take the bike to work
Trappen scoort	Provinces of Zeeland & Brabant	Campaign to stimulate bike usage under students from the lower and middle school in the Provinces of Zeeland and Brabant. Students register their rides on the website. A competition is set up to see which school cycles the most. This way, this program stimulates the bike usage among students
RingRing	Ring Ring	Application on the smartphone which registers bike rides. The kilometers can be exchanged for a certain discount at local shops who participate in the project
Toury	Toury	With the Toury application on the smartphone, cyclist are encouraged to cycle to work by adding a competition element in the application to see who has saved the most Co2 and has ridden the most kilometers by biking instead of taking the car
Doorgeeffiets	Mobycon	Campaign to stimulate bike usage by testing an e-bike for two weeks after which the e-bike is given to its next owner. Experiences of taking the e-bike to work are shared on a blog and on Facebook, Twitter and LinkedIn. This way, an online community is being created to positively change the image of the e-bike
Dero Zap	Dero Zap	Automated commuter tracking system, which utilizes RFID (radio-frequency identification) technology to track the chip on the bike. It automates your commuter wellness program so that the employees only have to bike, since the chip tracks the route of the cyclists. An app gives the cyclist insight in their bike statistics such as kilometers ridden or their average speed
Vitrual Reality Cycling Simulator	Cycle Spaces & NHTV	A Virtual Reality Cycling Simulator to evaluate design of future cycle infrastructure
Hightech 3D Engineeringstool	Compass	A reliable, realistic and efficient tool to design a tracé for underground infrastructure
BikePRINT	Breda University of applied sciences & DAT.mobility	Visualizes data of the cyclists (Fietstelweek, B-Riders)

Swapfiets	Stultech V.O.F	Subscription to a service which delivers your bike and allows you to swap your bike when broken
Skopei Cycling	Skopei Cycling	Skopei Cycling develops intelligent software- and hardware solutions needed to start a bicycle sharing system. The bikes in the system can be managed by a cloud-based web application or via smartphone apps
Bicycle Buddy App	Brandes en Meurs	App which provides route, weather and other cyclist information about the route Arnhem - Nijmegen - Zevenaar
XYZ SPACEFRAME VEHICLES	N55	A computer program which enables persons to build their own vehicles for transporting persons or goods
Slimme Fiets	TNO	Electric bicycle with on board camera which make it efficient for cyclists to look behind them. A vibration system sends its users a signal if it detects danger by vibrating handlebars
Traffic Lights	DK	By making use of sensors, Smart traffic lights 'see' a cyclist approaching. This way, the traffic lights can increase the efficiency of the traffic flow by favoring and recognizing cyclists
Linked&Locked	Linked&Locked	A parking spot with an integrated electronic lock: you can lock and unlock your bike with the app and the system automatically reports bikes that exceed the maximum parking duration
SolaRoad	TNO, Province Noord-Holland, Imtech Traffic&Infra and Ooms Civiel	A bike path with integrated solar panels that generate energy which is used for roadsignals and streetlights
UberRush	UberRush	On-demand delivery of packages on bikes which can be tracked and followed on the smartphone
ByCycling	ByCycling	Cycling tracker and community app that encourage you to take the bike more often for commuting and rewards you for doing it
Parkcycle	DHL	Package logistic on bike which uses e-bikes to deliver packages which are traceable by smartphone or on the website

10.2 The non-smart innovations

Innovation	Company	Description
Het vergevingsgezinde fietspad	Royal HaskoningDHV and Rijksuniversiteit Groningen	A widened bike line with soft ends designed to prevent or correct little mistakes
Overdekt fietspad	DUI	Indoor bike path under the Berlin subway
Hovenring	ipv Delft	Bicycle roundabout which is leveled up in order to separate cycling from motorized traffic, with a seventy meter high pylon
Bikezac	Bikezac	Bikezac makes it much safer to transport goods on the bike, because it hangs stable on the side of the luggage rack on the back of the bike
Levi's Commuter	Levi's	Jeans specifically designed for bike commuting
Alinker loopfiets	Barbara Alink	A non-motorized 'walking bike'
Mokumo	Bob Schiller	Inspired by the way cars are produced, the Mokumo bicycle is made out of two sheets of aluminum pressed into form and spot welded together
Cargobike container clicksystem	BusyBike	A roll-on-roll-off click system for cargobike containers. You can change the whole container in just one minute
Boncho	VanMoof	A full body bike poncho
Innovactory	Syndesmo	Service aimed at stimulating the workforce to take the bike to commute to work
Dynamisch Parkeervak Neude	Wholesalers & Municipality of Utrecht	Flexible bike park area which is also a loading and unloading space for the wholesalers between 07:00-11:30
Fully electrical folding bike	Yike Bike	e-bike designed to be fold simply. Designed for an urban commute.
Integrated Bike Locks	BluLock	Providing a bottom bracket anti-theft system that fits neatly inside the saddle tube. The mechanism blocks the pedals and locks the plug-in chain in one smooth turn of the key
Yellow Backie	Yellow Bikes	Share a ride on back carrier
Van Gogh fietspad	Studio Roosegaarde & Heijmans	Raising the experience of the bike lanes by making the bike lane interesting using art
Security Bolts	Hexlox	Security bolds to be placed on the bolts of bike parts such as saddles, thereby blocking the insertion of a standard tool to prevent theft.

10.3 List of SCF experts involved in the first round of the Delphi method

Marcus Popkema
Friso de Vor
Jacco Farla
Stephan Valenta
Syb Tjepkema
Hugo van der Steenhoven
Luca Bertolini
Rob Raven
Matthijs de Gier
Lucas Harms
Pieter van Wesemael
Willem Buunk

10.4 Online survey of the first Delphi round

Question 1: What is, according to you, the potential impact of the following smart bike innovation categories on the current bike system (broadly defined)?

Smart innovation category	Very Big	Big	Neutral	Small	Very Small	Don't know/ no opinion
e-bike						
Speed pedelec (45 km/h)						
Bike to e-bike transformators						
Bike ride information & tracker system						
On bike comunication						
Smart bike locks						
People 2 people bike sharing						
Company 2 people bike sharing						
Personalised green wave						
Smart bike infrastructure						
Smart bike park systems						
Food logistics on bike						
Tourist logistics on bike						
Package logistics on bike						
Bike nudging apps and websites						
Technology for supporting and creating bike policy						
Smart bike safety						

Question 2: Within which period do you think the impact, indicated in question 1, will be reached?

Smart innovation category	Very short	short	Middle	long	Very long	Don't know/ no opinion
e-bike						
Speed pedelec (45 km/h)						
Bike to e-bike transformators						
Bike ride information & tracker system						
On bike comunication						
Smart bike locks						
People 2 people bike sharing						
Company 2 people bike sharing						
Personalised green wave						

Smart bike infrastructure						
Smart bike park systems						
Food logistics on bike						
Tourist logistics on bike						
Package logistics on bike						
Bike nudging apps and websites						
Technology for supporting and creating bike policy						
Smart bike safety						

Question 3: If you think an important bike innovation category is missing, you can indicate that here:

…….

Question 4: Your name

…….

10.5 Feedback of the SCF experts on the smart bike innovation categories

Smart innovation category	Feedback on the bang	Feedback on the fuse
Bike to e-bike transformators	SCF3: "I don't believe that this technology will have a big impact; this will not be sold that much". SCF4: "I expect most cyclists just want a good bike, and won't invest in expensive ad-ons on the bike". SCF10:"I expect it to be a small impact because the degree of penetration will be small". SCF11: "A relatively cheap do it yourself operation and then I think it can have a big impact".	SCF4: "There is a lot of discussion about this, but there is not a lot of implementation or it is expensive". SCF11: "A relatively cheap do it yourself operation and then I think it can have a quick impact".
Bike ride information & tracker system	SCF3:"I see the future in intermodal movements, this technology can support this". SCF7:"Because it can help support the adoption of e-bikes". SCF9: "Change from 'Big' to Neutral". SCF10: "I cannot give an answer, I don't know enough about this innovation".	-
On bike communication	SCF3: "I see the future in intermodal movements, this technology can support this". SCF7: "I don't think this will lead to any significant change in behavior". SCF9: "Biking becomes an integrated transport system". SCF10: "I expect it to be a small impact because the degree of penetration will be small".	SCF7: "I estimate that the technology/behavior complexity to be high, with a lot of uncertainties as a consequence".
People 2 people bike sharing	SCF10: "Possibly a big impact outside the Netherlands, but in the context of the Netherlands, I think the effect will be minimal. I ask myself whether this innovation will change this, this is more of a 'druppel op de gloeiende plaat'….". SCF9: "Scaling up remains a point of attention → there is not that much necessary to activate this".	SCF10: "I think this could be implemented relatively quick, depending on the smart locks and such, but maybe in my qualification of 'short' I am being too optimistic, and is middle more realistic". SCF4: "it doesn't have to take long, there are initiatives already".

	SCF4: “Something like people 2 people bike sharing connects very well to what might be interesting to a lot of cyclists. Renting a bike if you need one, like UBER”. SCF3: “I change my estimation, for P2P I see a small impact”.	
Personalised green wave	SCF3: “I don’t believe in this”. SCF4: “The green wave meets the ‘normal cyclist’ without to many difficult adaptation on the facts itself”. SCF7: “Because it would sufficiently increase the ‘flow’ experience and with that the attraction of cycling”. SCF9: “This will make biking more comfortable and the (crossroad) resistance will decrease, but it won’t have any shocking consequence in the sense of modal shift or a strong growth of bike traffic”.	-
Smart bike infrastructure	SCF3: “Space for the bike!” SCF9: “Bikes shall be used more on the longer distances, however, there are slow political decisions”.	SCF3: “Infra just takes long”. SCF7: “I estimate that the technology/behavior complexity to be high, with a lot of uncertainties as a consequence”. SCF10: “Adaptations of infrastructure just is a lengthy process (depending on the scale you’re watching). Partly dependent on management and replacement demand. Locally it could go quick, but overall it will take some time”.
Smart bike park systems	SCF3: “Space for the bike!” SCF10: “Special that the impact is deemed ‘big’. I think mainly in terms of increasing comfort and less in system impact”.	SCF3: “infra just takes long” SCf10: “adaptations of infrastructure just is a lengthy process (depending on the scale you’re watching). Partly dependent on management and replacement demand. Locally it could go quick, but overall it will take some time”.
Food logistics on bike	SCF7: “I don’t expect it to go that fast, to many stays out”. SCF10: “Beautiful initiatives like	-

	TringTring and Foodora, and you see it grow fast, so maybe I am too pessimistic in my estimation".	
Tourist logistics on bike	SCF7: ""I don't expect it to go that fast, too many stays out". SCF10: "maybe locally, like in Amsterdam, but on the whole the impact is negligible".	-
Technology for supporting and creating bike policy	SCF4: "Technology for bike policy is very limited, I see it as something on which there are a lot of chances, especially with tools like Bikeprint etc. So therefore my impact estimation can be best changed to 'Neutral'". SCF7: "Can make policy more effective, and on multiple dimensions a once". SCF10: "Seeing is believing".	-
Smart bike safety	-	SCF3: "We still have to start with this…". SCF10: "It is dependent of the replacement degree of penetration of smart bikes and smart bike infra"

10.6 List of SCF experts involved in the second round of the Delphi method

Frans Sengers
Hugo van der Steenhoven
Jacco Farla
Friso de Vor
Luca Bertolini
Martijn Sargentini
Nathan Hooghof
Matthijs de Gier
Pieter van Wesemael
Lucas Harms
Pieter van Wesemael

10.7 Survey questions of the second Delphi round

The impact of the smart bike innovations on the motivational factors on modal choice

The decision to choose for a certain mode of travel can be partly explained by analyzing the motivational factors on modal choice from a psychology perspective. This goal of this interview is to analyse to what extent the motivational factors are impacted by the three most disruptive bike innovations. With the concept impact I mean the long term effect of a measure, intervention or innovation. The smart bike innovations are explained first. Thereafter, the individual motive of every question is explained. After the explanation I ask you to estimate the impact that the smart bike innovation will have on that individual motive. You can indicate that the innovation will have no impact, a small impact, am medium impact or a big impact on each motivational factor. I ask you to please explain why you choose a certain impact.

1. Perceived costs and benefits: assumes that individuals make reasoned choices and choose alternatives with the highest benefits against the lowest costs. This could either be expressed in terms of money, effort or social approval.
   - To what extent do you think that the e-bike will have an impact on this motivational factor?
   - To what extent do you think that the package logistic on bike will have an impact on this motivational factor?
   - To what extent do you think that the bike nudging apps and websites will have an ipact on this motivational factor?

2. Moral and normative concerns: this motive looks at how travel behavior is shaped by the norms of individuals. People will probably only reduce their car use when they value the environment and when they are concerned with the problems caused by car use
   - To what extent do you think that the e-bike will have an impact on this motivational factor?
   - To what extent do you think that the package logistic on bike will have an impact on this motivational factor?
   - To what extent do you think that the bike nudging apps and websites will have an ipact on this motivational factor?

3. Affection: This individual motive assumes that travel behavior is also motivated by affective outcomes. An affective outcome may be that driving to work is more fun than taking the bus.
   - To what extent do you think that the e-bike will have an impact on this motivational factor?
   - To what extent do you think that the package logistic on bike will have an impact on this motivational factor?
   - To what extent do you think that the bike nudging apps and websites will have an ipact on this motivational factor?

4. Habit: The final operationalized as an automatism of people to choose a certain mode of transport over and over again because it performed good during previous similar situations. People tend to focus on information that confirms their choices and neglect information that is not in line with their habitual behavior

- To what extent do you think that the e-bike will have an impact on this motivational factor?
- To what extent do you think that the package logistic on bike will have an impact on this motivational factor?
- To what extent do you think that the bike nudging apps and websites will have an ipact on this motivational factor?

e-bike. The first category of the smart bike system innovations is the e-bike. The e-bike is an bike with an electrical engine that goes up to 25 km/h and which use technology to connect the bike to the internet and the smartphone. Sensors in the bike indicate if the cyclist is pedaling and thus if the motor should support the cyclist. Moreover, the sensors also indicate if the cyclist is a potentially dangerous situation by vibrating handlebars.
Package logistic on bike: The innovations in this category , UberRush and Parkcycle, are an online platform accessible by an application on the smartphone and website. The application of UberRush functions as a platform for the transportation of goods on bikes in and around New York, but is planning to expand to Amsterdam. Parkcycle is an initiative by DHL to deliver packages in different cities on the electrical e-bike, thereby offering the package to be followed online by a track and trace code.
Bike nudging apps and websites: the innovations all share the characteristic of using websites and applications to stimulate the usage of the bike by developing an online platform on which cyclists, employers and health insurance companies can connect. The stimulation happens in various ways. Some applications and websites function as bike stimulus by developing a competition in which several schools in the provinces of Zeeland and Noord-Brabant compete with another to see which school can travel the most kilometers on their bikes. Other applications and websites reward people for kilometers traveled on the bike by awarding the cyclists with financial incentives received through their health insurance and their employer.

10.8 Explanation of the impact on perceived costs and benefits

10.8.1 Explanations of the impact of the smart e-bike on the perceived costs and benefits

No impact	Small impact	Medium impact	Big impact
	SCF1: "Could be contributing to this, but I think the e-bike will not be prevailing". SCF10: "If people could choose between a secondhand car and an e-bike, that will be difficult, because of the price of an e-bike. This will change when there will be a good functioning second hand market for e-bikes".	SCF2: "A positive impact, because it shortens the travel time with the bike, so in that sense there is a higher benefit". SCF3: "e-bike certainly is an alternative, because of the comfort of reaching your destination, faster, more flexible. With the car, congestion and parking, those are costs. So the e-bike is an good alternative". SCF4: "I think that the range increases because of the e-bike. This is cheaper as it is with the car, so the costs, the e-bike is more cheap. Regarding the benefits, maybe the e-bike can save you more time I think". SCF5: "in an area in which the costs for parking are high, the e-bike could be a good alternative. But you don't only have to look at money. The benefits can as well be fun and ease. And that shows. Research shows that people do choose the e-bike because of this. Not on a large scale, but it happens".	SCF6: "If people really notice how little an e-bike costs, then people will recognize that the costs and benefits are more favorable for the e-bike as for the car". SCF7: "Because mainly commuter traffic can have an impact. The distances that people now have to travel by car are replaceable by the e-bike. So people will calculate what the costs and benefits are, and if you take into account the costs for parking, well, then the e-bike will have a big impact".

		SCF8: "The e-bike already has an impact on the costs and benefits, because it is faster as a regular bike, and in some cases it can rival the car because of its flexibility. De smartness here is that all the possibilities all the costs and benefits, become insightful by using the smartphone". SCF9: "If you really focus on money, the purchase price definitely plays an role, but further it is quite accessible to keep an e-bike going".	

10.8.2 Explanations of the impact of the package logistic on bike on the perceived costs and benefits

No impact	**Small impact**	**Medium impact**	**Big impact**
SCF2: "No, I don't see the link". SCF7: "I cannot see this relation, it are two different aspects. I don't see a connecting here".	SCF1: "I think that municipalities make it difficult for diesel engines of the package logistic companies by introducing certain measures. In combination with this innovation, it can have an impact". SCF8: "For consumer it depends if the costs and benefits are impacted. For example if there are environmental zones, the costs of using the car will be much higher, and the consumer will notice this in the price he will pay. But the capacity	SCF3: "In Utrecht you see many companies working with these carrier bicycles. And you also see these companies such as Thuisbezorgd.nl, working more and more with bicycles instead of scooters to deliver packages". SCF6: "Especially in the inner-cities, where the speed plays an important role". SCF10: "For the companies using this innovation, I think it is beneficial regarding the costs and benefits, especially within inner-	SCF4: "Big influence, because with many bike couriers, they approach it more rationally as with individuals. So here with the rational costs and benefits, the impact will be bigger". SCF5: "Because the logistic looks at the finances. In the urban areas the bike is faster as the car, and therefore more cheap". SCF9: "This will have the biggest impact, for companies this can result in more

	of the bike is less as the capacity of a truck. So this can be negative for the innovation. So I think it is very complex, and therefore a small impact".	cities because the bike is clearly more efficient here. So this will work".	benefits, especially in highly urbanized cities this can result in time savings, so this is an win-win situation".

10.8.3 Explanations of the impact of the bike nudging apps and websites on the perceived costs and benefits

No impact	**Small impact**	**Medium impact**	**Big impact**
SCF2: "It does not have an impact on the costs and benefits".	SCF1: "I do think it has somewhat an effect. But there is proliferation. Too much effort, too many costs for all these people to activate the apps. The ones that reward the cyclists, I think if those are further developed, lead to high benefits". SCF3: "These are things like RingRing for example, if those apps gain ground, then I think it will have an impact. But it has to be accessible. So there cannot be too much hassle with logging in and such". SCF4: "Well, for example RingRing, what it does, it monetizes cycling, so it has costs and benefits. So it can have a small impact. But most of the apps make a game out of it, game-ification, and not so much the costs and benefits". SCF5: "The least of the three. But still a small	SCF6: "These apps make clear what the benefits of cycling are, and in combination with the e-bike. So in that sense, it does have an impact". SCF8: "Cyclists can be rewarded for their cycling, these are the benefits. But the participation with these apps will increase the awareness. You learn the benefits through the community that participate. So it will have an impact".	

	impact. It is not an incentive. I think it is something for a small target audience". SCF7: "To a certain degree, also depends on other factors. So first there needs to be good cycling infrastructure, and in combination these apps can be a good addition". SCF9: "Maybe a small one. Because people can become aware of the costs and benefits. This way they will have an impact. A small impact". SCF10: "These kinds of apps trigger the reward mechanism. And people can be sensitive for this. And these apps have an impact on this. But further, I don't expect that much of an impact".		

10.9 Explanation of the impact on the moral and normative concerns

10.9.1 Explanations of the impact of the smart e-bike on the moral and normative concerns

No impact	Small impact	Medium impact	Big impact
SCF2: "Either you are concerned with the environment or not. The e-bike only gives you a chance to do something about it". SCF4: "I don't know if this happens directly. I think that people think it is more practical, that could be possible. For example in China,	SCF1: "Can definitely play a role, but the health factor is more important here. That is the motive to take the bike, but climate awareness also plays a role". SCF3: "It can have an influence, but you also see the rise in electric cars, so that can have		SCF6: "I do think it is pretty big. People who want to cycle need a motive such as this, I think".

there are lot of e-bikes, I just came from there. What you see there is that mostly cyclists choose the e-bike, not so much the car drivers". SCF8: "Not significant, if people do have these moral and normative concerns, then they will not be changed because of the e-bike. But if you do have these concerns, it becomes easier to do something with it". SCF10: "I think the e-bike is a serious alternative for the ones who already neglect the car because of these concerns and take the public transport in regional transport. So I think it is more of a competitor for the public transport as it is for the car".	an counter effect. But it definitely plays an role, the environment, to take an e-bike". SCF5: "Minimal, normative concerns plays a minimal role. People don't think about this. This has been researched by the KiM, 'jongeren en mobiliteit', and it concludes that 10 to 15 percent thought about this, but no more". SCF7: "generically I think this will not have a big impact, a certain small part uses these concerns, the people who are concerned with the environment. Only for this small group that already is concerned about this". SCF9: "Can play a small role, this can be a pull factor, the smart e-bike, but also health concerns play a role to choose the e-bike".		

10.9.2 Explanations of the impact of the package logistic on bike on the moral and normative concerns

No impact	**Small impact**	**Medium impact**	**Big impact**
SCF1: "No I don't think so, not at this moment". SCF3: "I don't think this is a factor of influence. For those logistic companies the costs and benefits are of more importance as this".	SCF2: "To a small extent. The fact that it exists could make people think of the other possibilities". SCF5: "Small, people are not really busy with it". SCF7: "Small group will react positive	SCF4: "For the companies, such as in Amsterdam, they can make an marketingargument, so it is an stimulation to increase the green image, so indirectly it sure has an impact". SCF6: "not as strong as my previous	SCF9: "Here, it does play a big role, if you look at it from the marketing perspective of these companies. They show good they are. Customers will see that this company thinks about the environment".

SCF8: "Not directly, but it creates an option that if you have these concerns, you can do something about it".	about this. The same as with the e-bike, a small group is busy with this".	answer, but it applies here as well. For example, companies can show that they are doing good, being environmental friendly". SCF10: "I think this is a way for the companies to show they are social responsibly entrepreneurs".	

10.9.3 Explanations of the impact of the bike nudging apps and websites on the moral and normative concerns

No impact	Small impact	Medium impact	Big impact
	SCF1: "Could increase the awareness. Plays a role for fifty percent I think". SCF2: "A small influence. Because of its existence, it can have a small impact". SCF5: "Small, people are not busy with these concerns". SCF6: "I think something less. People who value the environment, they have a different motivation. They don't need such an app as people who always take the car". SCF9: "This could be, it is a way to become aware of the moral aspects. So I think a small influence, no big one".	SCF3: "Until a certain degree, this could have an impact. If you could see information about the emissions of Co2, if you can compare that with the car and the train. So the information definitely plays an role, that people become more aware of these subjects because of all this information on the apps". SCF4: "well, through the game-ification, if you can measure the emission of Co2 being produced, that could be an influence. That you see the number and because of that take the bike instead of the car". SCF7: "Something more as the others, a bigger audience is being targeted here because of these app	

		and websites". SCF8: "This one does, because you can learn from others. You can consider with others, because of this community. So it can have an impact". SCF10: "I think this one is interesting. People like to be with like-minded, with the same values, in this case the bike. They can form an online community, that can play a positive role".	

10.10 Explanation of the impact on the affection

10.10.1 Explanations of the impact of the smart e-bike on the affection

No impact	**Small impact**	**Medium impact**	**Big impact**
SCF4: "It does not make it more fun as the regular bike or car, but it is faster, because of the feeling of the acceleration. But these associations with the e-bike are about to change I think".	SCF2: "A little bit, because taking the e-bike to work is more fun than taking the regular car or bike to work". SCF3: "It is of importance. You can really like cycling, so it is an option. De switch to an e-bike could be made if you like cycling". SCF10: "Car drivers are very hard to convince I think. Unless the lifestyle aspect gets more recognition, like VanMoof does. Those e-bikes do an appeal on certain lifestyle groups through differentiation and branding and by making beautiful bikes".	SCF5: "Reasonable, there will be people who choose it on purpose because they like it. You are already seeing switching to e-bikes because of the emotions". SCF6: "I do think so. the car has a high status which the e-bike does not have. But I do think people enjoy it. So the effect is there, but not big". SCF7: "It could certainly have an impact. Especially among people who enjoy technology, they will find this very interesting. That you will have a group of forerunners". SCF8: "It could have an	SCF1: "This is important. Cycling gives a feeling of freedom, people meeting others. So a high emotional value". SCF9: "Yes, I do think that people can be happy because of this. This also becomes clear if you look at recent research. People saying it gives them the same feeling as drinking a glass of wine. The wind in the back, that feeling, could have an impact. People also travel longer because they enjoy the e-bike. So it certainly has an impact".

		impact. With the smartphone, you can enlarge the experience or see where you are. The positive impact of the bike can be enlarged and take naïve feelings concerning the bike away".	

10.10.2 Explanations of the impact of the package logistic on bike on the affection

No impact	**Small impact**	**Medium impact**	**Big impact**
SCF7: "Here, I am not so convinced. It seems as very handy, practical and cost beneficial. But no emotional value". SCF8: "Not substantial no". SCF10: "I don't think so. It does not really have an effect on the emotions such as happiness".	SCF3: "Not a big role or so. It is fun that my package is being delivered by bike, people could think that. The one who offers the service looks at the costs and benefits, but the potential customer could enjoy this. This is more related to the demand side I guess". SCF4: "Not so much, maybe through marketing, that people get a certain idea about it. But no so much an impact". SCF6: "No, not very much. The effect is not that much present I think". SCF9: "Something less, a small impact I guess. Because customers get a good feeling about this, but this effect does not happen on the companies".	SCF1: "Could influence the streetscape, bike couriers are being seen as something positive, people like it. So it can play a role". SCF2: "I think this has an influence, people can feel good because they order the package logistic to be done by bike".	SCF5: "Big, especially by clients and customers, the demand side. It seems like the scooter is gone, and I think it has to do with emotions. It has to do with the people who order there and who sign a contract with these companies".

10.10.3 Explanations of the impact of the bike nudging apps and websites on the affection

No impact	Small impact	Medium impact	Big impact
	SCF5: "A little bit more positive as I just did, but I still don't expect much of it. Because people are just not busy with it". SCF9: "Could definitely have an impact, because it triggers you in a way, it steers you. But it has a small impact and on a small group who is interested in these kind of technologies". SCF10: "I don't think that this is very big. The creation of the community could have an impact, but further I don't expect a big impact".	SCF1: "Yeah, it could be. I am mainly thinking about apps that could have an impact. That you get the idea that you are doing well because such an app". SCF2: "I do think they have an impact, because this is what they are aimed at to have an impact on". SCF3: "Yes I do think so. If cycle about 100 kilometers, and you get a reward on social media or so, that it can be stimulating". SCF4: "Could make it more fun, for example through game-ification, that people enjoy it more because of the game element". SCF6: "I do think this will have an impact, because you are coached on your emotions, reaching goals and such. So your emotion is being supported by these apps". SCF7: "I do think there is a relation here. Certain groups, such as the more younger people, they are impacted because of these apps. It can certainly have an emotional value. With apps who encourage	

		group behavior". SCF8: "Could have an impact because of the game element, it can positively have an impact on the emotions. So an impact yes".	

10.11 Explanation of the impact on the habit

10.11.1 Explanations of the impact of the smart e-bike on the habit

No impact	Small impact	Medium impact	Big impact
SCF5: "Barely, or even not at all. Because the habit is just ingrained in those groups that are not motivated to do something about these habits". SCF6: "Not very much. Or actually not at all". SCF8: "No, I don't think this is present. The problem with habits is that a rationally better choice is not being seen. So only the presence of such an smart e-bike does not have an impact on the break of the habit".	SCF2: "It does have an small impact, because people are confronted with the e-bike, and they will think about it if it is something for them. Even though they take the care every day". SCF4: "Maybe a little bit, people are creatures of habit. This can be broken, but they first need to do it a few times, experience that it is practical, get that 'aha' feeling. And so the habit can be slowly impacted". SCF9: "It could be that they are taken out of their habit. With targeted measures, this could take people out of their comfort zone with a lasting result. But the best impact will be when it comes together with a life event such as moving to a new house. But purely the e-bikes driving around, that will not do much".	SCF1: "Innovations in general play an important role here. But routine can also play a big role when people get a new job. e-bike can be seen as an alternative in these kind of situations. So in that combination it could work". SCF3: "Till 20 kilometers, this will definitely have potential. If you live on e-bike distance to your work, it is a good alternative to break with the routine, but it does have potential". SCF7: "I do think the smart e-bike will have an impact on this, on the behavior. You can see it in your social environment, and if you have an e-bike or in your surroundings, that could be a reason to break the habit". SCF10: "Yes, I do think so, Because you often that habit behavior, if there comes a	

		disruptive technology, then you can see an impact. It is a moment people reflect on their habit. But it would help if companies would brand it that way.	

10.11.2 Explanations of the impact of the package logistic on bike on the habit

No impact	Small impact	Medium impact	Big impact
SCF4: "I think there is no impact". SCF5: "Barely, or even not at all. People who have these habits won't be affected by these innovations". SCF6: "I don't think this has an impact. There needs to happen something to affect the habit, like costs or environmental reasons. The car is a good modal choice here". SCF8: "This does not break the habit. It has no impact on it".	SCF2: "I do think a little bit. The attention that it generates, it can have an impact on the habit". SCF7: "Partly, the companies that can make the switch can function as forerunners here, they will impact the behavior".	SCF1: "Can definitely have an impact, it is a nice alternative for these companies". SCF9: "Could set an example, others could follow this. It can also cause consumers to think about their travel behavior". SCF10: "From the company perspective, I do think this has an impact; in overcrowded cities it is a quick alternative for the car. Moreover, it is an efficient way to position yourself as a socially responsible company".	SCF3: "I do think this is stronger as with the e-bike. People are aware of the increasing crowdedness in the cities, that auto mobility is becoming more difficult. So yes, it will have an impact, it will become a routine because of the crowdedness".

10.11.3 Explanations of the impact of the bike nudging apps and websites on the habit

No impact	Small impact	Medium impact	Big impact
SCF2: "I think that there will be barely an impact, because you don't see it out on the streets. You first have to be interested in cycling, and then you have to search for these apps and such". SCF5: "Barely, or even not at all. People who have these habits	SCF9: "I think here as well, unless you are being approached while you are moving, that could have an impact. But if this does not happen, I don't expect that much of it, a small impact I guess".	SCF1: "Such an app can definitely help, I am convinced of it". SCF3: "Yes they can have an positive impact. It already is a habit of people to look at social media, so with this app you can see how much you have cycled. This contributes to the	SCF7: "Here, I see a big impulse. If people are being triggered by these apps, they will change their behavior". SCF8: "This will have the most impact, because the community does make habits clear because of the

won't be affected by these innovations".		awareness of cycling, and thus it has an impact on habitual behavior". SCF4: "Till a certain degree, I do think so. You can see that the smartphone is interwoven with daily activities. These apps and the smartphone completely changed everyday life. So maybe it can have an impact on cycling as well. The problem is that on the bike itself it is a little bit harder". SCF6: "Big if it happens in combination with others. On its own, it can have a reasonable impact, because the goal is influencing habitual behavior. It lets people cycle on a very relaxed way. So it does have a reasonable impact".	communication with others. So they can have a reasonable big impact". SCF10: "Big, if people are active on these apps this can be a technology on which the peer group can constantly be seen. These are all disruptive moments".

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