Assessing Financial Schemes for Commuter Cycling: A Comprehensive Social Cost-Benefit Analysis

TIL5060 TIL Master Thesis

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Preface

It is with great satisfaction that I present this master thesis. Undertaking this research has been an enriching experience, allowing me to expand my knowledge and insights into Social Cost-Benefit Analysis regarding financial schemes related to commuter cycling.

I am profoundly appreciative of the guidance and support of my supervisors, Bert van Wee, Jan Anne Annema, Dorine Duives, and Pim van der Zwet whose guidance, feedback, and expertise have been invaluable throughout this process.

As I present this thesis, I am filled with a sense of accomplishment and anticipation for the impact these findings may have. It is my hope that this work contributes to the advancement of cycling Social Cost Benefit Analyses and inspires further exploration.

I.M. Wienk
Delft, August 2023

Summary

The Netherlands is a leading cycling country with a high modal share of cycling compared to other European countries (Buehler & Pucher, 2012).The potential benefits of increasing the cycling modal share are significant, given the challenges of traffic congestion, overcrowded public transport, and obesity in the Netherlands (ANWB, 2017; Heinen, 2010; Ministry of Health Welfare and Sport, 2022; Nijland & Dijst, 2015; Olde Kalter, 2007; Rabl & de Nazelle, 2012; Rover, 2022; RTL Nieuws, n.d.). To encourage more people to cycle for commuting purposes, the government has implemented policies like the 'Kies de Fiets' initiative (Ministry of Infrastructure and Water Management, 2023b). However, despite these efforts, the percentage of people using bicycles for commuting remains at 25% as of 2019 (Centraal Bureau voor de Statistiek, 2021). This research aims to conduct a Social Cost-Benefit Analysis (SCBA) on financial schemes promoting bicycle commuting in the Netherlands, resulting in the following research question:

"What are the social costs and benefits associated with financial schemes promoting bicycle commuting in the Netherlands?"

Three financial schemes are examined: the tax-free kilometre allowance, lease bike scheme and the 'Fietsplan scheme (Ministry of Infrastructure and Water Management, 2023a). The tax-free kilometre allowance allows employees to receive a tax-free reimbursement for each kilometre travelled by bicycle for commuting purposes. As of January 2023, the allowance has been increased from 0.19 €/km to 0.21 €/km. Under the lease bike scheme, employees can lease a (electric) bicycle for commuting without having to purchase one personally. Employees are granted unrestricted personal use of the company bicycle from a tax perspective. However, they are required to pay an annual addition of 7% of the consumer price of the bicycle. Additionally, there are lease costs associated with leasing a bicycle, which can be paid by the employer, shared between the employer and employee, or entirely covered by the employee from their gross salary. The 'Fietsplan' scheme allowed employees to purchase a bicycle every three years using their gross salary. Employees could deduct a bicycle with a value of up to 749 euros from their gross salary, resulting in a tax benefit of 370.76 euros considering a tax rate of 49.5%. These schemes are evaluated compared to the reference alternative where no such schemes is implemented, and employees received a kilometre reimbursement of €0.19/km for both bicycle and car usage. The goal is to understand the societal impact of these schemes and their effectiveness in promoting bicycle commuting in the Netherlands. To answer this, the research focuses on developing a conceptual model and a computational model to analyse the effects of different cycling policies on social benefits and costs.

The first step is determining the factors which need to be considered when evaluating the social costs and benefits of financial schemes pertaining to commuter cycling. This done by performing a structured brainstorm, literature research, and conducting interviews. This led to an exhaustive list of 44 factors, among the identified factors, 19 factors were suitable for monetisation and are referred to as "priced factors." Given the time frame not all factors could be explored in the thesis, therefore these factors were filtered based on the availability of literature and interviews, resulting in 14 priced factors, the conceptual model is depicted below, Figure 1. A colour scheme is applied to maintain clarity. The red factor is the policy alternative financial scheme-specific factor. The white factors are the factors related to travel behaviour. The blue factors are the priced factors, these are divided into three different categories. The dark blue factors are the priced factors that influence society. The blue factors influence the individual that cycles due to the financial scheme. The light blue factors influences both the society as the individual. Next to that, there are also grey factors, these are the factors that are eliminated from this research. The light grey factors are the factors related to travel behaviour and the dark grey factors are the eliminated priced factors.

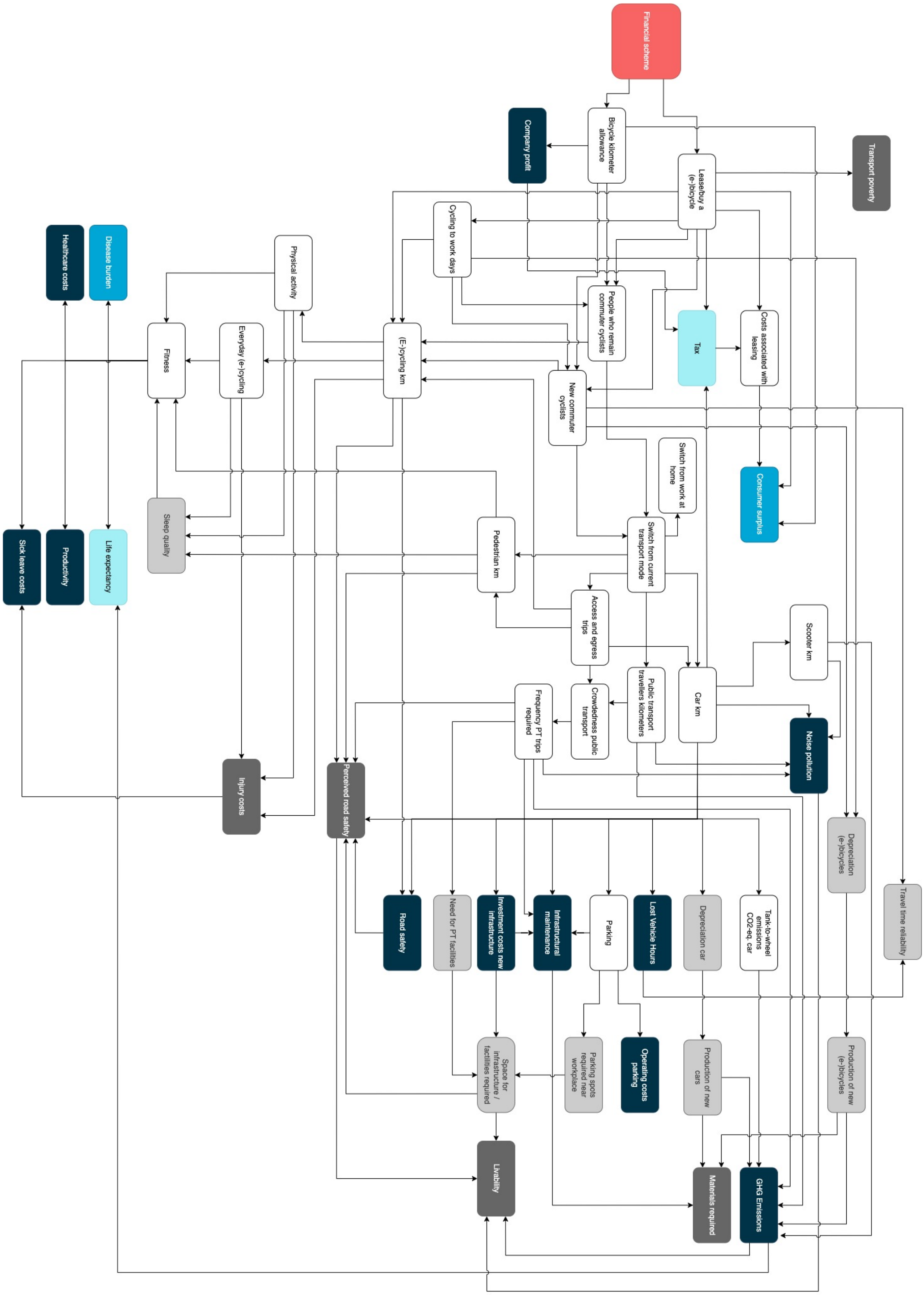

Figure 1: Conceptual model

A remarkable factor is the impact of emissions on the life expectancy of individuals who opt for cycling as their commuting mode instead of using a car. As these individuals transition from an enclosed vehicle to cycling in the open air, they encounter additional emissions, which marginally diminishes their life expectancy (de Hartog et al., 2010; Harms & Kansen, 2018; Rabl & de Nazelle, 2012). Conversely, the general public benefits from reduced emissions resulting from a decrease in car kilometres travelled. Additionally, the financial schemes show a notable influence in encouraging both new and existing cyclists to engage in cycling. Although this distinction may seem relatively insignificant, it is essential for assessing the implications for for example health outcomes. Specifically, individuals transitioning from an inactive lifestyle to a more active one can experience the full range of health benefits associated with cycling. Conversely, for those who are already highly active, the incremental health effects of further cycling engagement are relatively smaller (Decisio & Ministry of Infrastructure and Water Management, 2017).

For the purpose of effect determination, it is crucial to define the reference alternative (Beenker & Goedhart, 2018; Van Wee & Börjesson, 2015). In this analysis, the reference alternative is set as the 'do-nothing' or 'do-minimal' scenario (Annema et al., 2015). To ensure comparability across policy alternatives, the same reference alternative is adopted for all three schemes. Consequently, the "reference-alternative," should be set at 2020, since the introduction of the lease bike scheme and the abolition of the 'Fietsplan' were in 2020. Nonetheless, the year 2020 was profoundly shaped by the COVID-19 pandemic, leading to significant disruptions in commuting patterns. Hence, the reference alternative is set to 2022, as observations indicated that travel levels were recovering in 2021 and stabilising in 2022 (Ministry of Infrastructure and Watermanagment, 2023). This means that for example the annual commuter cycling distance was 4.1 billion kilometres in the reference alternative. More detail can be found in section 4.1.

When the reference alternative was established, the effects of the different financial schemes could be determined. The filtered conceptual model facilitated a systematic determination of which effects require quantification. First, the policy alternative-specific effects are determined, since these effects were not extensively studied, relying on insights obtained from grey literature and interviews was necessary (Appendix C). The data analysis from MuConsult (2019) provided valuable insights into the impact of increasing the kilometre allowance and adopting the 'Fietsplan' scheme on cycling kilometres. The effects of the lease bike scheme's were determined using a dataset derived from a survey conducted by lease-a-bike. Second, the general effects were quantified (subsection 5.1.4). These rely on available literature, given the significant body of research in this domain. The effects are categorised into seven distinct categories to maintain clarity in the explanation and facilitate separate discussions for each category, rather than repeatedly mentioning individual factors each time. The seven categories are as follows: Financial scheme-specific, healthcare, pollution, infrastructure & maintenance, travel time, tax, and road safety. All effects were converted to values that could be expressed in units such as €/km or €/h. This conversion process allowed for a standardised and comparable assessment of the effects across different financial schemes and factors. However, during the course of determining the effects, it emerged that certain factors introduced a level of uncertainty into the evaluation. To address this, a scenario analysis was undertaken. The initial step involved formulating scenarios for effects that were characterised by a range of values. These scenarios were anchored by a middle scenario, which functioned as the baseline for subsequent modifications. To better understand the variability within these ranges, both a lower and upper scenario were constructed. Next to that, the models sensitivity to certain factors was examined and lastly the models sensitivity to changes in the financial schemes was analysed.

In Figure 2 the results of the SCBA of the middle scenario are depicted. A few distinct trends become evident. Firstly, all three schemes demonstrate social viability, evident from their positive B/C ratios. A remarkable finding is related to the lease bike scheme, showing notable B/C ratio and NPV advantages. The kilometre allowance boasts a B/C ratio of 1.23 with an NPV of €42 million, while the lease bike has a B/C ratio of 2.56 with an NPV of €127 million, and the 'Fietsplan' has a B/C ratio of 1.31 with an NPV of €97 million. Remarkably, the lease bike scheme's effectiveness shines through, even with its annual scope limited to a mere 15,000 users, as opposed to the kilometre allowance's 1.5 million and the 'Fietsplan's' 176,320 users. This is mainly due to cost efficiency, with the Financial Scheme-specific

costs at €22 million, far lower than the that for the kilometre allowance €171 million and 'Fietsplan' €248 million. This arises as only 8.6% receive full lease cost reimbursement, 50.6% partial, and 40.8% lease without employer contribution (Appendix C). Employee costs are in their consumer surplus, while only employer contributions and missed tax are in costs. In contrast, the other schemes shift costs to business and government (Figure 5.7), erasing costs for self-funded lease bikes.
The high B/C and NPV of the lease bike scheme are also linked to substantial health benefits per user. E-bikes in the lease scheme average 11.4 km one-way, surpassing others at 6.85 km, and conventional bikes at 8.75 km vs. 4.2 km. This adds 30.7 million commuted km, 21 million as new cyclist km. Kilometre allowance adds 11.6 million km, 1.9 million as new cyclist km. The 'Fietsplan' adds 61.4 million km, 35.6 million as new cyclist km. However, per bike, lease scheme's figures are lower 15,000 vs. 176,320. Moreover, this extra cycling leads to enhanced health benefits, with many transitioning from non-active modes (de Haas & van den Berg, 2019).

Kilometer allowance 5 year	Net Present value (mil €)	
Financial Scheme	€	(9,228)
Benefit	€	161,703
Cost		(€ 170,931)
Health	€	60,277
Benefit	€	60,743
Cost		(€ 0,466)
Pollution	€	0,234
Benefit	€	0,234
Cost	€	-
Infrastructure & maintenance	€	0,114
Benefit	€	0,195
Cost		(€ 0,081)
Travel time	€	0,401
Benefit	€	0,401
Cost	€	-
Excise & Subsidies	€	(0,554)
Benefit	€	0,092
Cost		(€ 0,646)
Road safety	€	(9,076)
Benefit	€	0,530
Cost		(€ 9,607)
Total NPV	€	42,166
Benefit	€	223,898
Cost		(€ 181,732)
Benefit/Cost ratio		1,23

(a) Kilometre allowance

Lease bike 5 year	Net Present value (mil €)	
Financial Scheme	€	12,844
Benefit	€	34,734
Cost		(€ 21,889)
Health	€	152,575
Benefit	€	162,232
Cost		(€ 9,657)
Pollution	€	2,049
Benefit	€	2,049
Cost	€	-
Infrastructure & maintenance	€	0,566
Benefit	€	0,765
Cost		(€ 0,199)
Travel time	€	4,052
Benefit	€	4,052
Cost	€	-
Excise & Subsidies	€	(3,396)
Benefit	€	0,003
Cost		(€ 3,399)
Road safety	€	(41,274)
Benefit	€	5,232
Cost		(€ 46,506)
Total NPV	€	127,417
Benefit	€	209,067
Cost		(€ 81,650)
Benefit/Cost ratio		2,56

(b) lease bike

Fietsplan 5 year	Net Present value (mil €)	
Financial scheme	€	(124,215)
Benefit	€	124,215
Cost		(€ 248,430)
Health	€	251,300
Benefit	€	260,063
Cost	€	(8,763)
Pollution	€	3,398
Benefit	€	3,398
Cost	€	-
Infrastructure & maintenance	€	1,116
Benefit	€	1,655
Cost		(€ 0,539)
Travel time	€	6,797
Benefit	€	6,797
Cost		€ 0,000
Excise & Subsidies	€	(5,356)
Benefit	€	0,114
Cost	€	(5,470)
Road safety	€	(35,842)
Benefit	€	15,282
Cost		(€ 51,124)
Total NPV	€	97,198
Benefit	€	411,524
Cost	€	(314,326)
Benefit/Cost ratio		1,31

(c) Fietsplan

Figure 2: Results middle scenario

In addition to the middle scenario, several other scenario analyses were conducted (see section 5.3). These analyses highlighted that, even under a pessimistic setting where benefits were minimised and costs maximised, the financial schemes maintained positive NPV and B/C ratios. Notably, the model's outcomes were most sensitive to changes in the MET value for the E-bike, increased crash probability for the E-bike, and heightened productivity gains, subsection 5.4.3.

To conclude, the transition to the lease bike in comparison to the 'Fietsplan' emerges as a favourable transition based on the findings of this analysis. This implies that, based on this analysis, the national government should best concentrate on expanding the reach of the lease bike. Nevertheless, it is advisable that prior to immediate action, an additional experiment should be undertaken to assess the elasticity of the kilometre allowance associated to the travelled commuter cycling kilometres. This consideration stems from the fact that this particular measure holds a wide-reaching impact, as it reaches the majority of the working population. Furthermore, the consumer surplus of the lease bike is significantly lower than for the other two schemes, indicating that consumers experience less well-being under this scheme and may opt for a scheme where their consumer surplus is higher. Meaning that it may be difficult to increase the number of lease bikes significantly.

Several additional discussion points also warrant consideration. Initially, concerns emerged about using SCBA for this research due to complexities in quantifying effects monetarily, influenced by Van Wee and Börjesson (2015). Quantifying effects of specific cycling policies posed notable challenges due to cycling's prevalence in the Netherlands and the intricacies of studying the widespread effects. These challenges were indeed encountered during the study, leading to the utilisation of diverse data sources; interviews, lease-a-bike program survey data, and heterogeneous literature, including grey literature. While, this multifaceted approach aimed to establish a comprehensive analysis foundation, it's important to recognise the potential for numerical discrepancies that could stem from such an approach. To validate the coherence cross-referencing, expert contributions, and source alignment was applied.

Despite thorough data collection, some factors were excluded due to complexities in quantification or expressing monetarily. Injury costs were excluded due to limited impact assumptions from recreational-focused injury research. Livability, transport poverty, and perceived road safety were omitted due to commuter cycling research gaps. Exclusion of these factors is regrettable, yet the analysis presumably effectively represents policy effects comprehensively based on current understanding.

There are also several factors included in the analysis that raise points of discussion. Four of them have a significant impact and also carry uncertainty. The four pivotal factors warranting a discussion are the elasticity of the bicycle kilometre reimbursement in relation to the number of additional cycling kilometres, the distribution between new and existing cyclists for the kilometre allowance scheme, the extent of leisure cycling engagement for the 'Fietsplan', and the consumer surplus linked to the 'Fietsplan'. The first three all associated with travel behaviour factors. Meaning that these pivotal factors could have implications for all the priced factors.

One aspect that policymakers should consider when evaluating the results, is the distributional effects. Namely, the schemes lead to reduced tax incomes, impacting government budgets, potentially limiting resources for key social provisions. Additionally, alternative taxation sources may be needed for fiscal sustainability. However, increased cycling kilometres could potentially lower healthcare costs, infrastructure costs, etc., reducing budgetary pressures.

In conclusion, the SCBA methodology appears to retain its strength in delineating the socio-economic advantages and disadvantages linked to financial strategies that encourage commuter cycling. While certain elements have been excluded from the examination, a significant range of factors has been considered, resulting in a cohesive representation of the societal consequences of these fiscal interventions. This clearly emphasises the adaptability of the SCBA approach, highlighting its relevance not only within its traditional application to infrastructure projects but also to incentive-oriented endeavours.

Contents

1 Introduction

The Netherlands is widely known as a true cycling country. When comparing the Netherlands with the modal share of cycling in the other cycling countries in Europe, the Netherlands is firmly first, with a 27% share (Harms & Kansen, 2018). While the rest of the top 5, Denmark, Germany, Sweden, and Finland, respectively only have a share of 18%, 10%, 9%, and 9% (Buehler & Pucher, 2012). Cycling is known to have great benefits for society such as reduced CO2 emissions, decreased noise pollution, lower infrastructure costs, improved public health, reduced traffic congestion, equity benefits, and occasionally even being faster than other options, particularly in urban areas (Heinen et al., 2010; Nijland & Dijst, 2015; Noland & Kunreuther, 1995; Olde Kalter, 2007; Rabl & de Nazelle, 2012).

Increasing the modal share of cycling could have significant benefits. Definitely since the Netherlands is currently facing some challenges, including traffic congestion, overcrowded public transport, and obesity (ANWB, 2017; Ministry of Health Welfare and Sport, 2022; Rover, n.d.; RTL Nieuws, n.d.). During rush hour, the highways experience an average congestion of 350km, and in October 2022 alone, 2750 reports were filed regarding overcrowded trains. Additionally, around 50% of the Dutch population is overweight, with 19% suffering from obesity (Ministry of Health Welfare and Sport, 2022, 2023; Rijkswaterstaat traffic information, 2023; Rover, n.d.). To tackle these problems, the Dutch government has implemented various policies, including the 'Kies de Fiets' (Choose the Bicycle) initiative. 'Kies de Fiets' aims to encourage more people to use bicycles for commuting. It includes several approaches, such as financial schemes, improving bicycle infrastructure and facilities, and the promotion of cycling through campaigns (Ministry of Infrastructure and Water Management, 2023a).

Even though, these policies are in place the percentage that made use of the bicycle for commuting purposes was only 25% in 2019 (Centraal Bureau voor de Statistiek, 2021). There might be potential in increasing this share as for the distance up to 7.5 km only 30% of the individuals choose to cycle and for a distance between 7.5-15 km this share drops to 20% as of 2019 (Ministry of Infrastructure and Watermanagment, 2023). The Ministry of Infrastructure and Water Management (2023b) also found that 25% of the commuters by car are willing to choose for a different transport mode with the "appropriate arrangements". So, there is an opportunity for policymakers to adjust current policies to encourage more people to cycle to work. Therefore, it is interesting to research the social effect of the financial schemes that the national government employs. The three schemes that will be researched are the kilometre allowance, the lease bike and the 'Fietsplan' (Ministry of Infrastructure and Water Management, 2023a). The specification of these policies are addressed in section 4.1.

Assessing transport policies is often done using a Social Cost-Benefit Analysis (SCBA) (Annema et al., 2015; Hyard, 2012; Romijn & Renes, 2013). For most transport policies there is a clear framework for conducting a SCBA to evaluate the social costs and benefits. Unfortunately, for commuter cycling policies this is not as clear yet, especially for policies that promote cycling such as the financial schemes. This is described in the literature review in chapter 3. Although this framework is currently not yet established, employing the SCBA method remains advantageous. This approach enables the evaluation of a range of factors through their conversion into monetary equivalents. As a result, the capacity to comprehensively contrast the divergent effects of policy alternatives is enhanced. This, in turn, facilitates the ability to make informed decisions.

This research has a clear academic relevance, as it is found that there have not been any SCBAs conducted on policies regarding commuting-related fringe benefits for cycling. Most SCBAs for cycling policies are for infrastructure improvements, such as new roads or bridges (Decisio & Transaction Management Centre, 2012; Foltnova & Kohlova, 2002; Macmillan et al., 2014). A challenge of conducting a SCBA for cycling policies is that its difficult to establish a clear reference case, which is crucial to assess the impact of the specific policy (Beenker & Goedhart, 2018; Van Wee & Börjesson, 2015). Without a clear reference case, the true effects of the policy are hard to distinguish from other factors that influence the outcome, leading to confusion and inaccurate conclusions. Therefore, this study will create a conceptual model of the factors which are of influence on cycling policies regarding commuting, enhancing the SCBA technique for cycling policies by creating a well-rounded and extensive assessment of the costs and benefits associated with cycling policies regarding commuting. After this, a translation will be made to a computational model, to analyse the effect of different cycling policies on the social benefits and costs. It will be an instrument which can be used for further studies when new data is available.

All in all, the scope of this research will focus on assessing the policies regarding financial schemes for commuter cycling in the Netherlands. Combining the knowledge gap and scope, the following research question can be formulated:

"What are the social costs and benefits associated with financial schemes promoting bicycle commuting in the Netherlands?"

Since there is a gap in current literature on this matter, the initial stage involves establishing the significant effects and their respective impacts. Hence, a conceptual model will be developed to facilitate comprehension of the linkages between diverse variables and pinpoint the necessary elements for converting the conceptual model into a SCBA. Therefore, the following sub-questions can be established:

1. What factors should be considered when evaluating the social costs and benefits of financial schemes related to commuter cycling?
2. What are the effect of the financial schemes on travel behaviour and the priced factors?

When these questions are answered, it will be possible to construct a computational model. The well supported factors and their known effects will be incorporated as the base model. After this, the other more uncertain factors can be included, these effects need to be established with expert interviews. It will be interesting to see what their impact is on the benefit-cost ratio (B/C-ratio) and how sensitive the model is to these uncertain effects. This will help to indicate which uncertain factors have a significant effect on the model and thus need further research to make the SCBA more robust. Therefore, the additional sub-questions need to be answered:

3. What are the social costs and benefits of the identified factors?
4. What areas of research should be prioritised to address the identified gaps and improve the overall robustness of the model?

After answering these questions, the deliverable will be a computational model that allows for adjusting the uncertain but significant factors. Nevertheless, it already gives a preliminary estimation of the social costs and benefits of commuter cycling policies regarding financial schemes. This model can be further refined through gradual adjustments based on additional research, ultimately resulting in a robust model capable of evaluating various policy options for financial schemes related to bicycle commuting.
The aim of this research rests on three primary pillars. Firstly, to establish a consensus on the relevant factors that require consideration. Secondly, to determine the effects and interrelations between these factors. Thirdly, to develop a computational model that can serve as a basis for evaluating financial schemes related to policies promoting commuter cycling.
The methodology used in this research will be explained in detail in chapter 2. Subsequently, the structure outlined by Romijn and Renes (2013) will be followed to ensure the accurate execution of

the SCBA. Consequently, the initial step involves a problem analysis, achieved by analysing relevant literature in chapter 3 to identify any gaps and establish academic significance. Following this, the base alternative and policy alternatives will be defined in chapter 4. Moreover, this chapter will address the determination of effects, resulting in a conceptualisation of the alternatives and their respective effects. This model facilitates the determination of both direct and indirect effects, thereby clarifying the crucial effects to be incorporated into the SCBA while distinguishing those that are merely ancillary. Now the chapter about the conceptual model is finalised and in chapter 5, the initial step involves determining the benefits and costs, a task undertaken solely for the essential effects, given their significant influence on the social costs and benefits, and due to constraints on researching all costs and benefits associated with less consequential effects. Finally, this chapter also incorporates an examination of the model's sensitivity. To conclude, recommendations for further research will be discussed and the findings will be synthesised and discussed in section 6.2.

2 Methodology

This chapter explains the research methodology used to answer the main research question, mentioned in the introduction and shown at the top of Table 2.1. In Table 2.1 the different sub-questions are listed with their corresponding research method. Both quantitative and qualitative analyses are studied. Data from relevant studies, reports, surveys, and interviews are synthesised to assess the social costs and benefits of financial regulations for commuting by bicycle.

When these questions are answered, it will be possible to construct a computational model. The well supported factors and their known effects will be incorporated as the base model. After this, the other more uncertain factors can be included, these effects need to be established with expert interviews. It will be interesting to see what their impact is on the benefit-cost ratio (B/C-ratio) and how sensitive the model is to these uncertain effects. This will help to indicate which uncertain factors have a significant effect on the model and thus need further research to make the SCBA more robust. Therefore, the additional sub-questions need to be answered:

Table 2.1: Methodology

"What are the social costs and benefits associated with financial schemes promoting bicycle commuting in the Netherlands?"	
Sub-question	**Methodology**
1. What factors should be considered when evaluating the social costs and benefits of financial schemes related to commuter cycling?	Literature research & Brainstorm & Expert interview
2. What are the effect of the financial schemes on travel behaviour and the priced factors?	Literature research & Expert interview
3. What are the social costs and benefits of the identified factors?	Social Cost-Benefit Analysis
4. What areas of research should be prioritised to address the identified gaps and improve the overall robustness of the model?	Scenario analysis & Sensitivity analysis

Since the report will perform a Social Cost-Benefit analysis for determining the costs and benefits associated with financial schemes promoting bicycle commuting in the Netherlands, the general guidelines from Romijn and Renes (2013) will be followed. The steps in the guideline are as follows:

1. Problem analysis (Chapter 3)
2. Establish the base alternative (Chapter 4)
3. Define policy alternative (Chapter 4)
4. Determine effects
    a) Determine pertinent effects (Chapter 4)
    b) Quantify & monetise effects (Chapter 5)

5. Determine benefits and costs (Chapter 5)
6. Analyse variants and risks (Chapter 5)
7. Presentation of results (Chapter 5)

2.1. Sub-question 1 and Sub-question 2

”What factors should be considered when evaluating the social costs and benefits of financial schemes related to commuter cycling?”
”What are the effect of the financial schemes on travel behaviour and the priced factors?”

Answering sub-question 1 involves employing an iterative process that combines (grey) literature research, structured brainstorming, and interviews. This combination of methods is chosen to comprehensively capture the relevant factors relevant to the assessment of financial schemes. The initial step involves conducting literature research to gain insights from existing works and identify factors already considered in the current body of literature. The methodology for this literature review is described in subsection 2.1.1. Following the literature review, the structured brainstorming phase starts. Drawing upon existing knowledge, this stage generates additional ideas concerning relevant factors. The process is detailed in subsection 2.1.2. These identified factors are cross-referenced with the existing literature to ascertain their influence on the research question. Additionally, expert interviews are conducted to validate these brainstormed factors and potentially generate new factors. The structure and execution of expert interviews are outlined in subsection 2.1.3. The coding technique, explained in subsection 2.1.4, is then applied to structure the outcomes of the literature review, brainstorming, and expert interviews. This culminates in a conceptual model featuring the factors identified during the iterative process.

The findings from sub question one will be expanded with literature search and interviews to answer sub question two. The effects are thorough examined to validate the identified effects. Therefore, effects will be checked with multiple sources to see if the effects match in both researches. Some effects aren’t checked as they are public databases, such as ”CBS statline” and ”volkgsgezondheid en zorg”. When some effects are unsure or cannot be found, expert interviews will be conducted. The experts will help to determine how some effects can be measured or how potential ranges can be determined. The result of answering this sub-question will be that the effects of the financial schemes on travel behaviour and the priced factors are known.

2.1.1. Literature review

The literature review uses the conceptual framework depicted below for finding relevant literature, Table 2.2. First, only scientific literature was considered, using the search engine Scopus. Looking at articles which were published in renowned journals and were cited often. However, due to the little amount of scientific literature, also grey literature was touched upon using the search engine Google. Furthermore, generalisation effects are hardly discussed in current literature, therefore the concept group is limited to mode choice. The literature which is reviewed is described in chapter 3, Table 3.1.

Table 2.2: Conceptual framework

Concept groups	Mode choice; Cost-benefit analysis; Fringe Benefits	
Key words	Mode choice	Commuting; Effects; Cycle; Bicycle; Active mode; Active transport
	Cost-benefit analysis	Commuting; Cycle; Bicycle; Active mode; Active transport; Costs; Benefits; social
	Fringe benefits	Fringe; Travel; Transport; Allowance; Effects; Financial
Truncation	Commut* AND ((Bicycl* OR Cycl* OR (Active AND mode)) AND (Cost* OR Benefit* OR Effect*) AND (social OR Social)) OR ((Allowanc* OR Compensat*) AND (Transport* OR Travel)) OR (Fringe AND Benefit*)	

There will be worked upon the literature review in chapter 3, this creates the basis of the conceptual model. Subsequently, the found factors during the literature research and structured brainstorm are incorporated in this preliminary conceptual model. In order to incorporate the data it will be coded, explained in subsection 2.1.4, to structure the data and find cohesion between the factors.

2.1.2. Structured brainstorm

Brainstorming is a technique employed to generate relevant factors (Wilson, 2013). The process typically involves posing a clear question, in this case the first sub question. This is followed by a divergent ideation phase, during which as many factors are thought of. This structured brainstorming took place alone using post-it notes to store all the ideas. When no more ideas where thought of, the 5x why method was employed. Meaning that for every formulated idea, the question was asked why does this occur? Resulting in additional relevant factors. Furthermore, brainstorming will take place during informal conversations, with peers and during the interviews. When no more factors come to mind, these factors must be checked with current literature if they are really relevant for this research. When this is verified the factors are categorised using the coding method, subsection 2.1.4.

2.1.3. Interviews

Interview approach

The interviews will follow a semi-structured approach. This is a type of interview where predetermined questions are combined with questions that emerge during the interview. It is chosen to follow this approach, as this still ensures high validity, while it allows for additional questioning during the interview when this is required (George, 2022) This is important as certain effects must be validated and ranges need to be determined during the interview, but the interviewee is also an expert on this topic so there must be room for in-depth questions. Brief summaries can be found in Appendix C.

Interviewee selection

In order to select relevant interviewees it has to be clear which effects cannot be established from current literature. After obtaining this clarity, the stakeholder landscape is researched through desk research to identify individuals or groups with expertise on the subject matter. A stakeholder is described as a person or organisation who is impacted by or has an interest in the product or project (Hirshorn, 2020). The final list with interviewees is depicted in Appendix C.

2.1.4. Coding

The results of the literature research, the structured brainstorm and the interviews will be organised using the coding technique. It is chosen to use coding as it's a structured way of storing data. Furthermore, it helps defining the interrelations between the factors and to discover categories in the data. At the end of the coding process, the interrelation and the categories and sub-categories can be distinguished. In analysing the data, three different stages of coding can be distinguished, open coding, axial coding and selective coding. The different phases are explained below and are depicted in Figure 2.1.

Open coding

This first stage of coding, compares the found factors looking for similarities, differences and emerging patterns. The data is fractured as much as possible to find the relevant factors (Charmaz, 2014).

Axial coding

The next stage of coding, axial coding, builds upon the previously discussed open coding. While in the open coding stage the focus is breaking down the data into relevant factors, the goal of this stage is to convert this into overarching groups. In order to reveal the sub-categories (Melcer & Cuerdo, 2020). These sub-categories are labelled with codes, which in essence involves assigning descriptive labels to segments of data (Charmaz, 2014).

Selective coding

The final stage in the coding process is selective coding, here the cohesion between factors and sub-categories will be established (Chun Tie et al., 2019). Resulting in overarching categories, which helps in obtaining a coherent view of the aspects being addressed and identifying any potentially overlooked elements.

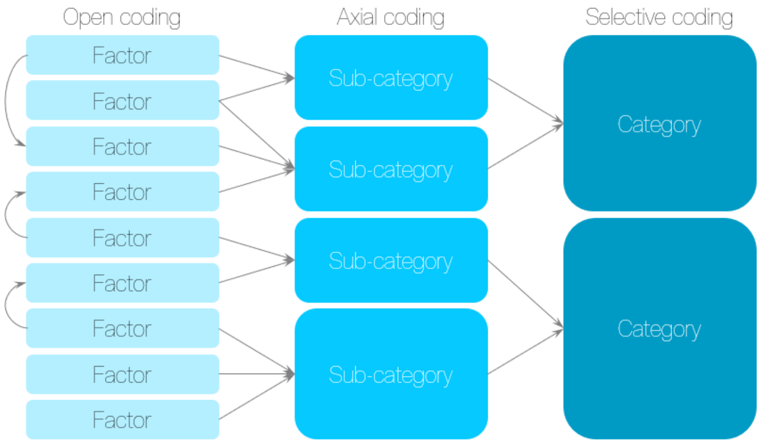

Figure 2.1: Coding

2.2. Sub-question 3

"What are the social costs and benefits of the identified factors?"

To address this question, multiple models can be employed to construct a computational framework to determine the social costs and benefits. Among the most prevalent are the Social-Cost Benefit Analysis (SCBA) and the Multi Criteria Decision Making (MCDM) methods. The selection has been made to adopt the SCBA approach due to its frequent utilisation in appraising transport and infrastructure projects (Hyard, 2012). This method effectively monetises all effects, facilitating a comprehensive comparison of different policy alternatives by expressing them in a common value. The outcome of the SCBA is manifested through the net present value (NPV), a measure depicting the disparity between present values of cash inflows and outflows over a specified time frame. It proves useful in evaluating the social and economical profitability of policy alternatives. However, it's noteworthy that the SCBA also harbours certain disadvantages, such as the requirement for all factors to be monetised, thereby excluding non-magnetisable aspects.

On the other hand, MCDM is another widely recognised appraisal method used to evaluate the potential performance of diverse alternatives across multiple criteria (Macharis & Bernardini, 2015; Romijn & Renes, 2013). One pivotal advantage of this approach lies in its capacity to accommodate both quantitative and qualitative criteria, allowing for the inclusion of factors that defy monetisation, which SCBA fails to consider. Furthermore, MCDM can incorporate varied expert opinions. Nonetheless, it grapples with the challenge of subjectivity due to its reliance on the viewpoints of diverse stakeholders (Barfod & Salling, 2015; Beria et al., 2012; Macharis & Bernardini, 2015). Additionally, MCDM is susceptible to double-counting certain effects (Rouwendal & Rietveld, 2000), and it's ill-suited for efficiency measurements like evaluating the specific costs or benefits derived from interventions (Beria et al., 2012), thus factoring into the decision to not opt for the MCDM method.

With the selection of the SCBA method now established, the construction of the computational model can proceed. This process involves dividing it into distinct segments, each corresponding to the categories derived from the coding process outlined in subsection 2.1.4. The first tab will give an overview of the total social costs and benefits of the financial schemes for commuter cycling. Next to that, it will show how this total cost is built up, by using the categories found during the selective coding process. After this, the following tabs will be go into more depth of these categories, showing the costs and benefits of the sub-categories found during the axial coding. In these tabs the factors found from the open coding can be found, they built up the social costs and benefits of the sub-categories. Which subsequently lead to the social costs and benefits of the overarching categories.

2.3. Sub-question 4

”What areas of research should be prioritised to address the identified gaps and improve the overall robustness of the model used to determine the social costs and benefits of financial schemes for bicycle commuting?”

It is essential to critically assess the model and identify its uncertainties. This approach can contribute to advancing the scientific understanding. Furthermore, as this method is being applied for the first time to evaluate policy alternatives related to financial schemes for commuting, it is important to recognise that potential limitations and challenges may exist.

To identify factors warranting further investigation, a scenario analysis will be executed. This analysis will focus on the effects that are uncertain or are presented within a range. The effects exerting the most significant influence on the benefit-cost ratio will be prioritised for further research, given that their impact yields the most substantial changes. Additionally, as the exploration progresses within sub-questions 2 and 3, certain factors may emerge that are challenging to quantify or monetise.These effects will be debated with experts on how important they consider these factors to be. Combining these two methods will result in an extensive overview of the factors which require further research.

3

Literature Review

As described in chapter 2, a Social Cost Benefit Anlaysis (SCBA) will be conducted to determine the the social costs and benefits associated with financial schemes promoting bicycle commuting in the Netherlands. In the guidelines for performing a SCBA the first step is performing a problem analysis. In this chapter the problem is analysed by researching current literature on fringe benefits which encourage bicycle commuting and establishing the knowledge gap and the academic relevance. For the scope of this literature review, articles about mode choice, cost-benefit analyses and fringe benefits are considered. All the researched literature is presented below.

Table 3.1: Researched literature

Author(s)	Year	Title	Journal	Key words	Methodology
		Literature about cycling related Cost-Benefit analyses			
Rabl, A. & Nazelle, A. de	2012	Benefits of shift from car to active transport	Transport Policy	Bicycling; Walking; Life expectancy; Mortality; Air pollution; Accidents	Cost Benefit Analysis
Macmillan, A., Connor, J., Witten, K., Kearns, R., Rees, D., Woodward, A.	2014	The social Costs and Benefits of Commuter Bicycling: Simulating the Effects of Specific Policies Using System Dynamics Modeling	Environmental Health Perspective	Bicycling; Cost-Benefit Analysis; Humans; Models, Theoretical; New Zealand; Transportation	social Cost-Benefit Analysis; Participatory System Dynamics Modeling; Interviews
Wee, B. van & Börjesson, M.	2015	How to make CBA more suitable for evaluating cycling policies	Transport Policy	Cycling; Cost–benefit analysis; Safety; Health; Accessibility	Desk research
Sieg., G.	2014	Costs and Benefits of a bicycle helmet law for Germany	n.a.	n.a.	Cost-Benefit Analysis

Table 3.1: Researched literature

Author(s)	Year	Title	Journal	Key words	Methodology
Foltynova, H. B., Kohlova, M.	2002	Cost-Benefit Analysis of Cycling Infrastructure: A Case Study of Pilsen	n.a.	n.a.	Social Cost Benefit Analysis
Decisio	2012	Social costs and benefits of investments in cycling	n.a.	n.a.	Social Cost Benefit Analysis
Beenker, J. & Goedhart, W.	2018	MKBA Fietsimpuls - De maatschap-pelijkebaten van 6 jaar fietsstimulering in Zuid-Limburg	n.a.	n.a.	Ex-post Social Cost Benefit Analysis
		Literature about peoples' mode choice			
Gatersleben, B. & Appleton, K.M.	2007	Contemplating cycling to work: Attitudes and perceptions in different stages of change	Transportation Research Part A	Cycling; Contemplation; Stages of change; Attitudes; Perceptions	Transtheoretical model of behaviour change; Stated choice survey; Living experiment; Interview
Parkin, J., Warman, M., Page, M.	2008	Estimation of the determinants of bicycle mode share for the journey to work using census data	Transportation	Bicycle; Journey to work; Logistic regression model; Census; Travel demand modelling	Aggregate data; Logistic regression model
Heinen, E., Wee, B. van, Maat, K.	2009	Commuting by Bicycle: An Overview of the Literature	Transport Reviews	n.a.	Review
Nielsen, T.A.S., Olafsson, AS., Carstensen, T.A., Skov-Petersen, H.	2013	Environmental correlates of cycling: Evaluating urban form and location effects based on Danish micro-data	Transportation Research Part D	Bikeability; Walkability; Active travel; Cycling policy; Urban / neighbourhood design	Statistical probit model
Fyhri, A. & Fearnley, N.	2015	Effects of e-bikes on bicycle use and mode share	Transportation Research Part D	Experiment; Bicycling; Public health; Gender	Living experiment; Surve

Table 3.1: Researched literature

Author(s)	Year	Title	Journal	Key words	Methodology
Oakil, A., Ettema, D., Arentze, T., Timmermans, H.	2016	Bicycle commuting in the Netherlands: An analysis of modal shift and its dependence on life cycle and mobility events	International Journal of Sustainable Transportation	Bicycle commuting; Life cycle events; Mobility events; Sustainable transport	Multivariate model; Binary logit model; Mixed binary logit model; Discrete choice model
Ton, D., Duives, D.C., Cats, O., Hoogendoor-Lanser, S., Hoogendoorn, S.P.	2019	Cycling or walking? Determinants of mode choice in the Netherlands	Transportation Research Part A	Active mode mobility Mode choice; Walking; Cycling; Mixed multinomial logit; Built environment	Discrete mode choice model; Mixed multinominal logit
Grudgings, N., Hughes, S., Hagen-Zanker, A.	2021	The comparison and interaction of age and gender effects on cycling mode-share: An analysis of commuting in England and Wales	Journal of Transport & Health	Cycling; Age; Gender	Generalised linear model; Logit models
Nijland, L. & Dijst, M.	2015	Commuting-related fringe benefits in the Netherlands: Interrelationships and company, employee and location characteristics	Transportation Research Part A: Policy and Practice	Fringe benefits; Mobility management; Telework; Flextime; Company car; Transport allowance	Literature review; Multinomial logistic regression
Heinen, E., Maat, K., Wee, B. van	2013	The effect of work-related facts on the bicycle commute mode choice in the Netherlands.	Transportation	Bicycle; Commuting; Work culture; Mode choice	
MuConsult	2019	Financiële prikkels om fietsen naar het werk te stimuleren – Een studie naar de effecten	n.a.	n.a.	Survey; Regression model

Table 3.1: Researched literature

Author(s)	Year	Title	Journal	Key words	Methodology
Winter, M., Buehler, R., Götschi, T.	2017	Policies to Promote Active Travel: Evidence from Reviews of the Literature	Current Environmental Health Reports volume	Active travel; Policy; Bicycle; Walking; Bicycling	Review
Muñoz, B., Monzon, A., Daziano, R.A.	2016	The Increasing Role of Latent Variables in Modelling Bicycle Mode Choice	Transport Reviews	Literature review; Bicycle; Mode choice model; Latent variable; Attitudinal and perceptual indicators	Review
Handy, S., Wee, B. van, Kroesen, M.	2014	Promoting Cycling for Transport: Research Needs and Challenges	Transportation Reviews	n.a.	Review

3.1. Analysis

To obtain a comprehensive understanding of the scientific landscape, two distinct areas of research will be examined. Firstly, the existing literature on (Social) Cost-Benefit Analyses ((S)CBA) in the field of cycling policies will be reviewed. This will involve identifying the types of analyses that have been conducted, the common factors that are included, and areas that require further research.

Secondly, a more general review will be conducted on other factors that may influence people's commuting-related mode choice. This will include examining whether the effects of commuter fringe benefits have already been researched, the potential impact of current cycling policies on commuting behaviour, and the determinants that influence people's commuting-related mode choice. The aim is to gain a better understanding of the various factors that may have an effect and identify which ones could be included in a (S)CBA. By exploring these two areas, a more comprehensive understanding of the scientific landscape can be achieved.

Cost-Benefit analysis

There is a limited amount of scientific literature on conducting social cost-benefit analyses for bicycle policies. But when enhancing this with the grey literature there is a substantial amount of information on bicycle cost-benefit analyses conducted (Beenker & Goedhart, 2018; Decisio & Transaction Management Centre, 2012; Foltnova & Kohlova, 2002; Macmillan et al., 2014; Rabl & de Nazelle, 2012; Sieg, 2014). Beenker and Goedhart (2018) were the first to perform an ex-post SCBA on a policy measure related to cycling in the Netherlands. This research was particularly valuable because it clearly showed the effects of both the reference case and the policy measure. Which in most cases is challenging to quantify, making it to be difficult to evaluate cycling policies (Van Wee & Börjesson, 2015).

Macmillan et al. (2014) look into the social costs and benefits of bicycle commuting policies in New Zealand. This is an ex-ante research, so the effects of policies are not yet known. To estimate the effect, they use a participatory system dynamics modelling approach, to simulate the future effects of the policies. The output is subsequent used as input for the CBA, to determine which kind of policies would have the most positive benefit-cost ratio (B/C-ratio). Sieg (2014) also uses a CBA for ex-ante research into the costs and benefits of a bicycle helmet law for Germany, but uses a different approach. He makes use of the result of a survey already conducted by other researchers in Australia. Other effects are also retrieved from current literature, only the “Health economic assessment tool for cycling and walking” (HEAT) is used, to evaluate the impact of cycling and walking on health. Rabl and de Nazelle (2012) uses data from different sources, such as ExternE and the World Health Organisation, to calculate the different effects. This article also includes the reduced health impacts for the people who switch from car to bike as they are now exposed to air pollution.

Foltnova and Kohlova (2002) mentions the change in insecurity, thus the change in the perception of safety of the bicyclist. Nonetheless, they don’t include it in their CBA as it is to hard to quantify this effect. This is also mentioned by Elvik (2000), that this is a factor which could be included in an ideal CBA, where all effects can be quantified and monetised.

The table presented below, Table 3.2, provides a summary of the literature related to Social Cost-Benefit Analyses for cycling policies. The Author(s) field indicates the researchers who have explored the subject, while the date signifies the time of the study. The location is described to see where the research is carried out as the scope of this research is the Netherlands, thus studies conducted in the Netherlands or in countries with similar bicycle usage are preferred. However, it should be noted that there is limited literature available on this topic, so research from different countries is also considered. The research goals are specified to assess their alignment with the selected keywords. Subsequently, the included effects are listed, as they serve as the foundation for establishing the conceptual model. Finally, the limitations are mentioned, as they can contribute to the structured brainstorming process aimed at identifying additional effects.

Table 3.2: Literature on (Social) Cost-Benefit Analysis

Author(s)	**Year**	**Location**	**Goal**	**Included effects**	**Limitations**
Beenker, J. & Goedhart, W.	2018	The Netherlands	Analysing the impact of six years of stimulating cycling in South-Limburg	Investment costs; Lost vehicle hours; Healthcare costs and sick leave costs; Life expectancy; Fitness; Road safety; External effect	The valuation figures are based on the health effects of cycling, which didn’t take the e-bike into consideration.
Foltynova, H.B. & Kohlova, M.	2002	Pilsen -Czech Republic	Analysing the impacts of improved cycling infrastructure on demand for this means of transport.	Health costs; Accident costs; Environmental costs; Benefits from reduced insecurity; Changed travel times	The results are very sensitive to a range of factors, so the model is not very robust.
Sieg., G.	2014	Germany	Analysing the costs and benefits of a bicycle helmet law for Germany	Health effects; Purchase costs; Decrease of comfort/style; Environmental effects; Gained protection and exposure to risk	Helmets can cause cyclists to cycle faster, increasing the risks; Cyclist heterogeneity is excluded; Fewer cyclists can decrease awareness, leading to decreased the safety.

Table 3.2: Literature on (Social) Cost-Benefit Analysis

Author(s)	Year	Location	Goal	Included effects	Limitations
Macmillan, A., Connor, J., Witten, K., Kearns, R., Rees, D., Woodward, A.	2014	New-Zealand	Analysing the social costs and benefits of specific policies for commuter bicycling	Injury; Physical activity; Fuel costs; Air pollution; Carbon emissions	Further research needed on benefits and costs that have not been counted to date. Such as improvements in water quality, workplace productivity, reduced morbidity, financial savings from reduced demand for new roads and urban car parks, bicycling injuries other than those resulting from a collision with a motor vehicle.
Decisio & Transaction Management Centre	2012	Alkmaar -the Netherlands	Determine the social costs and benefits of the cycling kilometre	Traffic safety; Noise; Emissions of harmful substances; Subsidies and excise taxes; Life expectancy; Labour productivity; Network effects	Reduced delays can be the most significant factor, but this is dependent on traffic volume on the specific route. Switching from bus to bicycle saves subsidies, it's debatable if the subsidy can indeed be saved. This will only occur when it concerns larger volumes, then public transport can be adjusted.
Decisio & Transaction Management Centre	2012	Utrecht -the Netherlands	Determine the social costs and benefits of a bicycle route which crosses a waterway/ railway/ highway	Traffic safety; Noise; Emissions of harmful substances; Public transport subsidies; Excise taxes on car traffic; Years of life; Labour productivity; Bicycle travel costs ;Permanently reduced travel time for car traffic; Reduced travel time for bicycle traffic; School benefits; Management, maintenance, and operational costs; Investment costs	Gaining a better understanding of the travel time elasticity and the resulting modal shift is crucial, to determine the travel time gain for the other car traffic and for the reduction of subsidies when people switch from bus to bicycle.

Table 3.2: Literature on (Social) Cost-Benefit Analysis

Author(s)	Year	Location	Goal	Included effects	Limitations
Decisio & Transaction Management Centre	2012	Utrecht -the Netherlands	Determine the social costs and benefits of paid versus unpaid bicycle parking facilities at railway stations	Traffic safety; Noise; Emissions of harmful substances; Urban public transport subsidies; Train public transport subsidies; Excise taxes on car traffic; Years of life; Labor productivity; Permanent reduction in travel time for car traffic; Valuation of disappearing bicycle traffic; Management, maintenance, and operational costs; Investment costs	It is uncertain how paid bicycle parking affects travel behavior, will they stop travelling, drive to their destination, take the bus to the station, or start walking? Furthermore, how many travellers will switch?
Rabl, A. & Nazelle, A. de	2012	Paris, Belgium & Amsterdam -the Netherlands	Analysing the cost and benefits of a switch from car to active transport	Benefits of physical activity; Car emissions; Health impacts of air pollution; Public benefit from reduced pollution; Effect of exposure change from car to bicycle and from car to walking; Non-fatal Accidents; Fatal accident	Population exposure is based on old data (2000); Only considered mortality, morbidity is not included; Only car emissions included, congestion & noise excluded

Determinants and their effects related to bicycle commuting incentive policies

In their study, MuConsult (2019) investigated the impact of four distinct commuting policies. These policies included providing everyone with a cycling allowance of 19 cents/km, implementing a maximum reduction of car parking (only applicable if the current mode of transportation is a car), ensuring that everyone has access to a public transport stop within 400 meters of their origin and destination, and increasing the cycling allowance by 10%. Nijland and Dijst (2015) and MuConsult (2019) both found that a combination of commuting-related fringe benefits could significantly increase the benefits.

Next to literature on specific commuting-related policies, there is a lot of studies on determinants which could effect someones mode choice. Individual characteristics, such as the socio-demographics are researched sufficiently (Fyhri & Fearnley, 2015; Gatersleben & Appleton, 2007; Grudgings et al., 2021; Heinen et al., 2010; Nielsen et al., 2013; Oakil et al., 2016; Ton et al., 2019). There are some remarkable outcomes, men tend to cycle more often than women in countries with a low cycling penetration rate (Fyhri & Fearnley, 2015; Gatersleben & Appleton, 2007; Grudgings et al., 2021; Oakil et al., 2016). However, in countries with a higher penetration rate such as the Netherlands and Denmark women tend to cycle more often than men (Heinen et al., 2010; Nielsen et al., 2013). Mixed results were found regarding age and education. Household characteristics are known to influence active mode choice, however income is a debatable determinant, there are mixed results regarding the directionality of income. For season and weather determinants, mostly rain and temperature have been studied. However regarding rain, mixed results have been found, but most studies find rain to have a negative effect on cycling (Ton et al., 2019). Work condition also play an important role, facilities related to the car negatively relate to the choice for cycling. Heinen et al. (2010) found that facilities beneficial for cyclists have a positive impact with cycling. Providing incentives or reimbursement for both the bicycle and public transport have a positive association with cycling (Handy et al., 2014; Muñoz et al., 2016; Winters et al., 2017). Geographical conditions lastly, also play a role, Nielsen et al. (2013) for example found that, flat terrain, short-distance to retail concentrations, as well population density and network connectivity within a 1.5 km 'personal' neighbourhood, all contribute to an increased likelihood of cycling. Favourable conditions for walking and public transport decrease the probability of cycling: A train station within 1000m and the number of daily bus and train departures within 500m of the home, retail jobs per resident within 500m walking range.

In addition, several other factors have been found to influence mode choice. According to Oakil et al. (2016), some factors are not static, but some are dynamic, meaning that mode choice can change over the course of one's life. Gatersleben and Appleton (2007) also believes mode choice can change based on the transtheoretical model of behavior change. This model looks at different stages of change, which includes pre-contemplation, contemplation, prepared for action, action, and maintenance. They suggest that different methods are needed to persuade individuals to move to a different stage of change. For example, increasing general awareness can bring individuals in the pre-contemplation stage closer to the action stage. Individuals who are contemplating cycling or are prepared for action should be motivated and encouraged to develop a plan for action. The e-bikes have also been found to have an impact on bicycle use (Fyhri & Fearnley, 2015). A living experiment with two groups was conducted, one who were given an e-bike and a control group. It was found that e-bikes increased the cycling trips per day from 0.9 to 1.4 per day, distance from 4.8km to 10.3 km and as a share of all transport from 28% to 48% and for the control group there was no significant change. The effect of the e-bike increased with time and was greater for women than for men.

3.2. Conclusion

It is found that there is not a lot of literature on the cost-benefit analyses of cycling policies. Most CBAs which are cycling related, look at infrastructural changes and look at the travel time savings, which is more similar to conventional transport CBAs (Decisio & Transaction Management Centre, 2012; Foltnova & Kohlova, 2002; Macmillan et al., 2014). There are however some that try to capture more behavioural aspects (Beenker & Goedhart, 2018; Rabl & de Nazelle, 2012; Sieg, 2014). These effects are however more difficult to capture. One of the problems is that it is difficult to establish a clear reference case and this is crucial to assess the impact of the specific policy (Beenker & Goedhart, 2018; Van Wee & Börjesson, 2015). Without a clear reference case, it can be difficult to distinguish the true effects of the policy from other factors that may be influencing the outcome, leading to confusion and inaccurate conclusions.

Next to that, there is no clear framework with the factors which must be included in a CBA regarding cycling policies. There is some overlap between the current CBA's. All take factors into account such as health and emissions. However, some also look at different aspects of health and emissions and some include additional factors such as, labour productivity, network effects, effects of exposure change from car to bicycle (Decisio & Transaction Management Centre, 2012; Rabl & de Nazelle, 2012). Some factors are spoken about but not yet taken into account, such as the change in the perception of safety of the bicyclist, the influence of commuting-related fringe benefits or the effect of e-bikes on cycling distance and health (Elvik, 2000; Foltnova & Kohlova, 2002; Fyhri & Fearnley, 2015; MuConsult, 2019).

The known CBAs also have different ways of estimating the effect on these factors. All use current literature for data points. But for some use extended modelling methods to gain extra information on effects that are not yet known. Beenker and Goedhart (2018) get additional information by a living experiment, which shows the revealed preference. Foltnova and Kohlova (2002) and Sieg (2014) use the stated preference to determine specific input data. Furthermore, modelling tools such as CUBE (a transport modelling tool), HEAT (a health economic assessment tool) and Vensim (a system dynamic modelling tool) (Foltnova & Kohlova, 2002; Macmillan et al., 2014; Sieg, 2014).

3.3. Discussion

Several studies, including Macmillan et al. (2014), Rabl and de Nazelle (2012), and Van Wee and Börjesson (2015), have highlighted the potential benefits of conducting further research using SCBA to evaluate cycling policies. Despite the relevance of commuting-related fringe benefits, they have not yet been addressed in SCBA studies. This is a significant research gap, given that traffic congestion, overcrowded public transport, and obesity are major challenges in the Netherlands. Effective policies aimed at encouraging more people to cycle to work could potentially have a significant impact on addressing these issues.

To conclude, the problems found in current literature is that there are no models to evaluate the social costs and benefits of financial schemes which promote bicycle commuting. In order to construct such a model this thesis will create consensus on the pertinent factors that must be considered when constructing such a SCBA. Thereupon, the interrelation between these factors will be researched, to prevent double counting. Ultimately, a computational model which can evaluate the social costs and benefits of financial schemes which promote bicycle commuting is modelled.

4
Conceptual model

This chapter focuses on the conceptualisation of financial schemes promoting bicycle commuting in the Netherlands. Mentioned in chapter 2, a Social Cost Benefit Analysis will be carried out, following he guidelines of Romijn and Renes (2013). In the preceding chapter the problem was analysed, revealing the lack of knowledge regarding the social costs and benefits of financial schemes promoting bicycle commuting in the Netherlands. Now, it is necessary to proceed with the subsequent steps outlined in the guideline. First, the base alternative and the policy alternatives need to be defined, in section 4.1. Subsequently, the pertinent factors will be identified, in section 4.2. The alternatives and the associated factors will be incorporated into a conceptual model to illustrate their interrelations and determine both direct and indirect effects, section 4.3. The findings of this chapter will serve as the foundation for the computational model developed in the the following chapter, chapter 5.

4.1. Establishing the alternatives

The first step in establishing the alternatives, is defining the base alternative. This is essential for a SCBA, as this serves as the benchmark for evaluating the impact of a policy (Beenker & Goedhart, 2018; Van Wee & Börjesson, 2015). Annema et al., 2015 mentioned that the base alternative of the SCBA can be a ‘do-nothing’ or ‘do-minimal’ scenario. To ensure comparability between policy alternatives, the baseline for the policy alternatives should be the same. This means that the baseline, also known as the ”zero-alternative,” should officially be set at 2020, as the lease-bike scheme was introduced in this year and the ’Fietsplan’ was abolished. However, there are some considerations to take into account. The year 2020 was heavily influenced by the COVID-19 pandemic, which had a significant impact on commuting patterns. Therefore, the baseline has been shifted to 2022, as it was observed that travel levels were recovering in 2021 and seemed to stabilise in 2022 (Ministry of Infrastructure and Watermanagment, 2023). This means that the annual commuter cycling distance was 4.1 billion kilometres in the reference alternative. The average cycling distance amounted to 4.2 km for conventional bicycles and 6.85 km for e-bikes. The distribution between conventional bicycles and e-bikes stood at 85% and 15%, respectively. The number of commuting days was on average 3.1 days per week. The average gross income was €38,500/year, accompanied by an average tax burden of 40.2%. The modal split for commuting trips encompassed 62% car usage, 8% public transport (2% bus and 6% train), 24% bicycle, 3% walking, and 4% other modes (Centraal Bureau voor de Statistiek, 2022; de Haas & Huang, 2022; Ministry of Infrastructure and Watermanagment, 2023; Stichting BOVAG-RAI Mobiliteit, 2022).

Now the policy alternatives can be defined. Given that this research focuses on financial schemes aimed at promoting bicycle commuting, an examination of the three schemes currently implemented by the Dutch government is warranted (Ministry of Infrastructure and Water Management, 2023a). Firstly, the tax-free kilometre allowance will be explored. As of January 2023, this allowance has been increased from 0.19 €/km to 0.21 €/km. Consequently, the first policy alternative to be investigated is the augmentation of the allowance by 0.02 €/km. For this policy alternative it is assumed that the kilometre allowance will only be increase for cycling kilometres, thus for car kilometres this will not be increased.

The second scheme under consideration is the ”Fiets van de zaak” or company bicycle, commonly known as the lease-bike scheme. This scheme enables employees to utilise a (electric) bicycle or a Speed Pedelec for their commuting purposes without the need to personally purchase a bicycle. From a tax perspective, individuals are granted unrestricted personal use of the company bicycle. However, the employee is required to pay an annual addition of 7% of the consumer price of the bicycle and accompanying accessories (including VAT). Next to that, there are also lease-costs associated with leasing a bicycle. There are three options for the payement of these lease costs. First, the employer pay the full amount. Second, the employer pays a part of the lease costs and the employee pays the remaining amount from its gross salary. Third, the employee pays the full amount from its gross salary. The implementation of this scheme took place in 2020, and thus, this research aims to retrospectively examine the social costs and benefits associated with its implementation compared to the base scenario of not implementing the lease-bike scheme and solely providing a kilometre reimbursement of €0.19/km for both bicycle and car usage.

The third and final financial scheme is the Work Costs Scheme (WCS). Under this scheme, employers can offer their employees a tax-free reimbursement of up to 1.7% of the payroll through the WCS. This scheme can be utilised for bicycles, e-bikes or Speed Pedelecs for employees. Nonetheless, employers also have the option to use this scheme for other purposes such as providing gym memberships or Christmas hampers, as long as it falls within the allotted free space of the WCS. However, during the interviews with I2, I4, I6, and I9 (Appendix C), it became evident that this scheme is not uniformly understood, and no one dared to estimate how frequently it is utilised or the approximate the amount of reimbursement received by employees. Additionally, several individuals mentioned that they rarely or never hear about this scheme within their network. Consequently, it’s determined that examining this scheme at present would not be feasible. Therefore, the previous company bicycle scheme, ”Fietsplan” will be scrutinised. Under this scheme, employees were allowed to purchase a bicycle every three years using their gross salary. Employees had the option to deduct a bicycle with a value of up to 749 euros from their gross salary, resulting in a benefit of 370.76 euros considering a tax rate of 49.5% (Belastingdienst, 2023). If the bicycle exceeded the value of 749 euros, the remaining amount was paid from the net salary. The Fietsplan scheme was replaced by the lease-bike scheme in 2020. Consequently, evaluating whether this change in the scheme has produced any positive societal effects becomes particularly intriguing. This can be evaluated since both policy alternatives are compared with the same base alternative.

4.2. Determining the relevant factors

Determining the effects and benefits is divided into three steps. The first step in determining the effects and benefits involves identifying the factors for creating a comprehensive SCBA (Romijn & Renes, 2013). The second step and third step where the effects will be quantified and monetised will be discussed in section 5.1.

When determining the relevant factors both direct and indirect effects, priced and non-priced effects, and externalities are taken into account. The first step in creating a comprehensive understanding of all pertinent factors, is looking back at the literature review in chapter 3. Multiple bicycle SCBAs were reviewed and the factors included in these SCBAs gives a good starting point. To build upon these factors a structured brainstorm is held. Subsequently, literature research is conducted to confirm that these factors play a role in financial schemes regarding commuter cycling. This is an iterative process, as in the literature new factors are found which give inspiration for another brainstorm session. The factors which are found, are organised following the coding method explained in subsection 2.1.4. The result of this coding is depicted in Appendix B, showing the different categories which are established. Now all the factors are assigned to a category and since the number of factors discovered is fairly large, namely 59, their justification can be found in Table B.1, in Appendix B. In the table below the exhaustive list of factors and their justification is summarised per category. To enhance the readability of the table, the **brainstorm** will be highlighted in bold, the sources will be presented in regular text, and the *interviews* will be indicated in italics.

The identified factors can be integrated into a conceptual model. First, an extremely simplified version

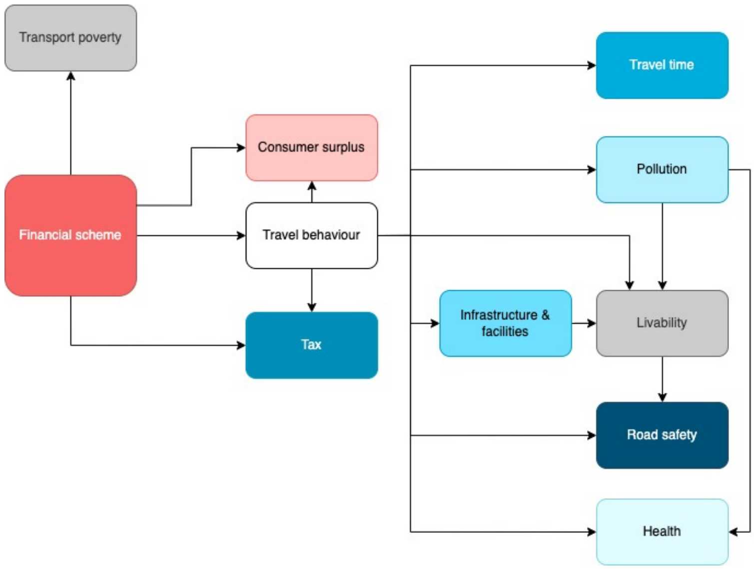

Figure 4.1: Simplified conceptual model

will be depicted showing the interrelation between the different categories. Serves as the foundation for the computational model. Therefore, for a clear and consistent overview, a colour scheme has been implemented, assigning a specific colour to each category, which will also be used in chapter 5, to maintain clarity throughout.

Table 4.1: Justification simplified conceptual model

Factor	**Source**
Consumer surplus	**Structured brainstorm**, Annema and van Wee (2021) and Romijn and Renes (2013)
Financial scheme	**Structured brainstorm**, BOVAG and KPMG (2023), *Expert group SCBA bicycles, I10*
Health	Bauman (2004), Beenker and Goedhart (2018), Decisio and Ministry of Infrastructure and Water Management (2017), Decisio and Transaction Management Centre (2012), de Haas (2019), Foltnova and Kohlova (2002), Harms and Kansen (2018), Macmillan et al. (2014), Mahfouz et al. (2020), Menai et al. (2015), Peters et al. (2021), Rabl and de Nazelle (2012), Sieg (2014), Sleep Foundation (2022), TNO (2009), van Beijsterveldt et al. (2020), Wang and Boros (2019), and Warburton et al. (2006)
Infrastructure & facilities	Amsterdam Bike City (2021), Centraal Planbureau en Kennisinstituut voor Mobiliteitsbeleid (2009), and Decisio and Transaction Management Centre (2012)
Livability	**Structured brainstorm**, *Interview I8*

Table 4.1: Justification simplified conceptual model

Factor	Source
Pollution	**Structured brainstorm**, Beenker and Goedhart (2018), BOVAG and KPMG (2023), CE Delft (2022, 2023), Decisio and Ministry of Infrastructure and Water Management (2017), Decisio and Transaction Management Centre (2012), Foltnova and Kohlova (2002), Macmillan et al. (2014), Mc Laughlin (2021), Ministry of Infrastructure and Watermanagment (2023), Rabl and de Nazelle (2012), and UN Environment Programme (2019), *Interview bicycle repairman*
Road safety	Beenker and Goedhart (2018), Decisio and Transaction Management Centre (2012), Foltnova and Kohlova (2002), Macmillan et al. (2014), Otero et al. (2018), and Rabl and de Nazelle (2012), *Interview I5*
Tax	Centraal Planbureau en Kennisinstituut voor Mobiliteitsbeleid (2009) and Decisio and Transaction Management Centre (2012)
Transport poverty	**Structured brainstorm**, BOVAG and KPMG (2023), Government of the Netherlands (2022), and Rabl and de Nazelle (2012),*Expert group SCBA bicycles*
Travel behaviour	**Structured brainstorm**, **Structured brainstorm**, Cairns et al. (2017), CE Delft (2022), Centraal Planbureau en Kennisinstituut voor Mobiliteitsbeleid (2009), Decisio and Transaction Management Centre (2012), de Haas (2019), de Haas and Huang (2022), Menai et al. (2015), Ministry of Infrastructure and Watermanagment (2023), Molin and Timmermans (2010), and MuConsult (2019), *I2, R., I10, I13, van I11*
Travel time	Annema and van Wee (2012), Beenker and Goedhart (2018), Decisio and Ministry of Infrastructure and Water Management (2017), Decisio and Transaction Management Centre (2012), Foltnova and Kohlova (2002), and Hilbers et al. (2020)

4.3. Conceptual model

In this section, all the identified factors are integrated into a conceptual model. This conceptual model aims to capture the complexity of the issue by describing the interrelationships among the factors. It illustrates the multitude of factors that exert influence on the ultimate priced factors. A different colour scheme is used to address the different types of priced factors. The conceptual model starts on the left with the financial scheme. Dark blue factors correspond to the priced factors for society, while the blue factors pertain to individual factors. These are the factors that directly impact the individual who engages in cycling. Lastly, the light blue factors encompass the factors that influence both society and the individual. It is noteworthy that not all the factors mentioned in Table B.2 are explicitly included in the conceptual model. This can be explained due to some factors have been combined and designated as sub-categories, which were identified during the axial coding phase. This decision was made to maintain the clarity and coherence of the conceptual model while removing unnecessary complexity. Below, a few noteworthy factors and their effects will be briefly discussed. However, a more detailed exploration of the effects will be presented in section 5.1, where the effects will also be quantified and monetised.

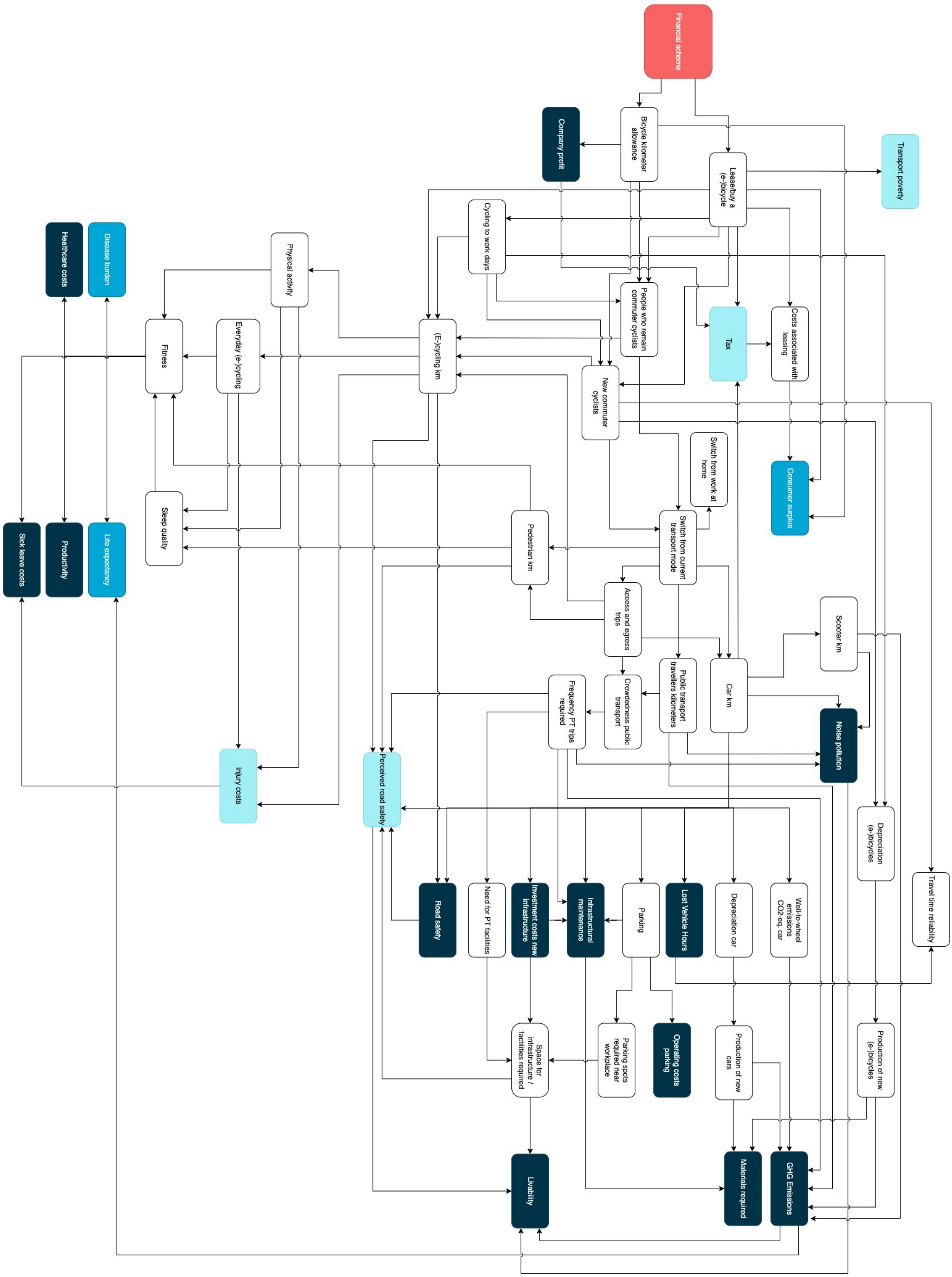

Figure 4.2: Conceptual model

Looking at the conceptual model, some relations are evident. For instance, the transition from the current mode of transportation to cycling would lead to a reduction in kilometres travelled using the original mode. Therefore, if an individual switches from a car to a bicycle, there would be a decrease in car kilometres, resulting in reduced emissions and alleviated congestion. The measure used to quantify congestion is Lost Vehicle Hours, which evaluates the amount of travel time lost due to constrained road capacity compared to an uncongested scenario.

Nevertheless, there are also less conspicuous relationships to consider. One such example is the impact of emissions on the life expectancy of individuals who opt for cycling as their commuting mode instead of using a car. As these individuals transition from an enclosed vehicle to cycling in the open air, they encounter additional emissions, which marginally diminishes their life expectancy (de Hartog et al., 2010; Harms & Kansen, 2018; Rabl & de Nazelle, 2012). Conversely, the general public reaps the benefits of reduced emissions resulting from a decrease in car kilometres travelled.

Another crucial finding is the significant impact of the financial scheme in encouraging both new individuals and existing cyclists to engage in cycling. Although this distinction may seem relatively insignificant, it is essential for assessing the implications for health outcomes. Specifically, individuals transitioning from an inactive lifestyle to a more active one can experience the full range of health benefits associated with cycling. Conversely, for those who are already highly active, the incremental health effects of further cycling engagement are relatively smaller (Decisio & Ministry of Infrastructure and Water Management, 2017).

This model effectively illustrates the interrelationships between all factors and the diverse array of facets associated with this problem. Nonetheless, the model does not comprehensively encompass all intricacies, particularly those related to road safety. The shift from cars to bicycles essentially leads to a decrease in road safety due to the elevated accident risk faced by cyclists compared to car users. However, this is not universally applicable. For instance, if an individual previously traversed hazardous roads but now cycles along a segregated bike path through a meadow, the cyclist may not necessarily confront an increased accident risk. Additionally, Elvik and Bjørnskau (2017) describes the existence of the safety-in-numbers phenomenon for cyclists. This means that an increase in the number of cyclists does not result in a proportional increase in the number of accidents. The estimated accident elasticity coefficient is 0.50, indicating that when the number of cyclists doubles, the number of accidents increases by the square root of two, resulting in a 1.41-fold increase in accidents.

Furthermore, the current model does not account for the concept of residential self-selection, which pertains to individuals actively choosing residential areas based on their specific travel preferences and needs (Ettema & Nieuwenhuis, 2017; Hu et al., 2023). For example, individuals who have a preference for commuting by train may opt to live in close proximity to a railway station. It is assumed that financial schemes, however, have the potential to alter individuals' preferences and attitudes, potentially leading them to prioritise cycling over other modes of transportation. Consequently, these financial schemes could potentially influence individuals to relocate to a location that is closer to their workplace. Nevertheless, modifying someone's behaviour is a more complex undertaking and would have a more significant impact on their commuting behaviour (Kroesen et al., 2017). Therefore, the relationship between residential self-selection and financial schemes for bicycles remains uncertain and is not included in the model. Furthermore, its relevance may be diminished given that the average commuting distance to work already falls within the acceptable cycling range, respectively 6.1km and 7.5km.

4.4. Filtering factors

When examining the conceptual model, it becomes evident that there is a multitude of priced factors involved in this issue. To comprehensively address this within a six-month time-frame, a distinction needs to be made between factors of significant impact and those of lesser importance to incorporate into the computational model. To achieve this, an analysis of the existing literature and interviews was conducted.

Based on the interview with I8, it was noted that there is insufficient research available to quantify and monetise the impact of increased cyclists on the living environment. Therefore, the factor ”liviblity” was excluded from further analysis. This was also highlighted during the initial consultation with an expert group for the development of a new version of the Bicycle SCBA made by Decisio. However, it was anticipated that this aspect could hold considerable interest and may yield substantial effects if successfully quantified. There was also a debate regarding the direction of this effect, as car-free streets can be both positively and negatively perceived.

During this consultation, the effect of bicycles on travel poverty was also addressed. The magnitude of this effect is uncertain and challenging to quantify. It has the potential for significant implications, such as enabling individuals who currently rely on welfare benefits to access employment opportunities by owning a bicycle, thereby reducing their dependence on welfare.

Additionally, the effect of cycling on productivity was discussed. Despite some studies exploring this aspect, a consensus on the magnitude of this effect has not been reached, making it challenging to draw a definitive conclusion. Consequently, this effect was also excluded. The same goes for the effect on injuries.

Furthermore, the subsidies for public transport are excluded as this study doesn’t look at a specific location but at the whole of the Netherlands and will not use transport models to see where the modal shift takes place, it’s not obvious that the modal shift will directly cause reduced necessity for public transport.

Lastly, the effect of perceived road safety was excluded based on an interview with I5, as quantifying and monetising this effect would require a separate thesis. Moreover, it is challenging to assess, as Duives, D. mentioned instances where individuals were not even aware that they were avoiding certain roads with their children due to perceiving them as unsafe.

Therefore, the effects that have been excluded are as follows:

- Societal priced factor:
  - Livability
- Societal and individual priced factor:
  - Transport poverty
  - Materials required
  - Injury costs
  - Perceived road safety

In addition to the above, there is another effect that is debatable. Namely, the disease burden costs. If the individual starts cycling to work to prevent a disease burden, this is an internalised choice and would be part of the consumer surplus. Nonetheless, during numerous informal conversations, where the question was asked why people would choose to cycle to work, preventing disease burden was never mentioned. Most people did mention that it improving their fitness, but not in order to prevent diseases. Therefore, it is chosen to take this factor into account. Next to that, the other remaining factors which will be incorporated into the computational model are listed below:

- Individual priced factors:
  1. Consumer surplus
  2. Disease burden
- Societal priced factors:
  3. Health care costs

4. Sick leave costs
5. Road safety
6. Investment costs for new infrastructure
7. Infrastructural maintenance
8. Public transport subsidies
9. Operating costs parking facilities
10. Lost Vehicle Hours (LVH)
11. Green House Gas emissions
12. Noise pollution
13. Productivity

- Societal and individual priced factor:

12. Life expectancy
13. Tax

Having completed the factor filtering process, a revised and simplified conceptual model is depicted in Figure 4.3. This model serves as the fundamental framework for quantifying and monetising the effects in the upcoming chapter, dedicated to computational model, chapter 5. The lighter grey factors are the travel behaviour factors which are eliminated and the darker grey factors are the priced factors which have been dropped.

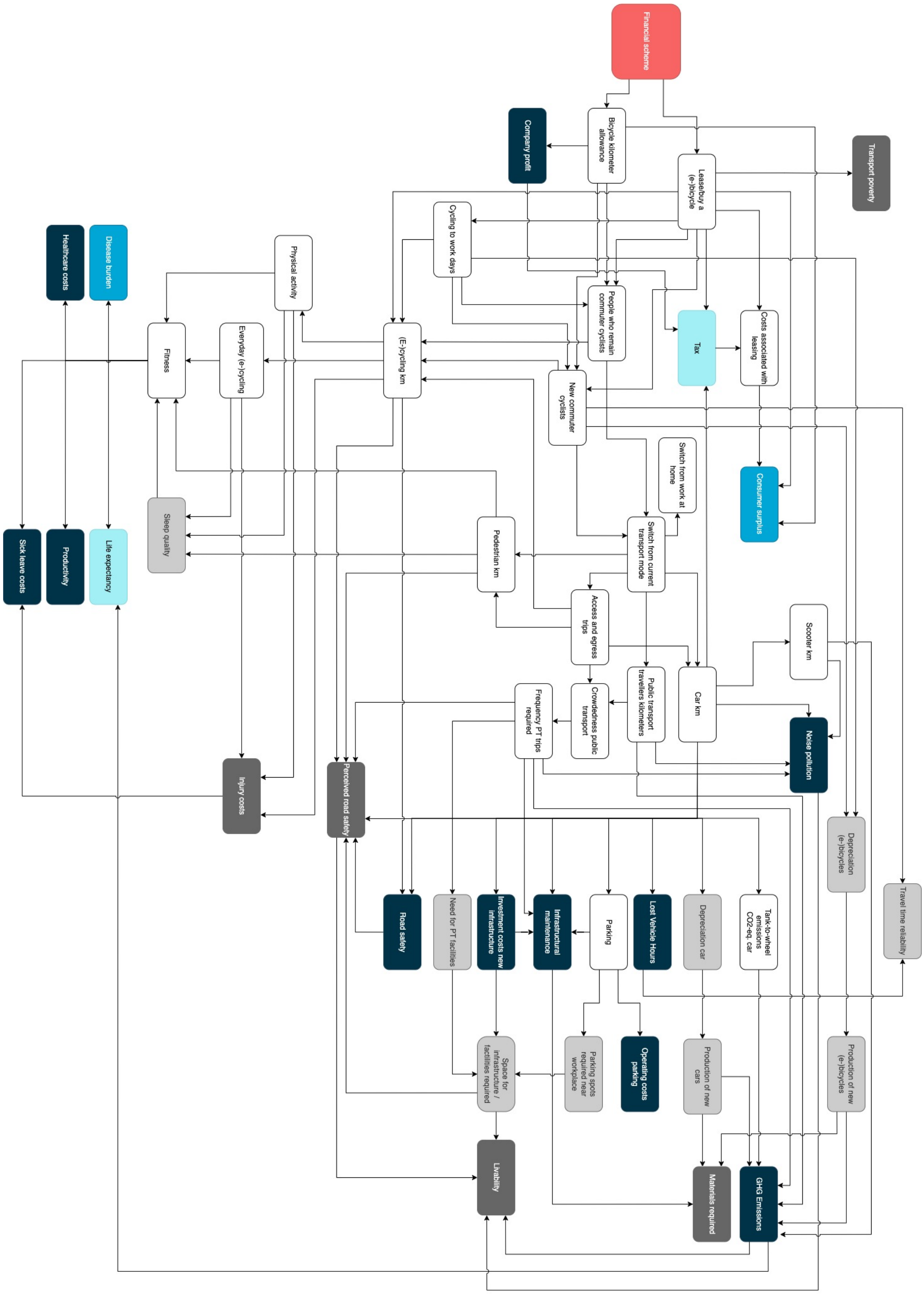

Figure 4.3: Filtered conceptual model

5
Computational model

Having conceptually modelled the base alternative, policy alternatives, and their associated factors, the next step involves translating them into a computational model. In accordance with the guidelines proposed by Romijn and Renes (2013),the quantification of factors and their subsequent monetisation (section 5.1) are essential to determine the societal benefits. Furthermore, the costs will be determined (section 5.2). Subsequently, various scenarios will be established, to address some uncertainty (section 5.3). Finally, the findings will be presented (section 5.4).

5.1. Quantifying & monetising the effects

The second step in determining the effects and benefits is to quantify the effects and then to monetise them (Romijn & Renes, 2013). In this section both these steps will be addressed. At Decisio, quantifying the effects is also referred to as the "Q-side," as it represents the change in quantity. For example, it measures the increase in cycling resulting from a policy and the corresponding decrease in other modes of transportation, such as reduced car travel. This part of the research is particularly challenging since this type of change has not been extensively studied in a Cost-Benefit Analysis (CBA) context. Therefore, a combination of existing research studies, expert interviews on plausible changes and substitution effects were considered, furthermore the dataset of the survey conducted by lease is analysed to quantify the lease bike specific effects. For the monetisation of the effects available literature is used. The quantification and monetisation of these effects is based on the conceptual model depicted in the previous chapter, in Figure 4.3 where each arrow represents a specific effect. In the following subsections the policy alternative specific effects will be explained first, there a snapshot of the complete figure will be depicted so it's clear which part is being explained. After this, the general effects will be explained. For a comprehensive list of the calculations of the priced factors see Appendix D.

5.1.1. Effects kilometre allowance

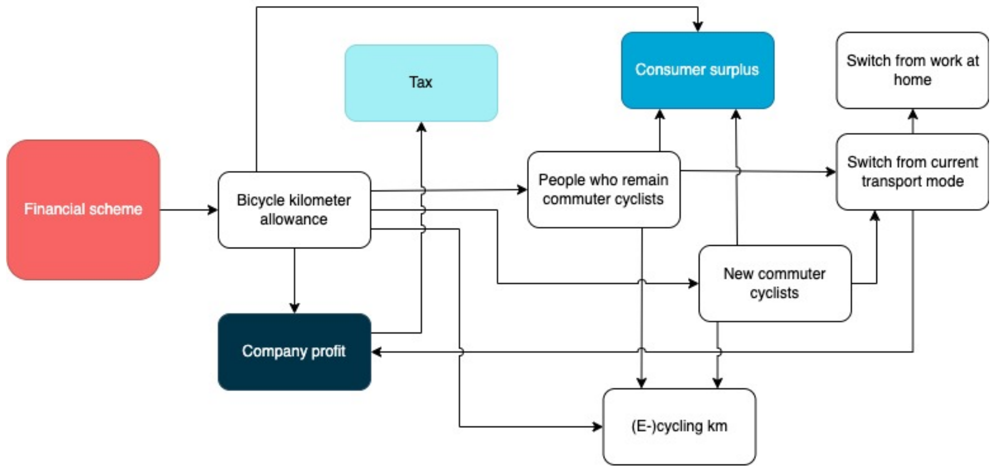

Figure 5.1: Simplified conceptual modal of the effects of the kilometre allowance

The first effect is the change in the financial scheme to the bicycle kilometre allowance. This effect represents the primary policy alternative mentioned in section 4.1. As mentioned earlier, the bicycle kilometre allowance will increase with €0.02 (Ministry of Infrastructure and Water Management, 2023a). This increase in the allowance impacts three other factors: ”company profits” and the ”cycling to work days”.

Initially, consumer surplus increases. The consumer surplus is a concept in economics that measures the discrepancy between a consumer’s willingness to pay and the actual price. In this case, it represents the difference in consumers’ willingness to cycle at a specific kilometre allowance rate. This can be visually represented as the triangular area above the price and below the demand curve. The consumer surplus includes all the considerations made by consumers. Switching from commuting by car to cycling to work may result in a longer travel time but can also lead to increased travel enjoyment and a sense of fitness. These effects do not need to be individually quantified, as they are intrinsic choices captured in consumers’ willingness to switch to cycling at a particular kilometre reimbursement rate. A higher consumer surplus signifies greater benefits experienced by consumers. It is important to acknowledge that the consumer surplus may vary among consumers due to differences in their willingness to pay. Hence, the consumer surplus diagram includes two incoming arrows representing individuals who remain commuter cyclists and new commuter cyclists. The former group was already willing to cycle at the previous kilometre reimbursement rate of €0.19/km and now receives an additional €0.02 for each kilometre cycled. Their willingness was already €0.19, resulting in a full increase of €0.02 per cycled kilometre in their consumer surplus. However, there are individuals who become willing to start cycling as a result of the increased kilometre reimbursement rate. Their willingness may have already been reached at €0.191 or could require €0.21. Consequently, the rule of half is applied to estimate their overall benefits. The rule of half assumes that, on average, newcomers derive half the benefits from the improvement compared to individuals who already use the infrastructure in the base alternative (Romijn & Renes, 2013).

Moreover, the financial burden of implementing the ”bicycle kilometre allowance” primarily rests on companies, as they are obligated to cover its costs. Consequently, this obligation directly impacts the overall profitability of these companies. Furthermore, the shift in transportation mode towards cycling also has implications for company profits, as they are no longer required to reimburse the kilometres that are now being covered by cycling. Keep in mind that the kilometre allowance is increased for cycling kilometres but not for the other transportation modes, so this does not result in a net zero effect.

It is important to note that corporate taxes, which are set at 19-25.8% on company profits, are directly influenced by changes in profitability. A decrease in profits consequently results in reduced tax revenue for the government. However, it is essential to recognise that this represents a transfer of benefits from the companies to costs incurred by the government. In this particular context, the absence of a consumer surplus or similar factors renders the net effect zero and, as such, it is not taken into consideration.

To determine the extent of the increase in consumer surplus, it is necessary to establish the number of kilometres to be travelled by existing and new bicycle commuters. MuConsult (2019) conducted research on this aspect by determining the elasticity of the bicycle kilometres with respect to a kilometre allowance, they found the elasticity to be 0.064 for a 10% increment in a €0.19/km reimbursement. This elasticity provides a basis for calculating the anticipated additional bicycle kilometres arising from an elevation in the kilometre allowance. However, not all commuting bicycle kilometres necessarily receive the kilometre allowance. MuConsult (2019) found that 42% of employees have the opportunity to receive the bicycle kilometre allowance. Consequently, 42% of the existing commuter cycling kilometres are assumed to be cycled by someone who receives a kilometre allowance. Now that the additional commuter cycling kilometres are established, the distribution between new and existing cyclists can be determined. It is found that the rise in cycling kilometres is primarily driven by existing bicycle commuters increasing their cycling frequency (80%-87.5%) and only partially by individuals who make the switch (12.5%-20%) (Appendix C).

Subsequently, it is necessary to determine the mode from which these additional cycled kilometres are displaced. It is assumed that existing cyclists who increase their cycling frequency will reduce their days of remote work by one and incorporate an additional day of cycling. Regarding the switchers, it is assumed that they will substitute their current transportation modality, including car usage, public transportation (bus or train), or walking. To ascertain the specific modality from which the extra cycling kilometres have been switched, an examination of the current distribution of travel patterns available in the National Travel Survey (Ministry of Infrastructure and Watermanagment, 2023) has been conducted. Consequently, this results in a reduction of 85% in automobile trips, 11% in public transportation trips, which encompasses 8% train journeys and 3% bus journeys, and a decline of 4% in pedestrian trips. This is based on trip data not on travel distances, it is chosen to use trip data since someone would substitute a trip and because car and train trips may otherwise be overestimated. This division is pivotal for subsequent calculations, such as estimating Greenhouse Gas (GHG) emissions. These effects will be discussed in detail in subsection 5.1.4.

Lastly, the bicycle kilometres are further classified into conventional bike kilometres and e-bike kilometres. This categorisation is based on the prevailing modal split in the Netherlands, which is estimated to comprise 85% conventional bicycles and 15% e-bikes (Stichting BOVAG-RAI Mobiliteit, 2022).

5.1.2. Effects lease bike

In the case of the financial scheme the lease bike, consumers are provided with the opportunity to lease a bicycle. According to interviews with I7, I6, and I13 it has been found that approximately 30,000 people ”lease a (e-)bicycle” in the Netherlands. In order to determine the ”consumer surplus”, it is necessary to examine the amount that consumers pay in terms of ”costs associated with leasing”. These costs are comprised of the expenses associated with leasing the bicycle, as well as the 7% addition based on the bicycle’s catalogue value. There are three different arrangements in place regarding the leasing costs. Under the first arrangement, the employer covers the entire lease cost, and the employee is only required to pay the addition. The second arrangement entails the employee personally bearing the full lease costs from their gross salary. As for the third arrangement, the employer provides a contribution to the employee, while the employee is responsible for covering the remaining lease costs and the addition. It is worth noting that this contribution typically amounts to around €20/month (Appendix C).

The effect of ”leasing costs” on ”consumer surplus” can be assessed by subtracting the lease costs per year from the value of the lease bike per year and multiplying this difference by the number of bicycles leased through the lease bike scheme. The lease costs is the sum of the addition and the lease price. The value of the lease bike is the catalogue divided by three as the lease period is three years and multiplied by (1-20%) since the take over price is 20% of the catalogue price. Furthermore, it is important to note that the rule of half is applied to account for the proportion of individuals who would have purchased a bike even without the discount offered by the scheme.

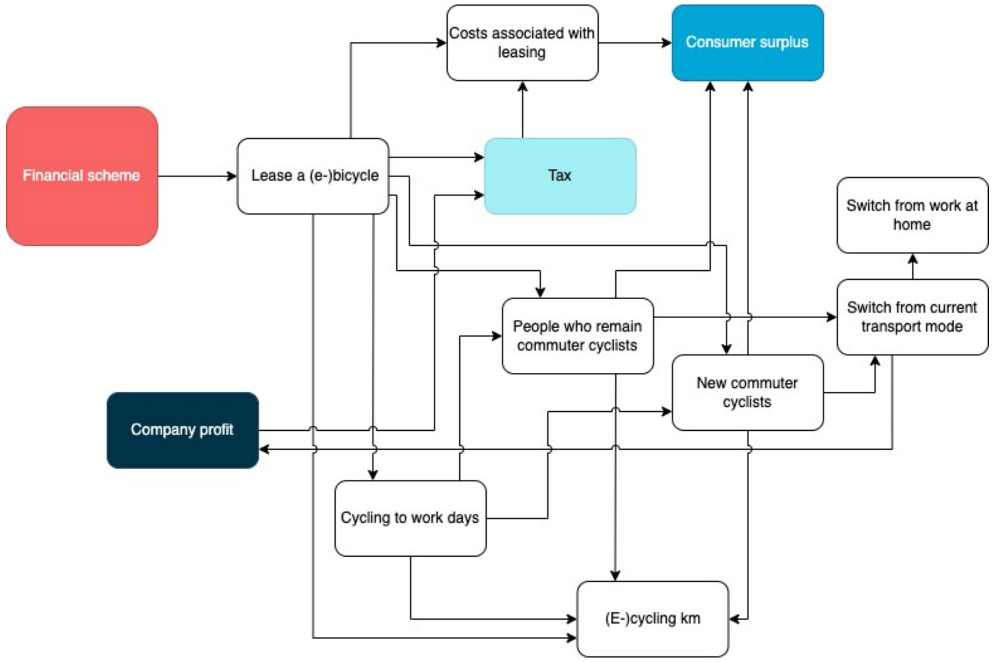

Figure 5.2: Simplified conceptual modal of the effects of the lease bike

In order to quantify further effects of the e-bike, survey data from a study conducted by Lease-a-Bike was utilised. A detailed explanation of the survey questions and dataset processing can be found below and in the Appendix E.

The findings reveal that the proportion of new bicycle commuters is significantly higher compared to the kilometre allowance, amounting to 61%. The survey also inquired data on the modalities from which these individuals made the switch, including none, scooter, car, private bike, public transport, or walking. An examination was conducted to determine if those who selected ”no switch” were individuals who solely use their lease bike for personal purposes. However, this was not the case for all instances. Therefore, it was assumed that for individuals who use the bike as their mode of transportation for commuting to work but still indicated ”no switch,” they are switching from working remotely rather than switching modalities. The distribution of this category is based on the type of bike users transitioned from, including the e-bike, speed pedelec, ’E-bakfiets’, conventional bike, mountain bike (MTB), and racing bike. However, to provide a general idea, the distribution is as follows: no switch 31%, scooter 2%, car 53%, private bike 8%, public transport 6%, or walking 1%.

5.1.3. Effects 'Fietsplan'

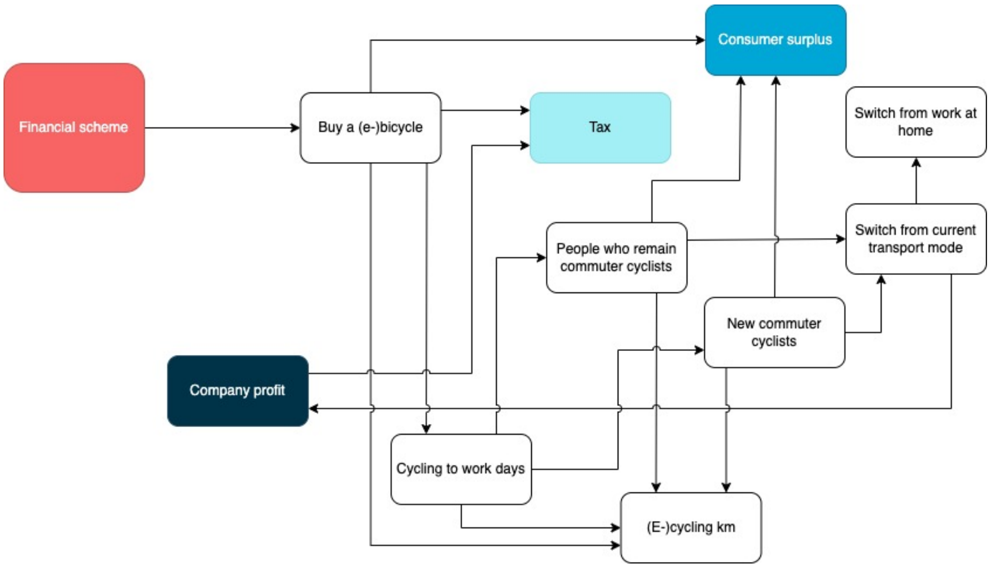

Figure 5.3: Simplified conceptual modal of the effects of the 'Fietsplan'

The final scheme is the "'Fietsplan'." This scheme resulted in the annual purchase of 176,320 bicycles. To determine the consumer surplus, the received discount can be multiplied by the number of bicycles purchased through the "'Fietsplan'." Since it is unknown how many of the people who took advantage of the "'Fietsplan'" were already willing to buy a bicycle without the discount, the rule-of-half is applied to all bicycle purchases.

It is also important to assess the impact of the "'Fietsplan'" on the increase in cycling. This was examined by MuConsult (2019). The same method as for the kilometre reimbursement was followed, which involved examining the average increase in cycling days. It was found that purchasing a bicycle through the 'Fietsplan' results in an average of 0.514 additional cycling days per person. The distribution between new and existing bicycle commuters is based on data available form the kilometre allowance and the lease bike scheme, since lacking of available literature. Meaning that for the conventional bicycle it is chosen to keep this consistent with the aforementioned shift of 1/8 and 1/5, mentioned by I11. However, the assumption is made that the shift for e-bikes and racing bikes or MTBs will be identical to that of the lease bike scheme. This choice is due to the lack of specific data for these types of bicycles. It is presumed that they can be compared because, in both cases, individuals receive a new bicycle.

Furthermore, it is assumed that existing bicycle commuters switch from remote work, and additional bicycle commuters switch from car, public transport, or walking, following the current mode of transportation mix. To determine the replaced distance, a distinction is made between three different bicycle types: e-bike, conventional bike, and racing bike/MTB. The distance used for e-bikes ranges from 6.5 to 7.2 km, while for conventional bikes, it ranges from 3.9 to 4.5 km for a single trip (de Haas & Huang, 2022; Ministry of Infrastructure and Watermanagment, 2023). For the average distance travelled with a racing bike/MTB, the survey data from lease bikes is used, which is 18.175 km. The modal split of purchased bicycles is 48% e-bike, 40% conventional bike, and 13% racing bike/MTB. By combining the data on the average commuting distance per bicycle type and the number of bicycles purchased per type, the additional commuting (e-)cycling kilometres can be determined. Multiplying this by the percentage of new commuter cyclists reveals the number of kilometres replaced by different modes of transportation. This can then be multiplied by the current mode of transportation mix to determine the specific effects of the "'Fietsplan'."

5.1.4. General effects

In this section, the effects that apply to all financial schemes are discussed. It builds upon the previous subsections, which concluded with the factors "switch from work at home," "car km," "public transport km," "pedestrian km," and "(e-)cycling km". In order to provide a clear visual representation of the progress within the conceptual model, Figure 5.4 is presented below. The shaded area indicates the portion of the model that has already been discussed. For the following subsections it's noteworthy that all kilometres mentioned are passenger kilometres and not vehicle kilometres.

Switch from work at home

As shown in Figure 4.3, there are no outgoing arrows from "switch from work at home." This means that the additional kilometres cycled instead of working from home only affect the factors related to (e-)cycling km. For pedestrian kilometres, there is also an incoming effect observable from access and egress trips, which will be discussed in the sub-subsection on public transport kilometres. The outgoing effect on fitness will be addressed in the sub-subsection regarding (e-)cycling kilometres.

Car km

The next factor is "car km." This factor has several visible effects, starting with noise pollution. Here, "public transport km" also has an effect on noise pollution. It is found that CE Delft (2022) expressed noise pollution in €0.0047/km for car kilometres and €0.0197/km for public transport (bus) kilometres, €0.0012/km for public transport (train) kilometres and €0.1450/km for scooter kilometres so there is no need for further specification.

The next effect of car km is on Greenhouse Gas (GHG) emissions. This is determined based on the concept of "CO_2-equivalent," which is a measure used to compare emissions of different greenhouse gases based on their global warming potential. It converts quantities of other greenhouse gases into the equivalent amount of carbon dioxide with the same global warming potential. This allows for a simplified analysis without considering each individual greenhouse gas. The driven car kilometres can be converted using a factor of 114.8 g CO_2-equivalent/km, which accounts for the current vehicle mix (80.3% gasoline, 12.3% diesel, 6% electric, etc.). The public transport kilometres can be converted using a factor of 1.7 g CO_2-equivalent/km, or for train it's 2.3 g CO_2-equivalent/km and for bus it's 59 g CO_2-equivalent/km. THe scooter kilometres can be converted using a factor of 58 g CO_2-equivalent/km. A kilogram of CO_2 is valuated in the WLO-low scenario at €0.19/kg and high at €0.77/kg (CE Delft, 2023). So, the GHG-emissions saved can be determined by multiplying the converted kilometres per transport mode and the valuation of CO_2. It is noteworthy that Tank-to-Wheel emissions are considered in this analysis. The conceptual model takes into account factors such as depreciation and the production of new bicycles. However, these factors are not included in this specific analysis. This is due to the complexity of the indirect effects that arise from increased cycling. For instance, as cycling increases, car usage may decrease, resulting in slower depreciation of cars and potentially reducing the need for new car production. However, this may also delay the transition from Internal Combustion Engine (ICE) gasoline cars to Battery Electric Vehicle (BEV) cars. Considering the numerous indirect effects involved, it was decided to not extensively investigate this aspect and keep it outside the scope of this analysis. Consequently, the emissions of both conventional bicycles and e-bikes/speed pedelecs are assumed to be equal to zero. It is important to note that the emissions associated with charging e-bikes fall under the category of Well-to-Tank emissions.

Car kilometres also have an impact on Lost Vehicle Hours (LVH). LVH refers to "the total number of hours of travel time delay (compared to uninterrupted flow) resulting from capacity restrictions on the way" (Encyclo, n.d.). Ministry of Infrastructure and Watermanagment (2020) and Netherlands Environmental Assessment Agency (PBL) (2009) found that a 1% decrease in car traffic leads to a 2.5% (2 to 3%) reduction in LVH. By dividing the replaced commuter car kilometres by the initial number of commuting car kilometres, the reduction in car traffic can be established. Multiplying this by 2.5 gives us the total reduction in LVH. The reduction in LVH can be multiplied by the value of time for car commuters this is valued at WLO-Low at €9.55/h and at WLO-high at €9.78/h (Kennisinstituut voor Mobiliteitsbeleid, 2013).

Subsequently, the impact on parking exploitation costs is examined. Centraal Planbureau en Kennisinstituut voor Mobiliteitsbeleid (2009) has quantified parking exploitation costs as €0.005/km. Therefore, no further specification of the effect quantification is necessary. However, it is important to adjust the monetisation to reflect the current price level, as this study was conducted in 2009. To account for this,

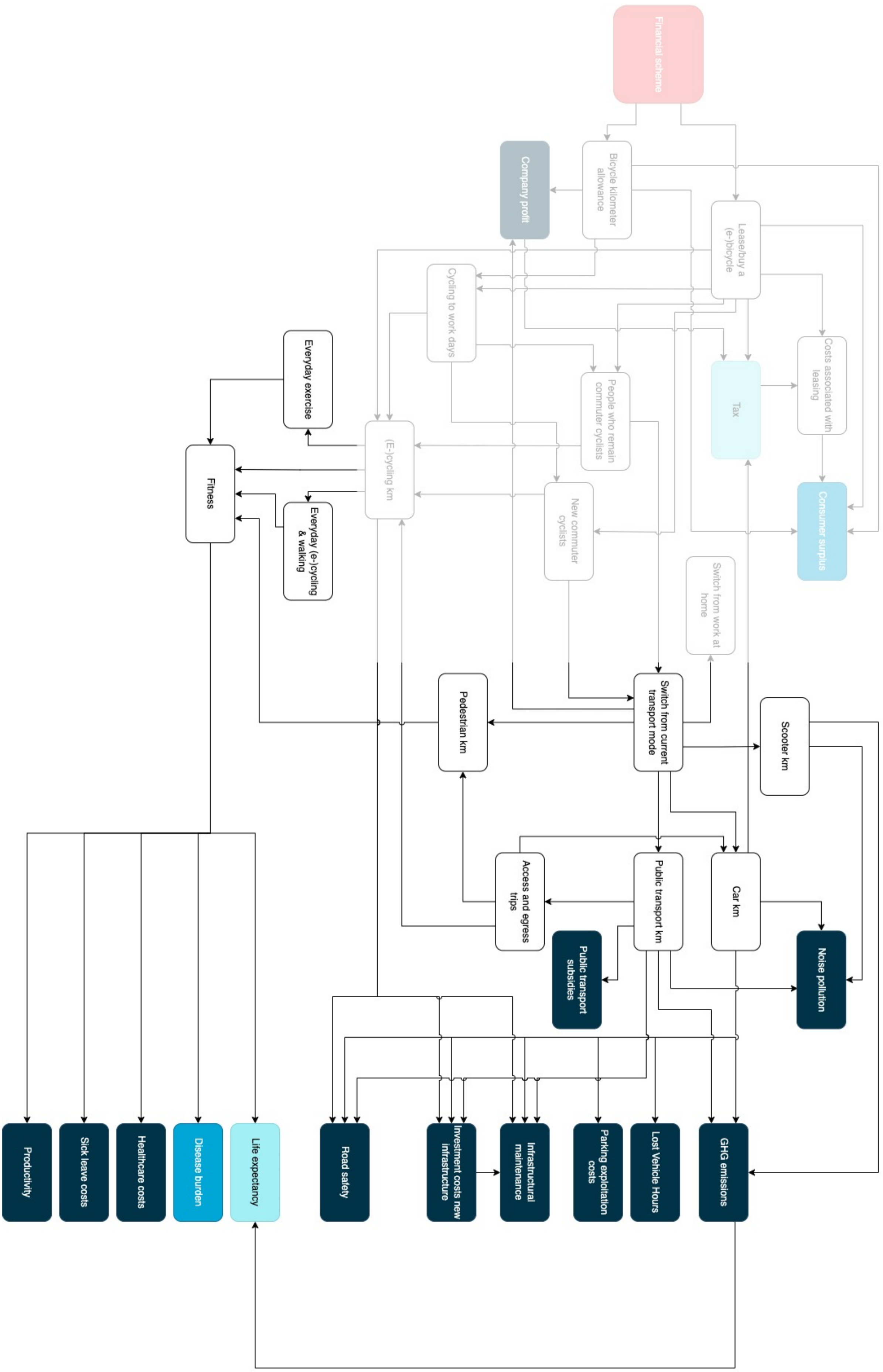

Figure 5.4: Conceptual model

an inflation adjustment factor of 1.51 is applied to bring the value to the price level of 2022 (Centraal Bureau voor de Statistiek, n.d.).

The next two effects are infrastructural maintenance and investment costs in new infrastructure. These factors also have incoming arrows from ”public transport km” and ”(e-)cycling km.” CE Delft (2022) expressed infrastructural maintenance and investment costs in one valuation. For car infrastructure this was valued at €0.0022/km, for scooter infrastructure this was valued at €0.0053/km, for bicycle infrastructure this was valued at €0.0015/km, for public transport (train) infrastructure this was valued at €0.0272/km and for public transport (bus) infrastructure this was valued at €0.0384/km.

The last effect of car km is on road safety. Here, too, there are effects from ”public transport km” and ”(e-)cycling km,” and CE Delft (2022) expressed these effects in €/km per different mode of transportation. The external crash costs of car are valued at €0.069/km, scooter 0.396€/km, bicycle €0.176/km, e-bicycle €0.176/km, public transport (train) €0.001/km and bus €0.050/km. Noteworthy is that CE Delft assumes the same costs for bicycles and e-bikes. This is supported by multiple articles, which state that there is no difference in crash chance between bicycles and e-bikes (Krul et al., 2022; P. Schepers et al., 2020; SWOV, 2017). However, some studies expect the crash chance to be higher for e-bikes (Otero et al., 2018; J. P. Schepers et al., 2014). Otero et al. (2018) found that the e-bike has a 1.49 to 2.48 times higher chance to be involved in a crash.

Public transport km
This factor effects several factors which already have been mentioned such as, ”noise pollution”, ”GHG emissions”, ”infrastructural maintenance”, ”investment costs new infrastructure” and ”road safety”. The only factors which have not been mentioned are the ”public transport subsidies” and the ”access and egress trips”. Decisio and Ministry of Infrastructure and Water Management (2017) already quantified the public transport subsidies as €0.03/km for train and €0.29/km for bus.

The factor ”access and egress trips” has an effect on the number of passengers who no longer use public transport. This effect can be quantified by dividing the total public transport kilometres by the average distance travelled by bicycle commuters (de Haas & Huang, 2022; Gemiddelden.nl, n.d.; Ministry of Infrastructure and Watermanagment, 2023). The resulting value can then be multiplied by the distribution of travel modes to and from train stations. For access trips, the distribution includes the following percentages: 20% have no access trips, 43% cycle, 11% walk, 9% drive by car, 15% use other modes of public transport (BTM), and 1% use alternative means of transportation. For egress trips, the distribution is as follows: 41% have no egress trips, 11% cycle, 22% walk, 3% drive by car, 20% use BTM, and 1% use alternative means of transportation (De Haas & Hamersma, 2021).By multiplying the reduction percentage in each mode of transportation by the average distance to a train station, it can be determined how many fewer kilometres are travelled using that specific mode of transportation as a result of replacing train commuting with bicycle commuting. The same approach can be applied to BTM. For access trips, the distribution is as follows: 69% have no access trips, 10% cycle, 9% walk, 2% drive by car, and 6% use BTM. For egress trips, the distribution is as follows: 76% have no egress trips, 1% cycle, 10% walk, 1% drive by car, and 7% use BTM (De Haas & Hamersma, 2021).

(E-)cycling km
The last factor is ”(e-)cycling km.” This factor has multiple discernible effects, some of which have already been mentioned, such as ”infrastructural maintenance,” ”investment costs in new infrastructure,” and ”road safety.” However, this factor also impacts ”fitness,” ”everyday exercise,” and ”everyday (e-)cycling & walking.”

Fitness is influenced by (e-)cycling, physical activity, and everyday (e-)cycling. Studies have shown that an increase in commuter (e-)cycling kilometres also affects individuals' levels of exercise, not limited to cycling and walking, and increases their everyday (e-)cycling (de Haas & Huang, 2022; Kroesen & Handy, 2014; Menai et al., 2015; Sahlqvist et al., 2013). To examine the effect of commuter cycling on ”everyday exercise” and ”everyday cycling & walking,” the findings from Menai et al. (2015) are utilized. The study reveals that commuter cycling leads to a weekly increase of 1-2.5 hours of exercise per person, with a factor of 1.26 (1.1-1.45) for exercise levels between 1-2.5 hours, 1.49 (1.28-1.72) for exercise levels exceeding 2.5 hours, 2.06 (1.79-2.37) for leisure cycling, 14.77 (13.09-16.68) for errands cycling, 0.81 (0.71-0.91) for leisure walking, and 0.72 (0.64-0.81) for errands walking. The average distances walked and cycled per week for leisure and errands in the Netherlands can be found in de Haas (2019). The mean value is used for exercise levels between 1-2.5 hours per week, while an average of 2.5 hours is employed for exercise levels exceeding 2.5 hours to avoid overestimation. By multiplying these averages with the effects reported by Menai et al. (2015), the average increase in exercise can be estimated. However, there is no evidence found that e-cycling affects individuals' exercise levels beyond cycling and walking. Nonetheless, it is found that the purchase of an e-bike does increase individuals' everyday e-cycling, conventional cycling, and walking. The acquisition of an e-bike leads to a decrease of 2.57 km per week in conventional cycling for leisure purposes, 1.63 km per week for errands cycling, a reduction of 0.47 km per week in errands walking, and an increase of 4.9 km per week in leisure e-cycling and 2.8 km per week in errands e-cycling.

To assess the impact of increased exercise on fitness, the distances travelled need to be converted into minutes of physical activity, which are then multiplied by the level of physical activity intensity. Physical activity intensity can be expressed in metabolic equivalents of task (MET) (Otero et al., 2018). Each type of physical activity has its own MET score, as determined by Voedingscentrum (2022). However, the MET score for e-cycling is not specified. Otero et al. (2018) found that e-cycling with "standard assistance" has a MET score of 6.12, compared to 6.8 for conventional cycling. E-cycling with "high assistance" is estimated to have a MET score of 5.4. Moreover, Langford et al. (2017) discovered that e-cycling requires 24% less effort than conventional cycling, resulting in a MET score of 5.17. With the increase in fitness, represented by METs per week per person, it is essential to examine its effects on "life expectancy," "disease burden," "healthcare costs," "sick leave costs," and "productivity."

The factor "life expectancy" is influenced by fitness and greenhouse gas (GHG) emissions. de Hartog et al. (2010) found that individuals who switch from enclosed modes of transportation (car or public transport) to cycling experience changes in life expectancy due to exposure to air pollution. This effect is estimated to range from a decrease of 0.8 to 40 days. To determine the impact of fitness on life expectancy, the number of individuals who switched from cars or public transport to commuter cycling needs to be multiplied by the effect of GHG exposure. Subsequently, this value should be multiplied with the Value Of a Life Year (VOLY), €31,500 (CE Delft, 2020). Nevertheless, someones life expectancy also increases due to increase of fitness (de Hartog et al., 2010; Kelly et al., 2014). This effect will be captured in the factor "disease burden."

The impact on the "disease burden" as a result of physical fitness is closely related to its effect on "healthcare costs." Ecorys (2021) conducted a comprehensive review of the literature to determine the reduction percentages for various diseases associated with regular physical activity. It was found that regular exercise leads to a reduction in breast cancer by 18% (12-23%), colon cancer by 17% (7%-27%), coronary heart disease by 23% (10%-35%), dementia by 35% (30%-40%), depression by 39% (30%-48%), diabetes by 33% (25%-40%), heart failure by 10%, neck and back pain by 13% (0%-25%), osteoporosis by 21% (14%-27%), and stroke by 23% (11%-35%). It is important to note that these reduction percentages are derived from individuals transitioning from a sedentary lifestyle to regular physical activity.

The monetary values of healthcare costs and disease burden costs per disease are as follows. The healthcare costs are in millions of euros: breast cancer €813, colon cancer €557.9, coronary heart disease €1,429, dementia €10,309, depression €1,040, diabetes €1,308, heart failure €524.7, neck and back pain €905.1, osteoporosis €110.7, and stroke €1,360 (Volksgezondheid en Zorg, 2023). The disease burden costs are expressed in Disability-Adjusted Life Years (DALY), which combines the years lived with a disease (YLD) and the years of life lost (YLL) caused by the disease. The DALY values for the respective diseases are as follows: breast cancer 81,300, colon cancer 90,400, coronary heart disease 271,300, dementia 163,600, depression 98,200, diabetes 201,000, heart failure 72,600, neck and back pain 162,600, osteoporosis (3,400), and stroke 248,000. To monetise these effects, DALY will be converted to Quality-Adjusted Life Years (QALY) using a factor of 0.92, with a value of €75,000 per QALY (CE Delft, 2020).

Now, the effect of "(e-)cycling km" on "Disease burden" and "Healthcare costs" can be calculated by multiplying the costs with the reduction percentages. However, it is crucial to consider the activity level of individuals who cycle the additional kilometres to work, as the reduction percentages are based on individuals transitioning from a sedentary lifestyle to regular physical activity. Kelly et al. (2014) conducted a study on the number of metabolic equivalents of task (METs) per week and its association with all-cause mortality. The findings indicate that even a small increase in physical activity from a sedentary state to a low level has a significant effect, see Figure 5.5. Consequently, the effect of physical activity is distributed by the following groups, individuals in the obese category experience 100% of the health benefits associated with physical activity. For those who are overweight, this percentage is estimated at 43%. Among healthy individuals, half of them receive a health benefit of 20%, while the other half experiences a 10% effect. These percentages are derived from the graph depicted in Figure 5.5, where $(1-0.83)/(1-0.7) = 43\%$ and $(1-0.76)/(1-0.7) = 20\%$. The number of individuals distributed across different health categories is based on the research conducted by de Haas and van den Berg (2019), which examined the prevalence of each health category among different transportation modes. Specifically, for individuals who predominantly use cars for transportation, 16% are classified as obese, 38% as overweight, and 46% as healthy. Among individuals who primarily rely on bicycles for transportation, the corresponding proportions are 12% obese, 29% overweight, and 59% healthy. For those who predominantly use e-bikes for transportation, the distribution is 22% obese, 38% overweight, and 39% healthy. Among individuals who heavily rely on public transport for transportation, 12% are obese, 24% are overweight, and 64% are healthy. Since specific data for individuals primarily walking for transportation is not available, it is assumed that their health distribution is similar to that of cyclists, as both walking and cycling fall under the category of active travel.

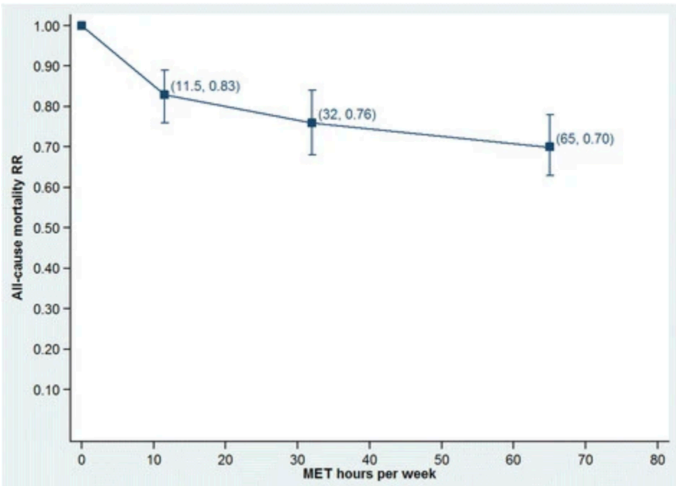

Figure 5.5: Relation between METs per week and all-cause mortality (Kelly et al., 2014)

TNO (2009) found that regular exercise has an impact on absenteeism. It is estimated to reduce absenteeism by 1.3 days per year per person when the individual cycles three kilometres, three times a week. These costs can be converted to €/km by multiplying the number of days by the labour productivity per working hour, estimated at $67/h in the Netherlands (TNO, 2023). Then, this value can be multiplied by the number of additional cycling kilometres. However, the proportions between the health effects, as described above, should be taken into account.

The final factor is "productivity." Multiple studies indicate that the work productivity of employees who engage in regular physical activity can increase (Ecorys, 2021; TNO, 2013). According to TNO (2013), work productivity can increase by 12.5%, while Ecorys (2021) suggests a 1.5% increase, and Decisio (2021) opts for a value of 3%. There is no consensus on the exact effect, but it is generally agreed that regular exercise is likely to improve work productivity. To avoid overestimating this effect, a conservative estimate of 1.5% is used. Similarly to the absenteeism costs, this value can be converted to €/km and adjusted based on the distribution of health benefits.

5.2. Determining the benefits and costs

The objective of cost determination is to identify the resources invested by the government and other stakeholders, including private parties, to implement the policy alternative. These costs need to be classified as either one-time or recurring, and as either fixed or variable. It is crucial to include only those costs that are in addition to the baseline alternative.

As mentioned earlier in the conceptual model (see chapter 4), the factors represented in dark blue are priced factors for society, while the blue factors relate to individual factors. These are the factors that directly impact the individual who engages in cycling. Lastly, the light blue factors encompass the factors that influence both society and individuals. From here, it is possible to determine which of these factors represent costs and which represent benefits. The benefits and costs will be discussed based on the categories they were assigned to during the coding process, as described below:

Factor	Who?	Category
Consumer surplus	Individual	Financial scheme specific
Tax	Individual & society	Excise & Subsidies
Public transport subsidies	Society	Excise & Subsidies
Noise pollution	Society	Emissions
GHG-emissions	Society	Emissions
Lost Vehicle Hours	Society	Travel time
Parking exploitation costs	Society	Infrastructure & facilities
Infrastructural maintenance & investment costs	Society	Infrastructure & facilities
Road safety	Society	Road safety
Life expectancy	Individual & society	Health
Disease burden	Society	Health
Healthcare costs	Society	Health
Sick leave costs	Society	Health
Productivity	Society	Health

Table 5.1: Priced factors and their designated category

5.2.1. Determining the benefits

As a result of financial arrangements, all policy alternatives will generate at least 12 benefits. The first benefit is the increase in consumer surplus. In the health category, there are five different benefits, namely the reduction of sick leave days, healthcare costs, disease burden costs, and the increase in productivity, which have been discussed earlier. Additionally, the health effects of increased physical activity due to commuter cycling are considered as a separate benefit, encompassing the four aforementioned effects. In the pollution category, both the decrease in GHG emissions and noise pollution are considered as benefits. Travel time benefits will also arise from the reduction in Lost Vehicle Hours (LVH). In the excise & subsidy category, a benefit will be realised as subsidies provided for public transport decrease, resulting in lower costs for the government. Lastly, in road safety, a benefit will be realised as accidents associated with the substituted modalities no longer occur.

For the kilometre allowance and lease bike policy alternatives, companies will experience an additional benefit. They will no longer need to allocate funds for the previous financial arrangements provided to employees who have now switched to cycling.

5.2.2. Determining the costs

As a result of financial arrangements, all policy alternatives will generate at least four costs. The first cost arises in the health category, specifically the reduction in life expectancy due to inhalation of GHG emissions, as individuals in each policy alternative will switch from cars or public transport to cycling. The second cost is associated with infrastructure and maintenance, as expenses will be required for the installation and upkeep of cycling infrastructure. The third cost falls under the excise & subsidy category, as the government will experience a decrease in excise income from gasoline due to the replacement of car and scooter kilometres. Lastly, in the road safety category, costs will arise due to road safety expenses associated with cycling kilometres.

Additionally, there are policy alternative-specific costs. For the kilometre allowance, the increased allowance provided by companies represents a cost for society. Companies will need to allocate funds for this reimbursement, covering both existing cycling kilometres and the additional kilometres that will now be cycled.

For the lease bike policy alternative, some companies will need to allocate funds either by fully reimbursing lease costs or by providing partial reimbursement. Moreover, the government will experience a loss in tax revenue when individuals who do not receive or partially receive reimbursement deduct the lease costs from their gross income, resulting in a decrease in taxable income.

5.3. Establishing the scenarios

In this research, given the uncertainty and reliance on estimated factors within a range, it is crucial to examine the impacts across these ranges. As a result, a middle, lower and upper scenario will be evaluated. The middle scenario is the base scenario, it represents the mean value derived from all effects based on a range, such as the reduction in healthcare and disease burden costs. Nevertheless, there are certain effects that have a range but do not utilise the mean value, such as travel time commuting costs or CO2 costs. These effects are determined by the WLO (The Netherlands Scientific Council for Government Policy) scenarios, which provide low and high values. It would not be appropriate to calculate an average from these scenarios. Therefore, the middle scenario is based on the WLO-low scenario.

The lower scenario is a pessimistic perspective, considering the lower bounds for all benefits and the upper bounds for all costs. It will be intriguing to observe whether the policy alternatives maintain positive outcomes even under the most unfavourable circumstances. Conversely, the upper scenario presents an optimistic viewpoint, incorporating the upper bounds for all benefits and the lower bounds for the costs. Realistic assumptions will be maintained for both scenarios, as these ranges are derived from expert interviews, scientific literature, and grey literature.

5.3.1. Sensitivity to certain factors

In addition to these scenarios, several interesting factors will be experimented with. Firstly, the middle scenario will be examined under different assumptions, such as the WLO-high scenario or a two-degree exploration scenario with low and high values.

In addition, the analysis will examine the impact on the middle scenario if it is found that e-cycling and conventional cycling result in a lower MET score than currently expected. Recently, a study conducted by Schreuder et al. (2023) investigated the MET value of different e-bikes. The study calculated the MET value at various levels of assistance, ranging from no assistance to turbo level assistance. This enables a comprehensive comparison between conventional cycling and cycling with pedal assistance.

Moreover, the analysis will investigate the effect of a less optimistic assumption regarding the increase in productivity, estimating it at either 3% or 12.5% (Decisio, 2015; TNO, 2013).

Additionally, the research will examine the effect of the e-bike having a higher average crash cost compared to a regular bicycle. During an interview with de Haas, it was mentioned that specific data for this aspect is not available due to significant underreporting, making it difficult to determine the precise effects. However, it is still valuable to explore how sensitive the model is to this change.

Lastly, the analysis will assess the effect of considering well-to-wheel emissions instead of tank-to-wheel emissions. Since charging e-bikes does release emissions, it is important to understand the implications of including these emissions. However, it should be noted that this may provide a somewhat distorted picture, as all indirect effects are not taken into account in the analysis.

5.3.2. Sensitivity to changes of the financial schemes

In addition to exploring various factors, the analysis will also examine the impact of changes in financial arrangements. For instance, KPN recently announced an increase in their bicycle kilometre reimbursement to €0.40/km (NOS, 2023). Therefore, it is intriguing to investigate the potential consequences if such a measure were implemented at the national level.

Regarding the lease bike scheme, it would be informative to explore the outcomes when an equal number of lease bikes are leased as the number of bicycles purchased during the 'Fietsplan'.

Moreover, it is intriguing to assess the effects on the B/C ratio if, for example, only conventional bicycles or only e-bikes could be acquired through the lease bike scheme. Since there is no available data on whether this would lead to an increase or decrease in purchases, the analysis will consider the effects based on the current sales volume.

Lastly, a thorough examination of the consumer surplus associated with the 'Fietsplan' is warranted. Presently, the working assumption considers that 100% of the consumer surplus adheres to the "rule of half" principle, as there exists no available data related to whether an individual would have acquired the bicycle even in the absence of the 'Fietsplan' scheme. Based on interviews, this assumption seems to underestimate the consumer surplus. Consequently, an exploration will be undertaken, varying the percentage of the consumer surplus subject to the "rule of half" approach.

5.4. Results

To determine the results, the previously mentioned costs and benefits (section 5.2) have been calculated for each policy alternative, across the different sub-categories established during the coding process, Appendix B. In the following subsections, the Net Present Value (NPV) and the Benefit/Cost ratio (B/C ratio) of the different policy alternatives will be computed for each scenario.

NPV is a financial metric used to determine the profitability. It measures the difference between the present value of cash benefits and the present value of cash costs over a specified time period. In other words, it calculates the value of future cash flows in today's terms by discounting them to their present value using an appropriate discount rate. A positive NPV indicates that the project is expected to generate more value than the initial investment, while a negative NPV suggests that the project may not be financially viable.

The B/C ratio, is another financial metric used in cost-benefit analysis. It compares the total present value of benefits resulting to the total present value of costs incurred. The B/C ratio is calculated by dividing the total present value of benefits by the total present value of costs. A B/C ratio greater than 1 indicates that the benefits outweigh the costs, suggesting that the project is economically favourable. Conversely, a B/C ratio less than 1 suggests that the costs exceed the benefits, indicating a potentially unfavourable project.

Both metrics, the NPV and B/C ratio, consider the present value of benefits and costs. In this study, the time horizon is set at five years. However, for mobility-related issues, the time horizon is often longer. For instance, when evaluating the construction of new infrastructure, the technically useful or physical lifetime of the infrastructure is commonly used as the time horizon (O'Mahony, 2021). In this analysis, such an extended time horizon is not necessary since there are no investment costs that need to be recovered over a specific number of years.Furthermore, it is essential to determine the discount rate used to discount future cash flows to their present value. According to Steunpunt Economische Expertise (n.d.), the discount rate for the standard analysis is set at 2.25%.

Firstly, the results of the various policy alternatives in the middle scenario will be presented (subsection 5.4.1). Subsequently, the results of the pessimistic scenario and optimistic scenario (subsection 5.4.2) will be presented. Afterwards, experiments will be conducted by modifying certain factors for the middle scenario, to determine the models sensitivity to these factors (subsection 5.4.3). Lastly, potential changes in the financial schemes will be explored (subsection 5.4.4).

To maintain clarity when presenting the results, the colour scheme mentioned in the previous chapter has been implemented, assigning a specific colour to each category, which will be used consistently in the detailed explanations for ease of understanding.

5.4.1. Middle scenario

The middle scenario takes the mean values for all effects where there was no clear effect and a range was assumed. The results for the different policy alternatives are presented in Figure 5.6. Subsequently, clarification will be provided for each policy alternative.

Kilometer allowance 5 year	Net Present value (mil €)	
Financial Scheme	€	(9,228)
Benefit	€	161,703
Cost		(€ 170,931)
Health	€	60,277
Benefit	€	60,743
Cost		(€ 0,466)
Pollution	€	0,234
Benefit	€	0,234
Cost	€	-
Infrastructure & maintenance	€	0,114
Benefit	€	0,195
Cost		(€ 0,081)
Travel time	€	0,401
Benefit	€	0,401
Cost	€	-
Excise & Subsidies	€	(0,554)
Benefit	€	0,092
Cost		(€ 0,646)
Road safety	€	(9,076)
Benefit	€	0,530
Cost		(€ 9,607)
Total NPV	€	42,166
Benefit	€	223,898
Cost		(€ 181,732)
Benefit/Cost ratio		1,23

(a) Kilometre allowance

Lease bike 5 year	Net Present value (mil €)	
Financial Scheme	€	12,844
Benefit	€	34,734
Cost		(€ 21,889)
Health	€	152,575
Benefit	€	162,232
Cost		(€ 9,657)
Pollution	€	2,049
Benefit	€	2,049
Cost	€	-
Infrastructure & maintenance	€	0,566
Benefit	€	0,765
Cost		(€ 0,199)
Travel time	€	4,052
Benefit	€	4,052
Cost	€	-
Excise & Subsidies	€	(3,396)
Benefit	€	0,003
Cost		(€ 3,399)
Road safety	€	(41,274)
Benefit	€	5,232
Cost		(€ 46,506)
Total NPV	€	127,417
Benefit	€	209,067
Cost		(€ 81,650)
Benefit/Cost ratio		2,56

(b) Lease bike

Fietsplan 5 year	Net Present value (mil €)	
Financial scheme	€	(124,215)
Benefit	€	124,215
Cost		(€ 248,430)
Health	€	251,300
Benefit	€	260,063
Cost	€	(8,763)
Pollution	€	3,398
Benefit	€	3,398
Cost	€	-
Infrastructure & maintenance	€	1,116
Benefit	€	1,655
Cost		(€ 0,539)
Travel time	€	6,797
Benefit	€	6,797
Cost		€ 0,000
Excise & Subsidies	€	(5,356)
Benefit	€	0,114
Cost	€	(5,470)
Road safety	€	(35,842)
Benefit	€	15,282
Cost		(€ 51,124)
Total NPV	€	97,198
Benefit	€	411,524
Cost	€	(314,326)
Benefit/Cost ratio		1,31

(c) 'Fietsplan'

Figure 5.6: Overview results SCBA for the middle scenario

When examining Figure 5.6, a few noticeable trends come to light. Firstly, it's evident that all three schemes demonstrate social viability, as indicated by their positive B/C ratios.

Secondly, a striking observation is the distinct advantage of the lease bike scheme in terms of its B/C ratio and NPV. Specifically, the B/C ratio for the kilometre allowance stands at 1.23 with an NPV of €42 million, while for the lease bike it's 2.56 with an NPV of €127 million, and for the 'Fietsplan' it's 1.31 with an NPV of €97 million. The lease bike scheme's performance, despite targeting only 15,000 individuals annually compared to the kilometre allowance's reach of around 1.5 million individuals and the 'Fietsplan's' target of 176,320 individuals, is intriguing. This underscores the lease bike scheme's efficacy in generating benefits despite its relatively limited user base. This is mainly attributed to the scheme's cost structure. While providing the kilometre allowance incurs costs of approximately €171 million and the 'Fietsplan' costs around €248 million, the expenses associated with the lease bike scheme are notably lower, at just €22 million. This cost advantage is partly due to the fact that only a small fraction (8.6%) receives full lease cost reimbursement from their employers, while the majority (50.6%) covers partial lease costs. Additionally, a considerable portion (40.8%) of lease bike users lease bicycles without any employer contribution (Appendix C). Employee-incurred costs are encompassed within their consumer surplus, hence not individually quantified. Only employer contributions and missed wage tax are considered in the cost assessment. In contrast, the other two schemes transfer full costs to the business sector and the national government, as depicted in Figure 5.7. Moreover, companies no longer bear expenses associated with past transportation reimbursement methods, effectively erasing costs for self-funded lease bike users.

The lease bike scheme's elevated B/C ratio and NPV are also fuelled by its notable health benefits per individual. This is primarily a result of two factors. Firstly, the scheme encompasses greater distances travelled by commuters and leisure cyclists. E-bikes covered an average one-way distance of 11.4 km within the lease bike scheme, surpassing the 6.85 km of the other two alternatives. Similarly, conventional bicycles averaged 8.75 km per trip, in contrast to the 4.2 km for other options. This translates to an additional 30.7 million commuting kilometres, including 21 million as new cyclist kilometres. In comparison, the kilometre allowance contributed only 11.6 million extra cycling kilometres, including 1.9 million as new cyclist kilometres. For the 'Fietsplan', the figure stood at 61.4 million additional cycling kilometres, comprising 35.6 million as new cyclist kilometres. Consequently, the 'Fietsplan' generates the highest number of new cycling kilometres. However, when viewed per bicycle, these figures are considerably lower, given that the lease bike scheme comprises only 15,000 bicycles compared to the 'Fietsplan's' 176,320 bicycles.

Secondly, these newly added commuter cycling kilometres yield enhanced health benefits. This stems from the fact that a significant portion of these individuals transition from non-active modes, leading to a relatively poorer baseline health condition compared to the additional cycling kilometres covered by existing commuter cyclists (de Haas & van den Berg, 2019).

In Figure 5.7 the benefits and costs of per categories have been determined. For the lease bike, notably high benefits arise from leisure (e-)cycling. Some lease bike users have indicated in the survey that they use the lease bike exclusively for private purposes. Furthermore, they have also specified how much more (or less) they have been cycling privately. In the context of the kilometre allowance and the 'Fietsplan', it is worth noting that the analysis also incorporated the consideration of leisure time usage, as indicated by the study conducted by Menai et al. (2015). However, it is important to acknowledge that this study primarily focused on the influence of new conventional bicycle commuters on leisure time exercise and for the lease bike also leisure e-cycling is taken into account. A more in depth overview of the results per scheme will be given below.

Kilometer allowance Variables	NPV (mil €)
Financial Scheme	***(€ 9,228)***
Consumer surplus	€ 161,703
Km allowance cost companies	(€ 170,931)
Health	***€ 60,277***
Sick leave costs	€ 12,101
Total health care cost reduction	€ 2,253
Total disease burden reduction	€ 11,248
Increased productivity	€ 12,401
Health effects of additional physical actvtity cyclists	€ 18,177
Total Health care effects e-bike commuting	€ 4,563
Reduced life exepctancy due to inhalations of pollutants during commuting	(€ 0,465)
Health effects decrease egress and access	(€ 0,001)
Pollution	***€ 0,234***
GHG emissions	€ 0,164
Noise pollution	€ 0,070
Infrastructure & maintenance	***€ 0,114***
Infrastructure costs reduction	€ 0,195
Additional bicycle infrastructure costs	(€ 0,081)
Parking exploitation costs	€ 0,057
Travel time	***€ 0,401***
Lost Vehicle Hours	€ 0,401
Excise & Subsidies	***(€ 0,554)***
Excise car	(€ 0,646)
Subsidies	€ 0,092
Road safety	***(€ 9,076)***
Crash costs saved	€ 0,530
Extra crash costs due to everyday cycling	(€ 0,052)
Extra cycling crash costs	(€ 9,554)

(a) Kilometre allowance

Lease bike Variables	NPV (mil €)
Financial Scheme	***€ 12,844***
Consumer surplus	€ 15,518
Costs for the reimbursement companies	(€ 7,954)
Total reduction previous financial schemes	€ 19,215
Total tax missed due to tax advantage Individuals	(€ 13,935)
Health	***€ 152,575***
Sick leave costs	€ 0,676
Total health care cost reduction	€ 0,118
Total disease burden reduction	€ 0,591
Increased productivity	€ 0,651
Health effects of additional physical activtity cyclists	€ 29,404
Total Health effects e-bike commuting	€ 53,841
Total health effects no switch conventional cycling leisure	€ 18,179
Total Health effects no switch e-bike leisure	€ 58,771
Health effects of e-bike purchase everyday life	(€ 8,425)
Reduced life exeptancy due to inhalations of pollutants during commuting	(€ 1,231)
Health effects decrease egress and access	(€ 0,001)
Pollution	***€ 2,049***
GHG savings	€ 1,688
Total noise pollution savings	€ 0,361
Infrastructure & maintenance	***(€ 0,006)***
Infrastructure costs reduction	€ 0,193
Additional bicycle infrastructure costs	(€ 0,199)
Parking exploitation costs	€ 0,571
Travel time	***€ 4,052***
Lost Vehicle Hours	€ 4,052
Excise & Subsidies	***(€ 3,399)***
Excise car	(€ 3,399)
Public transoprt subsidies	€ 0,003
Road safety	***(€ 41,274)***
Crash costs saved	€ 5,232
Extra commuter cycling crash costs	(€ 25,258)
Extra crash costs due to everyday cycling	(€ 0,065)
Extra leisure cycling crash costs	(€ 21,183)

(b) Lease bike

Fietsplan Variables	NPV (mil €)
Financial Scheme	***(€ 124,215)***
Increased Consumer surplus km allowance individuals	€ 124,215
Missed tax due reimbursement	(€ 248,430)
Health	***€ 251,303***
Sick leave costs	€ 49,851
Total health care cost reduction	€ 9,997
Total disease burden reduction	€ 49,905
Increased productivity	€ 51,087
Total Health effects e-bike commuting	€ 62,914
Reduced life exepctancy due to inhalations of pollutants during commuting	(€ 2,466)
Health effects of additional physical activtity due to commuter cycling	€ 36,310
Additional health effects of e-bike purchase	(€ 6,294)
Health effects decrease egress and access	(€ 0,003)
Pollution	***€ 3,398***
GHG savings	€ 2,779
Total noise pollution savings	€ 0,619
Infrastructure & maintenance	***€ 0,158***
Infrastructure costs reduction	€ 0,696
Additional bicycle infrastructure costs	(€ 0,539)
Parking exploitation costs	€ 0,958
Travel time	***€ 6,797***
Congestion effects WLO-LOW	€ 6,797
Excise & Subsidies	***(€ 5,356)***
Total Excise	(€ 5,470)
Subsidies	€ 0,114
Road safety	***(€ 35,842)***
Crash costs saved	€ 15,282
Extra crash costs due to everyday cycling	(€ 0,508)
Extra cycling crash costs	(€ 50,616)

(c) 'Fietsplan'

Figure 5.7: In depth overview results SCBA for the middle scenario

Kilometre allowance
In Figure 5.7, it's visible that the costs of the kilometre allowance lie with the employers. However, for the central government, there are also costs, but they are not currently visible in the SCBA because these costs and benefits net out to zero. Nevertheless, it's crucial to acknowledge that the increase in the kilometre allowance affects income distribution, which is not incorporated in this analysis. As individuals engage in higher levels of cycling and receive additional funds provided by companies as part of the reimbursement, it consequently leads to a decrease in the gross profits of these companies. This decrease in tax revenue has significant consequences, as the funds that would have otherwise been contributed by companies are no longer available for allocation towards public investments or for distribution among the wider population. Consequently, this may impact government budgets and potentially limit the resources available for financing essential social provisions such as healthcare, education, or infrastructure projects. Additionally, the shortfall in tax revenue resulting from decreased corporate profits might necessitate the consideration of alternative sources or methods of taxation to maintain fiscal sustainability. However, due to the extra cycling kilometres, healthcare costs decrease, which means government budgets might also need to cover fewer expenses.

Moreover, it becomes evident that a significant benefit is the consumer surplus. This is nearly as large as the costs for the employers, thereby implying that only a marginal proportion can be attributed to the additional cycling kilometres. This can be explained by the fact that for the existing cycling kilometres, one receives an extra €0.02 per kilometre. These were kilometres that were already being cycled to work, so people receive the full consumer surplus over these. Additionally, there are the extra cycled kilometres. Since these kilometres are only covered due to the increased kilometre reimbursement, the rule-of-half is applied here. Thus, over the kilometre allowance of €0.21 per kilometre, the consumer surplus is only €0.105 per kilometre. While the employer still pays the costs of €0.21 per kilometre. As a result, you can see that the NPV of the financial scheme category results in a negative value of €9.2 million. Therefore, if more new cycling kilometres were to arise due to the increase in the kilometre allowance, the NPV of the financial scheme category would become even more negative.

Nevertheless, additional new cycling kilometres wouldn't mean that the B/C ratio would only decrease. This would actually lead to additional significant benefits in categories like health. Here, you can see that additional new cycling kilometres yield higher benefits, as discussed in Figure 5.1.4. This is because new cyclists have the opportunity to switch from another mode of transport, and the relative health of, for example, car drivers is lower than that of cyclists. Therefore, this group experiences higher health benefits per cycled kilometre. Furthermore, new commuter cyclists also tend to become more active in their every day life (Menai et al., 2015).
There are several important aspects to consider when examining the outcomes of the SCBA for the kilometre allowance scheme. The first is that it's evident that by increasing the kilometre allowance, it primarily encourages existing cyclists to cycle more, as 84% of the additional cycling kilometres are attributed to existing cyclists (see Appendix C). Because it's assumed that existing cyclists switch from working from home, they do not replace another mode of transportation. This means that their kilometres only contribute to all the factors in the financial scheme category (Figure 5.7), all the factors in the health category and the cycling crash costs in the category road safety. The other 16% of the additional kilometres affect all the categories and their associated factors. It's clearly visible that the factors on which only the new cyclists kilometres have an effect on, have much smaller costs or benefits. Therefore, the model gives plausible results for the kilometre allowance scheme.

Lease bike
Upon conducting a more detailed analysis, it becomes evident that the "Financial Scheme" category differs from the other two schemes. Here, as with the other schemes, there is the benefit consumer surplus and there are costs including costs for employers/companies as seen in the kilometre allowance scheme, and missed tax as seen in the 'Fietsplan' scheme. However, in addition, there is also another benefit: the reduction in costs for employers due to employees transitioning from alternate schemes to the lease bike scheme. This distinctive aspect underscores a counter intuitive insight, namely providing the lease bike scheme actually yields net social benefits for the "Financial Scheme" category instead of costs, as seen with the other schemes.

Of equal interest is the relatively low consumer surplus within the ”Financial Scheme” category compared to the other two. A diminished consumer surplus within this context implies a lesser degree of benefit derived by the lease bike users. This, in turn, prompts contemplation about the attractiveness of the lease bike scheme to prospective users. Perhaps the low consumer surplus has influenced the widespread adoption of the lease bicycle program and people prefer the kilometre allowance and the former ’Fietsplan’? This difference in consumer surplus deserves attention because it has consequences for the potential trajectory and social acceptance of the lease bicycle programme.

What is particularly positive and striking is the substantial impact on health effects, considering the number relatively small number of cyclist. This is because the majority of lease bike kilometres are covered by individuals with obesity or overweight, accounting for 52%. In contrast, for the kilometre allowance, this figure was 43%. It has been estimated, based on Kelly et al. (2014), that the health effects for the obese and overweight group are much greater, respectively 100% and 43%, compared to 20% or 10% for the healthy group.

In addition, it is important to note that a substantial portion (61%) of the lease bike users are new bicycle commuters, with 13% using conventional bicycles and 48% using e-bikes. Research conducted by Menai et al. (2015) has demonstrated that new conventional bicycle commuters also engage in more physical activity during their leisure time. Therefore, these individuals experience additional health benefits beyond those derived solely from commuting. However, these additional health effects are not taken into account for new e-bike users. In fact, there is a cost associated with these users, as their additional e-bike kilometres reduce walking and conventional cycling kilometres for shopping and leisure purposes (de Haas & Huang, 2022). Nonetheless, there are also benefits associated with leisure e-bike cycling, which can be included in the analysis of the scheme. The survey conducted by lease-a-bike assessed whether individuals cycled more for leisure activities and the distance they covered. These leisure e-bike cycling kilometres can be converted into equivalent conventional cycling kilometres using the MET score for e-bikes and conventional bicycles. It is found that leisure e-bike cycling also has a significant impact on the health category.

Another reason for the high health benefits is the greater distance covered for commuting and leisure trips. The average one-way distance for e-bikes is 11.4 km, compared to 6.85 km for other policy alternatives. Similarly, the average distance for conventional bicycles is higher at 8.75 km, compared to 4.2 km for the other policy alternatives. These greater distances impact all categories except the financial scheme category. They are impacted since the average commuting distance is higher for the individuals of this scheme, meaning that the number of substituted kilometres are also higher per individual. Furthermore, the percentage of car substitution compared to the other modes is fairly high (76.3%). Meaning that the GHG emissions and noise pollution saved is higher per individual. The infrastructure costs for car, scooter and public transport and parking exploitation costs are reduced more. It however also means that bicycle infrastructure result in higher costs. The congestion effects will also be higher since more traffic is reduced because of the greater distanced substituted from car to (e-)bike. The excise missed out on is also larger because of the aforementioned reason and the subsidies for public transport are also higher per individual, nevertheless the substitution from public transport to the lease bike is relatively small (8.1%), so this is quite a small effect. Lastly, this also effects the road safety category. The crash costs saved versus the extra cycling crash costs are compared to the kilometre allowance scheme significantly higher.

Another important aspect of these schemes is that they enable less privileged individuals to lease, for example, an electric bicycle. This promotes the accessibility of sustainable transportation options to a broader audience, including people with limited budgets (BOVAG & KPMG, 2023). The survey also reveals that the majority of respondents choose a lease bike due to the advantage of not requiring a substantial upfront expenditure.

’Fietsplan’

One significant factor contributing to relatively high costs for this financial scheme is the application of the rule of half to the consumer surplus for all purchases. The extent to which individuals who bought a bicycle through the plan would have also leased a bicycle without the discount is unknown. It is worth noting that after the abolition of the bicycle plan in 2020, there was a significant increase in sales, likely driven by the surge in recreational cycling during the COVID-19 pandemic. However, there was a subsequent dip in sales in 2021 (Stichting BOVAG-RAI Mobiliteit, 2022), which is attributed to supply chain issues in the bicycle industry rather than the discontinuation of the plan (BOVAG & KPMG, 2023). Thus, it is challenging to determine the number of bicycles that would have been purchased without the plan, leading to an underestimation of the consumer surplus.

Furthermore, it is possible that individuals purchase a bicycle through the plan but only use it for personal purposes. However, this is not a concern for the calculation of additional commuter kilometres, as it is accounted for in the increase in the number of cycling days per week in the MuConsult (2019) study. Nevertheless, the effect on leisure cycling is unknown and cannot be included in the analysis, potentially resulting in an underestimation of leisure cycling kilometres, resulting in an underestimation of the potential health benefits but also of the road safety costs.

5.4.2. Pessimistic and Optimistic scenario

The pessimistic and optimistic scenario have an impact on the following factors: decreased life expectancy increases in the pessimistic scenario and the health care effects of e-bike commuting, health effects of additional physical activity among cyclists, total disease burden reduction, total health care cost reduction, and lost vehicle hours decrease. Consequently, the costs are higher and the benefits are reduced in this scenario in the pessimistic scenario and vice versa in the optimistic scenario.

For the kilometre allowance and the 'Fietsplan', this also affects the proportion of new and existing cyclists. This was estimated to be 1/8 or 1/5 new cyclists, as mentioned in Appendix C. However, for the lease bike scheme, these effects have already been accounted for through the survey, eliminating the need for ranges in these specific effects.

It is found that all schemes remain having a positive B/C ratio even in the pessimistic scenario, Figure 5.8 and Figure 5.9. Showing that even with the uncertainties of the ranges, the schemes remain economically viable. Something noteworthy is that in the optimistic scenario the NPV for the 'Fietsplan' (€162.4 million) just outperforms the lease bike (€161.8 million). Nevertheless, the B/C ratio remains the highest for all schemes in both scenarios.

Kilometer allowance 5 year		Net Present value (mil €)
Financial Scheme	€	(9,604)
Benefit	€	161,703
Cost		(€ 171,307)
Healthcare	€	44,598
Benefit	€	45,512
Cost		(€ 0,913)
Pollution	€	0,188
Benefit	€	0,188
Cost	€	-
Infrastructure & maintenance	€	0,110
Benefit	€	0,191
Cost		(€ 0,081)
Travel time	€	0,247
Benefit	€	0,247
Cost	€	-
Tax	€	(0,426)
Benefit	€	0,071
Cost		(€ 0,497)
Road safety	€	(9,187)
Benefit	€	0,408
Cost		(€ 9,595)
Total NPV	€	25,926
Benefit	€	208,319
Cost		(€ 182,393)
Benefit/Cost ratio		1,14

(a) Kilometre allowance

Lease bike 5 year		Net Present value (mil €)
Financial Scheme	€	12,844
Benefit	€	34,734
Cost		(€ 21,889)
Healthcare	€	122,463
Benefit	€	134,353
Cost		(€ 11,891)
Pollution	€	2,049
Benefit	€	2,049
Cost	€	-
Infrastructure & maintenance	€	0,566
Benefit	€	0,765
Cost		(€ 0,199)
Travel time	€	3,242
Benefit	€	3,242
Cost	€	-
Tax	€	(3,396)
Benefit	€	0,003
Cost		(€ 3,399)
Road safety	€	(41,274)
Benefit	€	5,232
Cost		(€ 46,506)
Total NPV	€	96,494
Benefit	€	180,377
Cost		(€ 83,884)
Benefit/Cost ratio		2,15

(b) Lease bike

Fietsplan 5 year		Net Present value (mil €)
Financial scheme	€	(124,215)
Benefit	€	124,215
Cost		(€ 248,430)
Healthcare	€	203,497
Benefit	€	211,329
Cost	€	(7,832)
Pollution	€	3,345
Benefit	€	3,345
Cost	€	-
Infrastructure & maintenance	€	1,090
Benefit	€	1,629
Cost		(€ 0,539)
Travel time	€	5,353
Benefit	€	5,353
Cost		€ 0,000
Tax	€	(5,272)
Benefit	€	0,112
Cost	€	(5,384)
Road safety	€	(35,964)
Benefit	€	15,043
Cost		(€ 51,007)
Total NPV	€	47,834
Benefit	€	361,026
Cost	€	(313,192)
Benefit/Cost ratio		1,15

(c) 'Fietsplan'

Figure 5.8: Benefit cost ratio pessimistic scenario

Kilometer allowance 5 year	Net Present value (mil €)	
Financial Scheme	€	(8,853)
Benefit	€	161,703
Cost		(€ 170,556)
Healthcare	€	81,981
Benefit	€	82,000
Cost		(€ 0,019)
Pollution	€	0,280
Benefit	€	0,280
Cost	€	-
Infrastructure & maintenance	€	0,117
Benefit	€	0,199
Cost		(€ 0,081)
Travel time	€	0,593
Benefit	€	0,593
Cost	€	-
Tax	€	(0,682)
Benefit	€	0,113
Cost		(€ 0,795)
Road safety	€	(8,966)
Benefit	€	0,653
Cost		(€ 9,619)
Total NPV	€	64,470
Benefit	€	245,540
Cost		(€ 181,070)
Benefit/Cost ratio		1,36

(a) Kilometre allowance

Lease bike 5 year	Net Present value (mil €)	
Financial Scheme	€	12,844
Benefit	€	34,734
Cost		(€ 21,889)
Healthcare	€	186,117
Benefit	€	193,540
Cost		(€ 7,423)
Pollution	€	2,049
Benefit	€	2,049
Cost	€	-
Infrastructure & maintenance	€	0,566
Benefit	€	0,765
Cost		(€ 0,199)
Travel time	€	4,863
Benefit	€	4,863
Cost	€	-
Tax	€	(3,396)
Benefit	€	0,003
Cost		(€ 3,399)
Road safety	€	(41,274)
Benefit	€	5,232
Cost		(€ 46,506)
Total NPV	€	161,769
Benefit	€	241,186
Cost		(€ 79,416)
Benefit/Cost ratio		3,04

(b) Lease bike

Fietsplan 5 year	Net Present value (mil €)	
Financial scheme	€	(124,215)
Benefit	€	124,215
Cost		(€ 248,430)
Healthcare	€	314,986
Benefit	€	320,519
Cost	€	(5,534)
Pollution	€	3,451
Benefit	€	3,451
Cost	€	-
Infrastructure & maintenance	€	1,142
Benefit	€	1,680
Cost		(€ 0,539)
Travel time	€	8,284
Benefit	€	8,284
Cost		€ 0,000
Tax	€	(5,441)
Benefit	€	0,115
Cost	€	(5,555)
Road safety	€	(35,720)
Benefit	€	15,521
Cost		(€ 51,241)
Total NPV	€	162,487
Benefit	€	473,786
Cost	€	(311,299)
Benefit/Cost ratio		1,52

(c) 'Fietsplan'

Figure 5.9: Benefit cost ratio optimistic scenario

5.4.3. Sensitivity to certain factors

WLO scenarios

WLO-High

This scenario only affects GHG-emissions and Lost Vehicle Hours (LVH). GHG-emissions increase from €0.19/km to €0.77/km, an increase of 305%. LVH increases because the travel time valuation for car commuters increases from €9.55/h to €9.78/h, an increase of 2%. The overall effects are not significant. The B/C ratio of the kilometre allowance doesn't change, the lease bike increases by 3%, and that of the 'Fietsplan' increases by 1%.

Two-degree-low scenario

This scenario only affects GHG-emissions, which increase from €0.19/km to €1.00/km, an increase of 426%. The B/C ratio of the kilometre allowance doesn't change, the lease bike increases by 3%, and that of the 'Fietsplan' increases by 3%.

Two-degree-high scenario

This scenario only affects GHG emissions, which increase from €0.19/km to €4.80/km, an increase of 2426%.The B/C ratio of the kilometre allowance increases with 2%, lease bike increases with 20%, and that of the 'Fietsplan' increases with 16%.

Emissions now become a significant component for both the lease bike and the 'Fietsplan'. For the lease bike, the benefits of reduced GHG emissions now account for 17% of the total benefits. For the 'Fietsplan', this figure is 15%. Previously, for both policy alternatives the GHG-emission only accounted for 1% of the total benefits.

To conclude, the WLO scenarios do not have a great effect on the schemes. Mainly the kilometre allowance is insensitive to a change, this is because only a small reductions in car kilometres is achieved with this scheme. This is because the majority of the additional kilometres come from individuals who previously worked from home and now choose to commute to the office by bike for an additional day.

METs E-bike

Recently, Expertpanel Fietsen & Gezondheid - VSG (2021) advised to use a MET score for the e-bike that was equal to 50% of the MET score of the conventional bicycle. So with a MET score of 6.8 for the conventional bicycle this would result in a MET score of 3.4 for the e-bike. The B/C ratio of the kilometre allowance decreases with 1%, that of the lease bike decreases by 21%, and the B/C ratio of the 'Fietsplan' decreases with 12%.

However, the lease bike scheme remains its position as the most economically favourable scheme when compared to the alternative two schemes. This observation is noteworthy, especially considering that the lease bike scheme incorporates a significant proportion of e-bikes (71%). Furthermore, the health benefits remain the most substantial benefit for the lease bike scheme. Despite the reduction in METs and the subsequent decrement in health benefits (-39%), the lease bike scheme continues to outperform the other two schemes. This outcome can be primarily attributed to the inclusion of leisure cycling, which, when combined with commuter cycling, yields substantial overall benefits. Additionally, the cost structure of the lease bike scheme remains notably low, quickly leading to a positive NPV when contrasted with the other schemes.

Productivity
This scenario analysis will use a less optimistic assumption regarding the increase in productivity, estimating it at either 3% (+200%) or 12.5% (+1150%) (Decisio, 2015; TNO, 2013).

For the scenario with an increase of productivity to 3%, the B/C ratio of the kilometre allowance increases with 9%, the B/C ratio of the lease bike increases with 21%, and that of the 'Fietsplan' increases with 20%.

For the scenario with an increase of productivity to 12.5%, the B/C ratio of the kilometre allowance increases with 65%, the B/C ratio of the lease bike increases by 129%, and that of the 'Fietsplan' increases with 138%. For this scencario the NPV of the 'Fietsplan' (€695 million) outperforms the lease bike (€497 million). Meaning that the Fietspan would result in greater benefits for society than the lease bike. Meaning that it's now up to debate if the lease bike scheme is the most favourable scheme or that the 'Fietsplan' is preferred.

The increase in productivity has a very big effect on the health benefits as the productivity doesn't not only increase due to the kilometres cycled to work but also leisure cycling effects the increase in someones productivity. Next to that, the valuation of labour productivity is quite high. One extra productive hour is worth €61.64 (TNO, 2023).

Crash chance e-bike
This scenario examines effect of the e-bike having a higher average crash cost compared to a regular bicycle. Otero et al. (2018) found that the average crash change of an e-bike is 1.49 to 2.48 times higher than for a conventional bicycle.

Increasing the crash chance with 1.49 doesn't effect the B/C ratio of the kilometre allowance, the B/C ratio of the lease bike drops with 20% and of the 'Fietsplan' with 3%.

Increasing the crash chance with 2.48 decreases the B/C ratio of the kilometre allowance with 1%, the B/C ratio of the lease bike drops with 43% and of the 'Fietsplan' with 10%.

The lease bike and 'Fietsplan' schemes have a much larger e-bike share, 71% and 48%, compared to the kilometre allowance, 15%, therefore the impact the change in crash chance of an e-bike is much larger for these two schemes. It becomes evident that increasing the crash chance of the e-bike has a large effect on the lease bike scheme. However, in both scenarios the lease bike scheme remains to have the higest B/C ratio.

Well-to-wheel emissions
Lastly, the effect of considering well-to-wheel emissions instead of tank-to-wheel emissions will be examined. Since charging e-bikes does release emissions, it is important to understand the implications of including these emissions. However, it should be noted that this may provide a somewhat distorted picture, as all indirect effects are not taken into account in the analysis.

None of the B/C ratios change, indicating that the well-to-tank emissions from e-bikes and speedpedelecs, as from the cars and public transport are negligible in the context of the overall analysis.

5.4.4. Sensitivity to changes of the financial schemes

Km-allowance to €0.40/km

Increasing the kilometre allowance to €0.40/km results in a 3% decrease in the B/C ratio (1.19) for the kilometre allowance scheme, but leads to an increase of the NPV (€389 million) with 822%. The decrease in the B/C ratio is mainly attributed to the fact that the overall benefits due to the additional cycling kilometres grow slower than the increase of the costs due to the increase of the kilometre allowance. MuConsult (2019) found a elasticity of the bicycle kilometres with respect to a kilometre allowance, of 0.0034 per €0.01 increase of the kilometre allowance. This means that they expect that the bicycle kilometres grow linear with the increase of the kilometre allowance. Furthermore, the health benefits also don't grow as fast as for the other two schemes because this scheme mainly targets existing cyclists (86%). Among this group, the health benefits are relatively smaller compared to the other schemes. According to research conducted by de Haas and van den Berg (2019), individuals who predominantly cycle tend to be generally healthy, with obesity rates of 12%, overweight rates of 29%, and a majority (59%) classified as healthy. Conversely, the other schemes attract a larger proportion of individuals who switch from modes such as the car, with obesity rates of 16%, overweight rates of 38%, and a healthy group comprising 46% of the participants.

Lease bike just as big as 'Fietsplan'

Increasing the amount of lease bikes to the same number of bicycle bought with the 'Fietsplan' (176,320) scheme doesn't make a difference for the B/C ratio. The NPV does increase to a value of 1.5 billion instead of 127 million. Meaning that the NPV of the lease bike is 15 times as high as for the 'Fietsplan' (€97 million). So, if the lease bike scheme would ever become as big as the 'Fietsplan' it would have significant higher social benefits than the 'Fietsplan'. However, it cannot be assumed that the lease bike will definitely become as big as the 'Fietsplan'. Nevertheless, the lease bike scheme currently already yields higher benefits with only 15.000 bicycles per year.

Only e-bikes for lease bikes

It is important to approach the analysis of the B/C ratio of the lease bike scheme with caution when considering a scenario in which only one type of bicycle can be leased. This limitation may have implications for the number of bicycles leased. However, as observed in the previous scenario, this particular aspect does not appear to significantly impact the B/C ratio. Nonetheless, other factors should be considered, such as the average price of a lease bike, which currently stands at €3,200, resulting in average monthly lease costs of €100 and an average annual addition of €90.05. In the case of exclusively leasing e-bikes, the average bicycle price could potentially increase, subsequently influencing the average lease costs, and vice versa for conventional bicycles. Consequently, this necessitates an examination of the corresponding changes in consumer surplus, company costs, and the tax revenue foregone by the government.

Neglecting these considerations, it is evident that restricting the lease options to exclusively e-bikes would result in a NPV of €114 million (-10%) and a 8% decrease in the B/C ratio, while still maintaining a positive value of 2.36. However, this outcome is an overestimation since the costs for the financial scheme would increase since the average lease costs would probably increase. Conversely, limiting the lease options to conventional bicycles would lead to a NPV of €146 million (+15%) and a B/C ratio increase of 88% to reach 4.81. Keeping in mind that this is an underestimation as the lease costs would decrease. In both scenarios the B/C ratio remains higher than for the other two schemes and the NPV of the kilometre allowance remains higher.

Higher consumer surplus 'Fietsplan'

When 25% of the consumer surplus is subjected to the "rule of half," the NPV increases to €128 million, consequently leading to an 8% rise in the B/C ratio to 1.41. Employing the "rule of half" across half of the consumer surplus yields an NPV of €159 million alongside a B/C ratio of 1.51, signifying a rise of 15%. When just 25% of the consumer surplus is subjected to the "rule of half", the NPV becomes €190 million, coupled with a B/C ratio of 1.61, demonstrating a robust 23% escalation.
In sum, it is plausible that the 'Fietsplan' may have a higher NPV compared to the present €127 million NPV of the lease bike. This suggests a potential for the 'Fietsplan"s societal impact to exceed that of

the lease bike. Nevertheless, the B/C ratio for the ’Fietsplan’ remains lower than that of the lease bike (2.56). Furthermore, if the lease bike scheme were againt to double in size next year, it would yield an NPV of €255 million. This projection implies that as early as next year, its NPV would surpass that of the ’Fietsplan’ even with a higher consumer surplus for the ’Fietsplan’.

6 Discussion & Conclusion

6.1. Discussion

An initial concern in the early stages of this investigation related to the appropriateness of employing a Social Cost-Benefit Analysis (SCBA) framework for conducting this research. This apprehension stemmed from observations made by Van Wee and Börjesson (2015), who noted the inherent complexities of conducting a robust SCBA due to the intricate challenges associated with estimating and quantifying effects within monetary parameters. Notably, the quantification of effects linked to certain cycling policies posed considerable challenges, primarily due to the ubiquity of cycling in the Netherlands and the intricacies of studying widespread effects throughout the country.

Indeed, these challenges manifested during the course of the study, prompting the utilisation of a diverse array of data sources. The employed methodologies encompassed interviews, survey data sourced from the lease-a-bike program, and an extensive array of heterogeneous literature, including grey literature. Although this multifaceted approach aimed to establish a comprehensive analysis foundation, it's important to recognise the potential for numerical discrepancies that could stem from such an approach. Notwithstanding the heterogeneity of data sources, the validation process included cross-referencing data, expert validation, and the pursuit of convergence among various sources. Although, establishing coherence within the context of such diverse inputs remains inherently challenging. It is assumed that through this validation procedure a level of coherence among the different data sets is achieved.

In spite of the comprehensive data collection, certain factors were excluded from the analysis due to either complexities in determining their effects or limitations in expressing these effects within monetary parameters. For instance, the decision to omit injury costs stemmed from the assumption that their impact might not be significant, driven by the prevailing focus of injury-related research on recreational and competitive cycling rather than conventional cycling. Additionally, factors such as livability, transport poverty, and perceived road safety were excluded due to the inadequacy of research regarding the ramifications of commuter cycling on these dimensions. Consider, for example, a scenario in which an individual transitions from receiving a welfare benefit to obtaining employment due to a financial arrangement facilitating the purchase or lease of a bicycle. The potential substantial benefits stemming from such a scenario underscore the need for further investigation into livability, transport poverty, and perceived road safety. Consequently, the omission of these factors from this analysis is a regrettable circumstance. Nonetheless, it is assumed that the current analysis effectively portrays the effects of the diverse policy alternatives, serving as the most comprehensive representation of our present understanding.

There are also several factors that raise points of discussion. Four of them have a significant impact and also carry uncertainty. The four pivotal factors warranting a discussion are the elasticity of the bicycle kilometre reimbursement in relation to the number of additional cycling kilometres, the distribution between new and existing cyclists for the kilometre allowance scheme, the extent of leisure cycling engagement for the 'Fietsplan', and the consumer surplus linked to the 'Fietsplan'. The first three all associated with travel behaviour factors. Meaning that these pivotal factors could have implications for all the priced factors.

Firstly, the elasticity concerning the bicycle kilometre reimbursement in relation to the number of additional cycling kilometres demands needs to be discussed. This is based on MuConsult (2019), which indicates a linear relationship between the increase in reimbursement and the increase in cycling distance. They found that an increase of €0.019 per kilometre leads to a rise of 0.064 in the distance cycled. Thus, they observe a linear correlation. However, from an intuitive perspective, one might expect that a €0.01 increase per kilometre has relatively less effect than a €0.20 increase per kilometre, and that there might be a threshold point from when people start cycling, indicating that a linear relationship cannot be assumed. Therefore, it is recommended that an experiment is executed to determine when people are willing to switch to cycling or increase their cycling.

Secondly, the distribution between new and existing cyclists for the kilometre allowance should also be debated. The difference between new cyclists under the kilometre allowance and the lease bike scheme is significant, 16% compared to 61%. This can partly be explained by the fact that a relatively large portion of the group offered the kilometre allowance and already uses this arrangement for distances within cycling range. Furthermore, if what has been described above is accurate, it could also be the case that the increase from €0.19 to €0.21 per kilometre doesn't significantly influence people to switch, but that there's a point at which the increase is significant enough to cause a larger group of switchers. Additional research might offer a deeper understanding of the actual influence of the policy on the modal shift.

Thirdly, an in-depth exploration of the consumer surplus associated with the 'Fietsplan' is necessary due to its significant impact on both net present value (NPV) and benefit-cost ratio (B/C ratio). This might involve an exploration of the willingness-to-pay to determine the part of consumer surplus that should be unaffected by the rule-of-half principle. It's possible that the current estimation of consumer surplus for the 'Fietsplan' is underestimated. Moreover, the analysis didn't account for the additional cycling days that individuals intending to purchase a bicycle even without the 'Fietsplan' might undertake. Further exploration could provide insights into the true impact of the policy on cycling behaviour.

Lastly, an exploration into the extent of leisure cycling associated with the 'Fietsplan' is warranted. Since this makes up a substantive component of lease bike usage, while being scarcely considered within the 'Fietsplan' context. The difference could potentially be explained by the fact that the lease bike addresses a lot of new cyclists. However, it might still hold true for new 'Fietsplan' cyclists that they engage in more leisure cycling than calculated in this model. This could mean that the health benefits would be much higher, potentially leading to a higher NPV and perhaps a higher B/C ratio for the 'Fietsplan'. This doesn't need to be investigated for the kilometre allowance as someone doesn't purchase a new bike. The effects of purchasing an e-bike have already been included in this research based on de Haas and Huang (2022). It's notable that in that study, the net health effects are negative, while for the lease bike, the health benefits are very positive. This discrepancy requires further research.

It is also worth noting that existing survey data was utilised in this study, the raw survey data was used from lease-a-bike yielding the opportunity to perform the analyses. Nevertheless, it's important to acknowledge that this company derives its revenue from lease bike services. Furthermore, the formulation of certain questions posed challenges for the respondents to comprehend them correctly. As a result, it is possible that the reported average travel distances may have been overestimated. When comparing these distances to the average commuting distance, they were nearly twice as high. This discrepancy raises questions about the accuracy of the reported travel distances and emphasises the importance of ensuring clear and precise survey questions in future research to enhance data validity and reliability.

Lastly, it is necessary to acknowledge an additional effect; all three schemes result in a decrease in tax income. This decline in tax revenue has noteworthy consequences, as this could lead to funds no longer being available for allocation towards public investments or for distribution among the broader population. Consequently, this may affect government budgets and potentially limit the resources available for financing crucial social provisions such as healthcare, education, or infrastructure projects. Additionally, the shortfall in tax revenue resulting from decreased corporate profits might necessitate the consideration of alternative sources or methods of taxation to maintain fiscal sustainability. Nevertheless, because of the extra cycling kilometres the healthcare costs, infrastructure costs, etc., decrease. Resulting in the fact that government budgets might also need to cover less expenses. Meaning that it is vital to underscore the significance of carefully evaluating these broader economic and fiscal implications when formulating policies. While the promotion of cycling and the provision of financial incentives to individuals for adopting healthier transportation choices hold inherent merits, policymakers must take into account the potential trade-offs and distributional effects. Ensuring an equitable balance between on the one hand incentivising sustainable mobility and on the other sustaining public finances requires thoughtful deliberation and the inclusion of relevant stakeholders to arrive at informed and socially responsible decisions.

6.2. Conclusion

This thesis can be concluded by answering the research questions, formulated in chapter 1. The main research question was as follows:

”What are the social costs and benefits associated with financial schemes promoting bicycle commuting in the Netherlands?”

In order to answer this question, sub-questions 1-4 needed to be answered first. A short conclusion of each sub-question is presented below, including a reference to the corresponding report sections.

Sub-question 1: What factors should be considered when evaluating the social costs and benefits of financial schemes pertaining to commuter cycling?

Van Wee and Börjesson (2015) pointed out that to enhance the Social Cost-Benefit Analysis (SCBA) technique for cycling, more studies should strive to present a well-rounded and extensive assessment of the costs, benefits, and repercussions of cycling policies. This study has made a valuable contribution towards this enhancement by meticulously compiling a comprehensive list of 59 factors, as illustrated in Table B.1 and Table B.2. The construction of this list was achieved through a methodical brainstorming process, extensive literature review, and insightful interviews. From this comprehensive list, 19 factors were identified as suitable for monetisation within the context of the Social Costs-Benefit analysis; these were referred to as ”priced factors.”

Following this, a conceptual model was developed to visually represent the interdependencies among these factors, underscoring the intricate nature of the subject matter, depicted in chapter 4. Once the relations between factors were established, clarifying which factors affected each other, it became possible to ascertain which effects could and could not be determined. This determination was made based on the availability of existing literature and insights gained from interviews.

As a result, five of the priced factors were eliminated, namely Transport poverty, Materials required, Livability, Perceived road safety and Injury costs. Leaving a total of 14 priced factors, which could be categorised into seven categories, namely Financial Scheme-specific, Health, Pollution, Infrastructure & Maintenance, Travel Time, Excise & Subsidies and Road Safety. These remaining factors were subsequently subjected to in-depth exploration and analysis through sub-questions two to four. This comprehensive investigation significantly contributed to an enriched understanding of the subject matter.

Sub-question 2: What are the effects of the financial schemes on travel behaviour and the priced factors?

When all effects where depicted in the conceptual model and the factors where filtered, the quantification of the diverse effects took place. Guided by the conceptual model a systematic determination of which effects required quantification could be determined, as outlined in section 5.1. The first step was determining the travel behaviour effects, which are policy alternative specific. Since these effects were not extensively studied, relying on insights obtained from interviews, documented in detail in Appendix C, was necessary. Additionally, empirical data analysis from MuConsult (2019) provided valuable insights into the impact of increasing the kilometre allowance and adopting the 'Fietsplan' scheme on cycling kilometres. The effects of the lease bike scheme's were determined with a dataset derived from a survey conducted by lease-a-bike. Although some of these values were debated in section 3.3, they proved to give some valuable insights and were considered the most robust available at the time. The second part required determining the effects on the priced factors (subsection 5.1.4). For this step the available literature proved to be a reliable resource, given the considerable body of research conducted in this domain.

Sub-question 3: What are the social costs and benefits of the identified factors?

The priced factors that have the most substantial influence on the social costs and benefits encompassed the costs and benefits associated with the implementation of the financial schemes, the health-related benefits and the road safety costs. Within the context of the kilometre allowance, the financial scheme accounts for the largest benefits and costs. Specifically, the consumer surplus constituted 72% of the total benefits, while the costs attributed to companies represented 94% of the total costs. In contrast, the lease bike scheme demonstrated comparatively lesser magnitudes of benefits and costs for the implementation of the financial scheme. The consumer surplus accounted for 8% of the overall benefits, and company costs constituted only 10% of the total costs. Notably, the health benefits were pronounced in this scheme, comprising a substantial 78% of the total benefits, while costs were predominantly associated with crash incidents stemming from increased cycling activity, constituting 57% of the total costs. Regarding the 'Fietsplan' scheme, health benefits accounted for 63% of the total benefits, while consumer surplus contributed 30% of the overall benefits. The most substantial cost for this scheme was attributed to the tax income missed by the central government, encompassing 79% of the total costs.

Furthermore, certain costs and benefits that had minimal influence were considered in the analysis. Notably, the pollution category accounted for less than 1% of total benefits across all three schemes and incurred no associated costs. The Infrastructure & Maintenance category displayed a similar pattern, contributing to less than 1% of costs and benefits for all three schemes. The Travel Time category exhibited no costs and the benefits were below 2% for all schemes. Finally, the Excise & Subsidies category demonstrated relatively limited influence, with benefits less than 1% in all cases. For the lease bike scheme, this category constituted 4.2% of costs, while for the other two schemes, it remained below 2%.

Although some benefits and costs were excluded from the analysis since their effects couldn't be determined, although these factors were excluded it is assumed that the SCBA gave a comprehensive overview of the costs and benefits associated with the subject matter.

Sub-question 4: What areas of research should be prioritised to address the identified gaps and improve the overall robustness of the model?

As discussed in section 3.3, it became evident that there are four factors that have a significant impact and carry uncertainty. The four pivotal factors requiring further research are the elasticity of the bicycle kilometre allowance in relation to the number of additional cycling kilometres, the distribution between new and existing cyclists for the kilometre allowance scheme, the consumer surplus linked to the 'Fietsplan', and the extent of leisure cycling engagement for the 'Fietsplan'. Improving the robustness of these factors would improve the knowledge on the travel behaviour factors, consequently improving the overall robustness of the model.

Next to that, further research should be carried out on the factors which are excluded because of the lacking of available literature. These factors are Transport poverty, Livability and Perceived road safety. The magnitude of these factors is now unknown but they may have a significant impact on the subject matter.

After answering the sub-question, it is now possible to answer the main research question:

"What are the social costs and benefits associated with financial schemes promoting bicycle

commuting in the Netherlands?"

The social cost-benefit analysis reveals that the lease bike scheme outperforms the other schemes in terms of societal benefits, with a net present value (NPV) of €127 million and a benefit cost ratio (B/C ratio) of 2.56, whereas the kilometre allowance has a NPV of €42.2 million and a B/C ratio of 1.23 and the 'Fietsplan' scheme has a NPV of €97.2 million and a B/C ratio of 1.31. The success of the lease bike scheme can be attributed to its success in attracting a significant number of new cyclists. Moreover, insights from the lease-a-bike survey shed light on the increased kilometres covered by participants in their private lives, allowing for the inclusion of these effects for individuals who exclusively use the lease bike for personal purposes. For the kilometre allowance and the 'Fietsplan' scheme leisure activity was also taken into account. However, for these schemes only the influence of new conventional bicycle commuters on leisure time exercise was accounted for, leading to less benefits.

The transition to the lease bike in comparison to the 'Fietsplan' emerges as a favourable transition based on the findings of this analysis. This implies that, based on this analysis, the national government should best concentrate on expanding the reach of the lease bike. Nevertheless, it is advisable that prior to immediate action, an additional experiment should be undertaken to assess the elasticity of the kilometre allowance associated to the travelled commuter cycling kilometres. This consideration stems from the fact that this particular measure holds a wide-reaching impact, as it reaches the majority of the working population. Furthermore, the consumer surplus of the lease bike is significantly lower than for the other two schemes, indicating that consumers experience less well-being under this scheme and may opt for a scheme where their consumer surplus is higher. Meaning that it may be difficult to increase the number of lease bikes significantly.

All in all, the SCBA method seems to remain a robust approach for describing the socio-economic costs and benefits associated with financial schemes promoting commuter cycling. While certain factors have been omitted from the analysis, a substantial array of factors has been encompassed, thereby presenting a coherent picture of the societal ramifications of these financial interventions. Evidently, this underscores the versatility of the SCBA methodology, indicating its applicability not solely to its conventional use in infrastructure projects but also to incentive-driven initiatives.

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A

Scientific paper

Abstract

The Netherlands is confronted with challenges such as traffic congestion, overburdened public transportation, and obesity. These issues could potentially be mitigated by elevating the cycling modal share. To attain this objective, the Dutch central government has introduced a range of strategies aimed at fostering commuter cycling. This study examines one of these strategies, namely financial schemes encompassing the kilometre allowance, lease bike, and ’Fietsplan’. The financial schemes are analysed by creating an extensive conceptual model which is thereafter used to make a comprehensive Social Cost-Benefit Analysis (SCBA). Using both methods contributes to improving the SCBA technique for cycling policies by presenting a well-rounded and extensive assessment of the associated costs and benefits. The results of the SCBA show that the lease bike scheme is the most socio-economically favourable financial scheme. The validity and reliability of the results could be improved by researching the elasticity of the kilometre allowance in relation to the number of additional cycling kilometres, the percentage switcher by different heights of the kilometre allowance and to determine the willingness to pay of individuals for a bicycle to better determine the consumer surplus of the ’Fietsplan’.

Keywords: Financial Scheme, Commuting, Cycling, SCBA, Conceptual Model.

Introduction

The Netherlands is a leading cycling country with a high modal share of cycling compared to other European countries (Buehler & Pucher, 2012).The potential benefits of increasing the cycling modal share are significant, given the challenges of traffic congestion, overcrowded public transport, and obesity in the Netherlands (ANWB, 2017; Heinen, 2010; Ministry of Health Welfare and Sport, 2022; Nijland & Dijst, 2015; Olde Kalter, 2007; Rabl & de Nazelle, 2012; Rover, 2022; RTL Nieuws, n.d.). To encourage more people to use bicycles for commuting, the government has implemented policies like the ’Kies de Fiets’ initiative (Ministry of Infrastructure and Water Management, 2023b). However, despite these efforts, the percentage of people using bicycles for commuting remains at 30% for a distance up to 7.5 km and 20% for a distance between 7.5-15 km as of 2019 (Ministry of Infrastructure and Watermanagment, 2023). It is found that for 33% of the people who cycle to work, the availability of the kilometre allowance plays a role in their mode choice. Ministry of Infrastructure and Water Management (2023b) also found that 25% of the commuters by car are willing to choose for a different transport mode with the ”appropriate arrangements”. So, there is an opportunity for policymakers to adjust current policies to encourage more people to cycle to work. Therefore, this paper will look into three different financial schemes which are in place to motivate people to cycle to work, namely the kilometre allowance, the lease bike and the ’Fietsplan’ (Ministry of Infrastructure and Water Management, 2023a).

The tax-free kilometre allowance allows employees to receive a tax-free reimbursement for each kilometre travelled by bicycle for commuting purposes. As of January 2023, the allowance has been increased from 0.19 €/km to 0.21 €/km, therefore it's interesting to see what the social effects are of this increase. Under the lease bike scheme, employees can lease a (electric) bicycle for commuting without having to purchase one personally. Employees are granted unrestricted personal use of the company bicycle from a tax perspective. However, they are required to pay an annual addition of 7% of the consumer price of the bicycle. Additionally, there are lease costs associated with leasing a bicycle, which can be paid by the employer, shared between the employer and employee, or entirely covered by the employee from their gross salary. The 'Fietsplan' scheme allowed employees to purchase a bicycle every three years using their gross salary. Employees could deduct a bicycle with a value of up to 749 euros from their gross salary, resulting in a tax benefit of 370.76 euros considering a tax rate of 49.5%. These schemes are evaluated compared to the reference alternative where no such schemes is implemented, and employees received a kilometre reimbursement of €0.19/km for both bicycle and car usage.

The goal is to understand the societal impact of these schemes and their effectiveness in promoting bicycle commuting in the Netherlands. To answer this, the following research question is formulated: the following research question: *What are the social costs and benefits associated with financial schemes promoting bicycle commuting in the Netherlands?*. This is answered by developing a conceptual model to create a well-rounded overview of the effect of the financial schemes on travel behaviour and the priced factors, thus the social benefits and costs. Hereafter, a computational model is constructed to calculate the effect of the financial schemes on the social costs and benefits.

This paper is structured as follow. First, this paper addresses current literature Appendix A, to determine which priced factors are taken into account when analysing the social costs and benefits of cycling policies. In Appendix A the different modelling techniques are elaborated on. The results will be presented in Figure A. A discussion will be presented in Figure A. To conclude, in Figure A the conclusions of the paper are presented and recommendations for further research are done.

Literature review

It is found that there is not a lot of literature on the cost-benefit analyses of cycling policies. Most (S)CBAs which are cycling related, look at infrastructural changes and look at the travel time savings, which is more similar to conventional transport (S)CBAs (Decisio & Transaction Management Centre, 2012; Foltnova & Kohlova, 2002; Macmillan et al., 2014). There are however some that try to capture more behavioural aspects (Beenker & Goedhart, 2018; Rabl & de Nazelle, 2012; Sieg, 2014). These effects are however more difficult to capture. One of the problems is that it is difficult to establish a clear reference case and this is crucial to assess the impact of the specific policy (Beenker & Goedhart, 2018; Van Wee & Börjesson, 2015). Without a clear reference case, it can be difficult to distinguish the true effects of the policy from other factors that may be influencing the outcome, leading to confusion and inaccurate conclusions.

Next to that, there is no clear framework for the factors which must be included in a (S)CBA regarding bicycle commuting incentive policies. There is some overlap between the current CBA's. All take factors into account such as health and emissions. However, some also look at different aspects of health and emissions and some include additional factors such as, labour productivity, network effects, effects of exposure change from car to bicycle (Decisio & Transaction Management Centre, 2012; Rabl & de Nazelle, 2012). Some factors are spoken about but not yet taken into account, such as the change in the perception of safety of the bicyclist, the influence of commuting-related fringe benefits or the effect of e-bikes on cycling distance and health (Elvik, 2000; Foltnova & Kohlova, 2002; Fyhri & Fearnley, 2015; MuConsult, 2019).

Several studies, including Macmillan et al. (2014), Rabl and de Nazelle (2012), and Van Wee and Börjesson (2015), have highlighted the benefits of conducting further research using SCBA to evaluate cycling policies. Despite the relevance of commuting-related policies, they have not yet been addressed in SCBA studies. Therefore, this paper will provide a well-rounded picture of the costs and benefits associated with commuter cycling policies. Subsequently, it becomes evident which factors require to be included in a SCBA analysing cycling policies. Thereupon, a SCBA will be constructed using incorporating these factors to evaluate a commuting-related policy, namely the three aforementioned three financial schemes.

Modelling

Conceptual model

The first step is determining the factors which need to be considered when evaluating the social costs and benefits of financial schemes related to commuter cycling. This done by performing a structured brainstorm, literature research, and conducting interviews. This led to an exhaustive list of 44 factors, among the identified factors, 19 factors were suitable for monetisation and are referred to as ”priced factors.” Given the time frame not all factors could be explored in the thesis, therefore these factors were filtered based on the availability of literature and interviews, resulting in 14 priced factors.

These factors were modelled in a conceptual model to show how these factors affect each other. The conceptual model is depicted below, Figure A.1.The red factor is the policy alternative financial scheme-specific factor. The white factors are the factors related to travel behaviour. The blue factors are the priced factors, these are divided into three different categories. The dark blue factors are the priced factors that influence society. The blue factors influence the individual that cycles due to the financial scheme. The light blue factors influences both the society as the individual. Next to that, there are also grey factors, these are the factors that are eliminated from this research. The light grey factors are the factors related to travel behaviour and the dark grey factors are the eliminated priced factors.

A remarkable factor to consider is the effect of emissions on the life expectancy of individuals who choose cycling as their commuting mode over driving a car. This shift entails a transition from an enclosed vehicular environment to cycling in an open-air setting, introducing additional emissions that marginally impact their life expectancy (de Hartog et al., 2010; Harms & Kansen, 2018; Rabl & de Nazelle, 2012). Conversely, the wider populace benefits from the reduction in emissions attributable to the decrease in car kilometres travelled. Furthermore, the financial incentives show a significant impact on fostering engagement in cycling among both new and established cyclists. While the distinction between these two groups may appear relatively insignificant, it is essential in assessing implications, particularly for health outcomes. Specifically, individuals transitioning from a sedentary lifestyle to a more physically active one can access the comprehensive spectrum of health advantages associated with cycling. Conversely, for those who are already highly physically active, the incremental health effects arising from increased cycling involvement are slightly more modest (Decisio & Ministry of Infrastructure and Water Management, 2017).

Computational model

Having established a comprehensive understanding of how financial schemes influence travel behaviour and subsequently impact the priced factors, these factors need to be quantified and then monetised. The conceptual model offers a structured framework for determining the effects that necessitate quantification. Primarily, the specific impacts of the financial schemes on travel behaviour are evaluated, given their limited prior examination, insights obtained from interviews were required. Moreover, valuable insights into the effects of augmenting the kilometre allowance and implementing the 'Fietsplan' scheme on cycling kilometres were derived from data analysis by MuConsult (2019). In the case of the lease bike scheme, a dataset sourced from a survey by lease-a-bike was employed.

For the purpose of effect determination, it is crucial to define the reference alternative (Beenker & Goedhart, 2018; Van Wee & Börjesson, 2015). In this analysis, the reference alternative is set as the 'do-nothing' or 'do-minimal' scenario (Annema et al., 2015). To ensure comparability across policy alternatives, the same reference alternative is adopted for all three schemes. Consequently, the ”reference-alternative,” should be set at 2020, since the introduction of the lease bike scheme and the abolition of the 'Fietsplan' were in 2020. Nonetheless, the year 2020 was profoundly shaped by the COVID-19 pandemic, leading to significant disruptions in commuting patterns. Hence, the reference alternative is set to 2022, as observations indicated that travel levels were recovering in 2021 and stabilising in 2022 (Ministry of Infrastructure and Watermanagment, 2023). This means that the

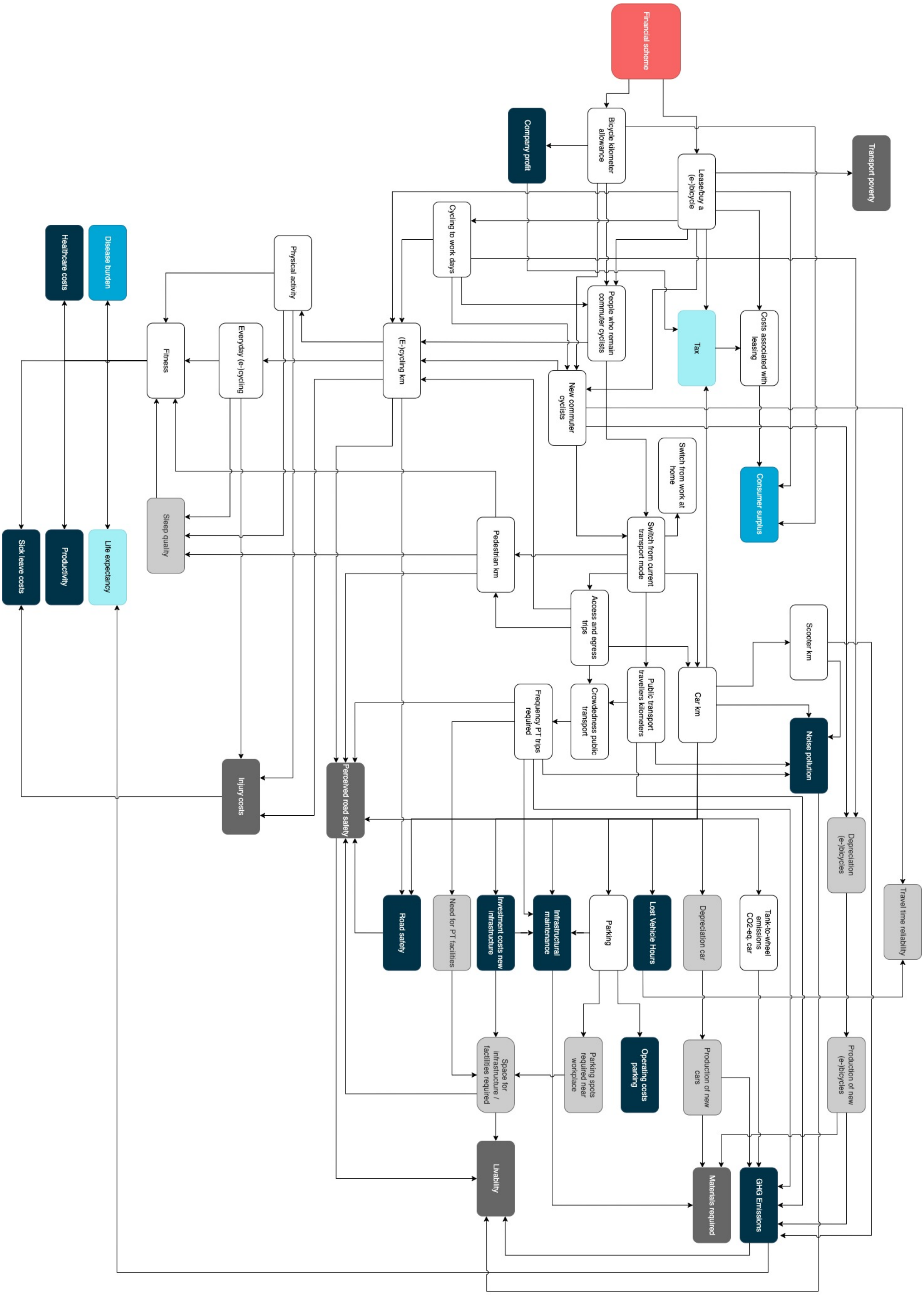

Figure A.1: Conceptual model

annual commuter cycling distance was 4.1 billion kilometres in the reference alternative. The average cycling distance amounted to 4.2 km for conventional bicycles and 6.85 km for e-bikes. The distribution between conventional bicycles and e-bikes stood at 85% and 15%, respectively. The number of commuting days was on average 3.1 days per week. The average gross income was €38,500/year, accompanied by an average tax burden of 40.2%. The modal split for commuting trips encompassed 62% car usage, 8% public transport (2% bus and 6% train), 24% bicycle, 3% walking, and 4% other modes (Centraal Bureau voor de Statistiek, 2022; de Haas & Huang, 2022; Ministry of Infrastructure and Watermanagment, 2023; Stichting BOVAG-RAI Mobiliteit, 2022).

Subsequently, the general effects, priced factors, underwent quantification, drawing upon extant literature due to the substantial corpus of research in this domain. These effects are categorised across seven domains: financial scheme-specific, healthcare, pollution, infrastructure & maintenance, travel time, tax, and road safety. Following quantification, all effects were translated into monetary values expressed in units such as €/km or €/h. This conversion process enabled a standardised and comparable evaluation of effects across diverse financial schemes and factors. By expressing effects in monetary terms, a comprehensive Social Cost-Benefit Analysis (SCBA) was facilitated, enabling the ascertainment of the social costs and benefits associated with each financial scheme geared towards enhancing bicycle commuting in the Netherlands.

In the course of this analysis, it emerged that certain factors introduced a level of uncertainty into the evaluation. To address this, a scenario analysis was undertaken to provide a more comprehensive perspective. The initial step involved formulating scenarios for effects that were characterised by a range of values. These scenarios were anchored by a middle scenario, which functioned as the baseline for subsequent modifications. To better understand the variability within these ranges, both a lower and upper scenario were constructed.

The lower scenario, framed from a cautious standpoint, embraced the minimised the benefits and maximised the costs. This approach aimed to explore whether the policy alternatives could withstand positive outcomes even when faced with the most challenging circumstances. Conversely, the upper scenario adopted an optimistic stance by considering the upper bounds for benefits and the lower bounds for costs. Crucially, both scenarios retained a foundation in reality, as the ranges were derived from insights sourced from expert interviews, established scientific literature, and relevant grey literature sources.

Furthermore, the analysis extended beyond the scenario analysis to encompass experimentation with discrete variables within the emissions, health, and road safety categories. This investigative step enriched the understanding of how individual variables interplayed within the broader framework.

Finally, the study examined the impact of different financial schemes through experiments. For instance, one notable experiment involved the adjustment of the kilometre allowance to €0.40 per kilometre, mirroring a recent change introduced by KPN (NOS, 2023). This rounded out the exploration of various factors and policy alternatives, shedding light on their potential implications in different scenarios.

Results

When examining Figure A.2, several prominent trends emerge. Firstly, all three schemes exhibit social viability, evident from their positive Benefit-Cost (B/C) ratios.

Secondly, a noteworthy observation pertains to the lease bike scheme's distinctive advantages in terms of B/C ratios and Net Present Value (NPV). Specifically, the kilometre allowance boasts a B/C ratio of 1.23 with an NPV of €42 million, while the lease bike attains 2.56 with an NPV of €127 million, and the 'Fietsplan' records 1.31 with an NPV of €97 million. The lease bike's strong performance in noteworthy, since it targets only 15,000 individuals annually compared to the kilometre allowance's outreach to around 1.5 million individuals and the 'Fietsplan's' scope of 176,320 individuals. This underscores the lease bike scheme's efficacy in generating benefits despite its relatively limited user base. This is primarily attributed to its cost structure. While providing the kilometre allowance results in costs of approximately €171 million and the 'Fietsplan' incurs around €248 million, the lease bike scheme's expenses are significantly lower, at just €22 million. This cost-effectiveness is due to the fact that most employees partially of fully pay the lease costs themselves. his cost-effectiveness is partly due to a small fraction (8.6%) receiving full lease cost reimbursement from employers, while most (50.6%) cover partial lease costs. Additionally, a substantial portion (40.8%) of lease bike users lease bicycles without employer contributions (I10, I13). Employee-incurred costs are encompassed within their consumer surplus and are therefore not individually quantified. Resulting in the significantly lower costs for the lease bike scheme.

The lease bike scheme's elevated B/C ratio and NPV are also fuelled by its considerable health benefits per individual. This arises primarily from two factors. Firstly, the scheme involves greater distances covered by commuters and leisure cyclists. Specifically, for commuting distances, lease bike users cover nearly twice the distance compared to the other two schemes. This translates to an additional 30.7 million commuting kilometres, including 21 million new cyclist kilometres. In comparison, the kilometre allowance contributes only 11.6 million extra cycling kilometres, including 1.9 million as new cyclist kilometres. For the 'Fietsplan', the figure stands at 61.4 million additional cycling kilometres, encompassing 35.6 million new cyclist kilometres. Consequently, the 'Fietsplan' generates the highest number of new cycling kilometres. However, when viewed per bicycle, these figures are significantly lower, given that the lease bike scheme comprises only 15,000 bicycles compared to the 'Fietsplan's' 176,320 bicycles.

Secondly, these newly added commuter cycling kilometres yield enhanced health benefits. This is due to a significant proportion transitioning from non-active modes, resulting in relatively poorer baseline health conditions compared to the additional cycling kilometres covered by existing commuter cyclists (de Haas & van den Berg, 2019).

Kilometer allowance 5 year	Net Present value (mil €)	
Financial Scheme	€	(9,228)
Benefit	€	161,703
Cost		(€ 170,931)
Health	€	60,277
Benefit	€	60,743
Cost		(€ 0,466)
Pollution	€	0,234
Benefit	€	0,234
Cost	€	-
Infrastructure & maintenance	€	0,114
Benefit	€	0,195
Cost		(€ 0,081)
Travel time	€	0,401
Benefit	€	0,401
Cost	€	-
Excise & Subsidies	€	(0,554)
Benefit	€	0,092
Cost		(€ 0,646)
Road safety	€	(9,076)
Benefit	€	0,530
Cost		(€ 9,607)
Total NPV	€	42,166
Benefit	€	223,898
Cost		(€ 181,732)
Benefit/Cost ratio		1,23

(a) Kilometre allowance

Lease bike 5 year	Net Present value (mil €)	
Financial Scheme	€	12,844
Benefit	€	34,734
Cost		(€ 21,889)
Health	€	152,575
Benefit	€	162,232
Cost		(€ 9,657)
Pollution	€	2,049
Benefit	€	2,049
Cost	€	-
Infrastructure & maintenance	€	0,566
Benefit	€	0,765
Cost		(€ 0,199)
Travel time	€	4,052
Benefit	€	4,052
Cost	€	-
Excise & Subsidies	€	(3,396)
Benefit	€	0,003
Cost		(€ 3,399)
Road safety	€	(41,274)
Benefit	€	5,232
Cost		(€ 46,506)
Total NPV	€	127,417
Benefit	€	209,067
Cost		(€ 81,650)
Benefit/Cost ratio		2,56

(b) lease bike

Fietsplan 5 year	Net Present value (mil €)	
Financial scheme	€	(124,215)
Benefit	€	124,215
Cost		(€ 248,430)
Health	€	251,300
Benefit	€	260,063
Cost	€	(8,763)
Pollution	€	3,398
Benefit	€	3,398
Cost	€	-
Infrastructure & maintenance	€	1,116
Benefit	€	1,655
Cost		(€ 0,539)
Travel time	€	6,797
Benefit	€	6,797
Cost		€ 0,000
Excise & Subsidies	€	(5,356)
Benefit	€	0,114
Cost	€	(5,470)
Road safety	€	(35,842)
Benefit	€	15,282
Cost		(€ 51,124)
Total NPV	€	97,198
Benefit	€	411,524
Cost	€	(314,326)
Benefit/Cost ratio		1,31

(c) Fietsplan

Figure A.2: Results SCBA middle scenario

The priced factors that have the most substantial influence on the social costs and benefits encompassed, the costs and benefits associated with the implementation of the financial schemes, the health-related benefits and the road safety costs. In the kilometre allowance, the category financial scheme drives significant benefits (72% consumer surplus) and costs (94% company costs). Conversely, the category financial scheme shows lower benefits for the lease bike scheme (8% consumer surplus) and costs (10% company costs), but the lease bike scheme has notable health benefits (78%) and crash-related costs (57%). For the 'Fietsplan', health benefits (63%) and consumer surplus (30%) dominate the benefits, while missed tax income forms a major cost (79%).

However, some categories were also analysed that ultimately turned out to have less influence. The less influential categories include pollution (less than 1% benefits, no costs), Infrastructure & Maintenance (less than 1% costs and benefits), Travel Time (no costs, under 2% benefits), and Excise & Subsidies (benefits below 1%, 4.2% costs for lease bike, below 2% for others).

The scenario analyses underscored that, even in a pessimistic scenario characterised by minimised benefits and maximised costs, the financial schemes upheld positive NPV and B/C ratios. Furthermore, the investigation delved into specific influential factors that held a more significant sway over the model's results. In particular, changes in the MET value for the E-bike, an increased crash probability for the E-bike, and a heightened valuation for productivity gains emerged as primary drivers. This exploration accentuated the model's responsiveness to shifts in these particular parameters, highlighting their pivotal role in shaping the overall results.

Discussion

An initial concern in the early stages of this investigation related to the appropriateness of employing a Social Cost-Benefit Analysis (SCBA) framework for conducting this research. This apprehension stemmed from observations made by Van Wee and Börjesson (2015), who noted the inherent complexities of conducting a robust SCBA due to the intricate challenges associated with estimating and quantifying effects within monetary parameters. Notably, the quantification of effects linked to certain cycling policies posed considerable challenges, primarily due to the ubiquity of cycling in the Netherlands and the intricacies of studying the effects of widely prevalent infrastructural provisions throughout the country.

Indeed, these challenges manifested during the course of the study, prompting the utilisation of a diverse array of data sources. The employed methodologies encompassed interviews, survey data sourced from the lease-a-bike program, and an extensive array of heterogeneous literature, including grey literature. While this multitudinous approach aimed to provide a comprehensive foundation for analysis, it is worth acknowledging the potential for numerical inconsistencies that may arise from such an approach. Notwithstanding the heterogeneity of data sources, the validation process included cross-referencing data, expert validation, and the pursuit of convergence among various sources. Although, establishing coherence within the context of such diverse inputs remains inherently challenging. It is assumed that through this validation procedure a level of coherence among the different data sets is achieved.

In spite of the comprehensive data collection, four factors raise discussion as they have a significant impact and also carry some uncertainty. The four pivotal factors warranting a discussion are the elasticity of the bicycle kilometre reimbursement in relation to the number of additional cycling kilometres, the distribution between new and existing cyclists for the kilometre allowance scheme, the extent of leisure cycling engagement for the 'Fietsplan', and the consumer surplus linked to the 'Fietsplan'. The first three all associated with travel behaviour factors. Meaning that these pivotal factors could have implications for all the priced factors. Therefore, additional research into these four factors could provide insights into the true impact of the policy alternatives on cycling behaviour.

Although all schemes have positive NPV and B/C ratios, it's important to note distributional effects occur. Namely, the schemes lead to reduced tax incomes, impacting government budgets, potentially limiting resources for key social provisions. Additionally, alternative taxation sources may be needed for fiscal sustainability. However, increased cycling kilometres could potentially lower healthcare costs, infrastructure costs, etc., reducing budgetary pressures.

Conclusion & Recommendations

Van Wee and Börjesson (2015) pointed out that to enhance the Social Cost-Benefit Analysis (SCBA) technique for cycling, more studies should strive to present a well-rounded and extensive assessment of the costs, benefits, and repercussions of cycling policies. This study has made a valuable contribution towards this enhancement by meticulously compiling a comprehensive list of 59 factors, of which 19 priced factors. Of these factors some were eliminated from the analysis due to the unavailability of literature. Resulting in 14 priced factors, across six different domains; Financial Scheme-specific, Health, Pollution, Infrastructure & Maintenance, Travel Time, Excise & Subsidies and Road Safety.

The social cost-benefit analysis reveals that the lease bike scheme outperforms the other schemes in terms of societal benefits, with a net present value (NPV) of €127 million and a benefit cost ratio (B/C ratio) of 2.56, whereas the kilometre allowance has a NPV of €42.2 million and a B/C ratio of 1.23 and the 'Fietsplan' scheme has a NPV of €97.2 million and a B/C ratio of 1.31. The success of the lease bike scheme can be attributed to its cost structure. Next to that, the scheme is very successful in attracting a significant number of new cyclists. Moreover, insights from the lease-a-bike survey shed light on the increased kilometres covered by participants in their private lives, allowing for the inclusion of these effects for individuals who exclusively use the lease bike for personal purposes. For the kilometre allowance and the 'Fietsplan' scheme leisure activity was also taken into account. However, for these schemes only the influence of new conventional bicycle commuters on leisure time exercise was accounted for, leading to less benefits.

The transition to the lease bike in comparison to the 'Fietsplan' emerges as a favourable transition based on the findings of this analysis. This implies that, based on this analysis, the national government should best concentrate on expanding the reach of the lease bike. Nevertheless, it is advisable that prior to immediate action, an additional experiment should be undertaken to assess the elasticity of the kilometre allowance associated to the travelled commuter cycling kilometres. This consideration stems from the fact that this particular measure holds a wide-reaching impact, as it reaches the majority of the working population. Furthermore, the consumer surplus of the lease bike is significantly lower than for the other two schemes, indicating that consumers experience less well-being under this scheme and may opt for a scheme where their consumer surplus is higher. Meaning that it may be difficult to increase the number of lease bikes significantly.

All in all, the SCBA method seems to remain a robust approach for describing the socio-economic costs and benefits associated with financial schemes promoting commuter cycling. While certain factors have been omitted from the analysis, a substantial array of factors has been encompassed, thereby presenting a coherent picture of the societal ramifications of these financial interventions. Evidently, this underscores the versatility of the SCBA methodology, indicating its applicability not solely to its conventional use in infrastructure projects but also to incentive-driven initiatives.

B
Factors and effects

Table B.2 shows the factors found that are relevant for the analysis of the societal costs and benefits of financial schemes regarding commuter cycling, including their associated effects and their assigned category.

Table B.1: Justification conceptual model

Factor	Source
Access and egress trips	**Structured brainstorm**, Molin and Timmermans (2010)
Climate effects	Beenker and Goedhart (2018), Decisio and Transaction Management Centre (2012), Foltnova and Kohlova (2002), Macmillan et al. (2014), Ministry of Infrastructure and Watermanagment (2023), and Rabl and de Nazelle (2012)
Consumer surplus	**Structured brainstorm**, Annema and van Wee (2021)
Crowded public transport	**Structured brainstorm**, Centraal Planbureau en Kennisinstituut voor Mobiliteitsbeleid (2009) and Decisio and Transaction Management Centre (2012)
Cycling to work days	Ministry of Infrastructure and Watermanagment (2023) and Mu-Consult (2019)
Depreciation bicycle	**Structured brainstorm**, BOVAG and KPMG (2023), *Interview bicycle repairman*
Depreciation car	**Structured brainstorm**
Disease burden	Bauman (2004), Decisio and Ministry of Infrastructure and Water Management (2017), Peters et al. (2021), and Warburton et al. (2006)
(E-)cycling km	**Structured Brainstorm**, Cairns et al. (2017) and de Haas and Huang (2022)
Everyday cycling	Menai et al. (2015)
Everyday e-cycling	**Structured Brainstorm**, de Haas (2019)
Excise taxes	Centraal Planbureau en Kennisinstituut voor Mobiliteitsbeleid (2009) and Decisio and Transaction Management Centre (2012)
GHG (Green House Gas) emissions	Beenker and Goedhart (2018), Decisio and Transaction Management Centre (2012), Foltnova and Kohlova (2002), Macmillan et al. (2014), Ministry of Infrastructure and Watermanagment (2023), and Rabl and de Nazelle (2012)
Fitness	Beenker and Goedhart (2018), Macmillan et al. (2014), Rabl and de Nazelle (2012), and Sieg (2014)

Table B.1: Justification conceptual model

Factor	Source
Frequency public transport trips required	Centraal Planbureau en Kennisinstituut voor Mobiliteitsbeleid (2009) and Decisio and Transaction Management Centre (2012)
Fuel burn	Macmillan et al. (2014)
Health care cost	Bauman (2004), Beenker and Goedhart (2018), Foltnova and Kohlova (2002), Peters et al. (2021), and Warburton et al. (2006)
Infrastructural maintenance	Centraal Planbureau en Kennisinstituut voor Mobiliteitsbeleid (2009) and Decisio and Transaction Management Centre (2012)
Injury costs	Peters et al. (2021) and van Beijsterveldt et al. (2020)
Investment costs new infrastructure	Centraal Planbureau en Kennisinstituut voor Mobiliteitsbeleid (2009) and Decisio and Transaction Management Centre (2012)
Labour productivity	Decisio and Transaction Management Centre (2012)
Life expectancy	Beenker and Goedhart (2018), Decisio and Transaction Management Centre (2012), Harms and Kansen (2018), Peters et al. (2021), and Rabl and de Nazelle (2012)
Livability	**Structured brainstorm**, *Interview Talens, H.*
Lost vehicle hours	Beenker and Goedhart (2018), Decisio and Transaction Management Centre (2012), and Hilbers et al. (2020)
Materials required	**Structured brainstorm**, Mc Laughlin (2021) and UN Environment Programme (2019)
New commuter cyclists	**Structured brainstorm**, *Interview Aarts, R., Woltjer, J., Hartmans, K., van Bekkum, P.*
Noise pollution	Beenker and Goedhart (2018), CE Delft (2022, 2023), Decisio and Ministry of Infrastructure and Water Management (2017), Decisio and Transaction Management Centre (2012), and Foltnova and Kohlova (2002)
Parking	**Structured brainstorm**, Centraal Planbureau en Kennisinstituut voor Mobiliteitsbeleid (2009) and Decisio and Transaction Management Centre (2012)
Parking spots required near workspace	**Structured brainstorm**, Amsterdam Bike City (2021)
People who remain commuter cyclists	**Structured brainstorm**, Decisio and Transaction Management Centre (2012), *Interview Aarts, R., Woltjer, J., Hartmans, K., van Bekkum, P.*
Perceived road safety	**Structured brainstorm**, *Interview Papadimitrou, E.*
Physical activity	**Structured brainstorm**, de Haas (2019) and Menai et al. (2015)
Possibility to own/lease a bike	**Structured brainstorm**, BOVAG and KPMG (2023), *Expert group SCBA bicycles, Woltjer, J.*
Production of new (e-)bicycles	**Structured brainstorm**
Production of new cars	**Structured brainstorm**
Road safety	Beenker and Goedhart (2018), Decisio and Transaction Management Centre (2012), Foltnova and Kohlova (2002), Macmillan et al. (2014), Otero et al. (2018), and Rabl and de Nazelle (2012)
Scooter km	CE Delft (2022) and Ministry of Infrastructure and Watermanagment (2023), *Lease-a-bike*

Table B.1: Justification conceptual model

Factor	Source
Sick leave cost	Beenker and Goedhart (2018), Decisio and Ministry of Infrastructure and Water Management (2017), Peters et al. (2021), and TNO (2009)
Sleep quality	**Structured brainstorm**, Mahfouz et al. (2020), Sleep Foundation (2022), and Wang and Boros (2019)
Space for infrastructure/facilities required	**Structured brainstorm**
Subsidies for public transport	Decisio and Transaction Management Centre (2012)
Switch from current transport mode	Decisio and Transaction Management Centre (2012)
Transport poverty	**Structured brainstorm**, BOVAG and KPMG (2023), Government of the Netherlands (2022), and Rabl and de Nazelle (2012), *Expert group SCBA bicycles*
Travel time reliability	Annema and van Wee (2012), Decisio and Ministry of Infrastructure and Water Management (2017), Decisio and Transaction Management Centre (2012), and Foltnova and Kohlova (2002)

Table B.2: Effects

Factors (Open coding)	**Monetary value**	**Sub-category** (Axial coding)	**Category** (Selective coding)
Stroke	€1,360 mil	*Health care costs*	*Healthcare*
Depression	€1,040 mil		
Breast cancer	€812.7 mil		
Colon cancer	€557.9 mil		
Diabetes	€1,308 mil		
Dementia	€10,309 mil		
Osteoporosis	€110.7 mil		
Coronary heart disease	€1,439 mil		
Depression	€84,320 DALY	*Disease burden*	
Breast cancer	€45,900 DALY		
Colon cancer	€36,000 DALY		
Diabetes	€80,400 DALY		
Dementia	€5,880 DALY		
Osteoporosis	€730 DALY		
Stroke	€68,100 DALY		
Coronary heart disease	€81,000 DALY		
Productivity	72.83 €/h	*Labour*	
Sick leave costs	641.06 €/year (1-3 days per year)		

Table B.2: Effects

Factors (Open coding)	**Monetary value**	**Sub-category (Axial coding)**	**Category (Selective coding)**
Exposure to emissions	1760.55 €/person (1-40 days short living)	*Other*	
Tank to wheel CO_2-eq. car	0.022 €/km (114.8 g CO_2-eq./tkm	*Emissions*	*Pollution*
Tank to wheel CO_2-eq. public transport	0.00032 €/km (39.7 g CO_2-eq./tkm)		
Noise pollution car	0.0047 €/tkm		
Noise pollution scooter	0.145 €/tkm		
Noise pollution public bus	0.0197 €/tkm		
Noise pollution train	0.0012€/tkm		
Urban public transport subsidies train	0.03 €/km	*Subsidy*	*Tax*
Urban public transport subsidies bus	0.29 €/km		
Excise tax Gasoline	0.79 €/l	*Excise*	
Excise tax Diesel	0.52 €/l	*Excise*	
Excise tax LPG	0.19 €/l	*Excise*	
Car crash costs	0.069 €/km	*Crashes*	*Road safety*
Scooter crash costs	0.396 €/km		
(E-)bike crash costs	0.176 €/km		
Bus crash costs	0.050 €/km		
Train crash costs	0.001 €/km		
Lost vehicle hours	9.55-9.78 €/h	*Congestion*	*Travel time*
Infrastructural maintenance & investment costs car	0.0022 €/km	*Infrastructure & maintenance costs*	*Infrastructure & maintenance*
Infrastructural maintenance & investment costs bike	0.0015 €/km		
Infrastructural maintenance & investment costs scooter	0.0053 €/km		
Infrastructural maintenance & investment costs bus	0.0384 €/km		
Infrastructural maintenance & investment costs train	0.0272 €/km		
Parking exploitation costs	0.005 €/km	*Parking*	

C
Interviews

Table C.1: Interviewees

Interviewee	Employer	Expertise	Argumentation
I1	BOVAG	Spokesperson of BOVAG	Could offer documents on lease-bikes and insights in the WCS.
I2	Breikers	Promoting cycling to work among employers	Could offer additional contacts for potential interviews and provide data regarding the lease-bike and the Work Cost Scheme.
I3	RAI	Spokesperson RAI	Could offer documents on lease-bikes
I4	3PM	Helping employers stimulate employees to cycle to work	Gathering data and understanding of the effects of the lease-bike and the work-related costs scheme.
I5	TU Delft	Road safety	Could offer assistance in obtaining data and articles concerning perceived road safety, as well as contribute to the determination that this factor may be excluded from the computational model.
I6	RAI-vereniging	Section manager of cycling at RAI	Performed a quickscan on the lease-bike.
I7	HelloRider	Director of HelloRider	Could give insight into the lease-bike market.
I8	CROW	Improving the role of the bicycle in the transportation system and the optimisation of the quality of public spaces	Could offer assistance in obtaining data and articles concerning livability, as well as contribute to the determination that this factor may be excluded from the computational model.

Table C.1: Interviewees

Interviewee	Employer	Expertise	Argumentation
I9	BOVAG	Contact person for the report from BOVAG and KPMG (2023)	To get some clarification on some statements made in the report
I10	Lease-a-bike	Contact through I2 as she has knowledge on the lease-bike scheme	They conducted a survey on their costumers behaviour such as their change in travel behaviour and showed my the preliminary results.
I11	MuConsult	Advisor at MuConsult	I11 assisted on the report MuConsult (2019), so he could help clarify some question.
I12	Ministry of Infrastructure and Water Management	Determining health effects of a modal shift to cycling	Is part of the Mobiliteitspanel Nederland. So he could offer assistance in which knowledge is available.
I13	Lease-a-bike	General Manager at lease-a-bike	They conducted a survey on their costumers behaviour such as their change in travel behaviour and agreed to provide me with the data sheets so I could conduct my own data analysis.
I14	MuConsult	Lease bike scheme	I14 researched the lease bike scheme for his own master thesis.
I15	Ecorys	Health benefits of cycling	Could offer insigths into the analysishe performed on the health benefits of cycling.

I1 - BOVAG, Spokesperson - 16/05
BOVAG lacks insights into lease bicycles and the Work Cost Scheme, and does not conduct in-depth analyses of bicycle sales. It is suggested that Breikers or RAI, represented by Linda van Dijk, may offer more comprehensive information. However on 24/05 he could provide me with the report BOVAG and KPMG (2023), which gave a lot of insight into the lease-bike market.

I2 - Breikers, Director - 16/05
Aarts believes that people are completely deterred from opting for a lease bike due to the inclusion of additional costs. Thus, implying a binary price elasticity. He recommends contacting PON, a company offering lease-a-bike services, as they may possess greater insights into the matter. Aarts himself doesn't know specific types and approximate quantities of leased bicycles. Breikers provides complimentary mobility advice to encourage businesses to adopt more sustainable commuting options. Through this initiative, they have successfully motivated approximately 7% of employees to transition to more eco-friendly commuting practices. He is not familiar with any specific implementation details of the Work Cost Scheme or whether a standardised approach even exists.

I3 - RAI, Spokesperson - 17/05
Regrettably, RAI does not possess information pertaining to lease bicycles. It is recommended to directly contact bicycle leasing companies for such inquiries. RAI's available data is limited to new sales. Alternative contacts suggested include reaching out to BOVAG or ANWB.

I4 - 3PM Mobility Advisor for Employers - 17/05
Lenoir opines that individuals are generally insensitive to the taxable benefit associated with lease bicycles, as he perceives it to be negligible. He provides a contact, Gijs I7, the CEO of HelloRider, with the hope that I7 may offer further insights into the market. Regarding the RAI Association's advocacy for a reduced taxable benefit, Lenoir directs inquiries to I6. He explains that Teksta told hem that the implementation of the Work Cost Scheme is entirely flexible.

I5 - TU Delft, Road Safety - 22/05
The quantification and monetisation of perceived road safety could prove to be an engaging endeavour. However, it poses significant challenges and could serve as a separate thesis or Ph.D. research topic. Conducting surveys or similar methodologies would be required, rendering it a promising avenue for future research.

I6 - RAI Association, Bicycle Division Manager - 22/05
I6 highlights a crucial change whereby, in addition to lease bicycles, there is now an option to provide a kilometre allowance for employees who do not commute by bicycle. Nevertheless, the perception of lease bicycles presents challenges, as individuals perceive a reduction in income due to the elimination of commuting allowances and the requirement to pay for the lease bicycle. I6 posits that the Work Cost Scheme is presently ineffective, although it may still be practised in certain contexts, its rarely discussed within the RAI-vereniging network. He argues that reducing the taxable benefit from, for instance, 7% to 4% would yield little impact, as individuals are already deterred by the notion of incurring expenses and would assess whether they are financially better off using the bicycle. By that stage, the impetus for change is already lost. Lease bicycles have not yet reached the level of the previous company bicycle scheme, constituting approximately 20% of its scope.

I7 - HelloRider, Director - 23/05
On average, around 10% of the employees per employers choose for a lease bicycles, which can rise to 40% over time. The extent of daily usage among these users remains uncertain. However, I7 anticipates that it exceeds current estimations, as these predominantly focus on regular bicycles, whereas electric bicycles are primarily leased. He cannot specify the number of lease bicycles they possess, but the market consists of approximately 30,000, the same number mentioned by I6. The lease bike market approximately doubles in size every year. He wouldn't cooperate with sharing information from their survey, because I declined sharing the final computational model.

I8 - CROW, Project Manager - 24/05
Quantifying the attractiveness of a bicycle path presents a considerable challenge. Determining the criteria for attractiveness, such as the number of trees, poses difficulties in establishing a precise measure. Nevertheless, studies have explored the relationship between bicycle path width and the corresponding ratings received.

I9 - BOVAG - 08/06
For obtaining specific data on lease bicycles, it is advisable to contact VNA-Lease. Currently, the lease market in the Netherlands is relatively small, yet it holds considerable potential. Other countries, such as Belgium and Germany, provide subsidies for lease bicycles, which is particularly crucial for incentivising bicycle adoption among a larger segment of the population. In contrast, the Dutch government's focus is less on stimulating bicycle ownership, given the high prevalence of bicycles already in use. Consequently, efforts are primarily aimed at encouraging bicycle usage. I9 contends that the issue of taxable benefit is not a significant concern, as individuals can lease a brand-new e-bike at a relatively low cost. Instead, he identifies employers as the main hurdle due to complex regulations, especially for small and medium-sized enterprises (SMEs), which may impede their engagement in the leasing process. Furthermore, he suggests that estimating the number of lease bicycles at 20% (equivalent to 30,000 units) is an underestimate, favouring the more realistic figure of 100,000 lease bicycles stated in the BOVAG & KPMG report (BOVAG & KPMG, 2023). Additionally, he speculates that approximately 90% of the corporate leasing market comprises lease bicycles.

I10 - Lease-a-bike - 15/06

I10 presented a preview of the expected publication in early July. They conducted a study among 4500 lease bike users, which yielded interesting data. The results indicate that, as a result of the lease bike, 53% of the users cycle more for commuting purposes, with an average increase of approximately 1-3 additional trips. Furthermore, the initial estimate of 90% e-bike usage was found to be overstated. Specifically, 68% of the users have an e-bike, while the remaining bicycles consist of bakfietsen (6%) and speed pedelecs (8.7%). Additionally, 7.1% leased a city bike, and 8.7% opted for a race bike. The average purchase price of the lease bikes is €3200.

I11 - MuConsult - 19/06
He worked on the sidelines of the report MuConsult (2019) and it was already four years ago, so he couldn't give an in depth explanation about the change in cycling days due to the financial schemes. However, he mentioned that people who already cycle are easier to convince to cycle a bit more than people who have to switch. Furthermore, he could give an estimate on the ratio between switchers and existing cyclists. Namely, best case would be 1/5 to 4/5 and worst case would be 1/8 to 7/8.

I12 - KiM - 17/07
He notes a shift in the user group of e-bikes, which renders his previous research on user groups from 2021 less applicable. In addition, he conducted a study on the health of users employing different transportation modes. Presently, e-bike users exhibit relatively poorer health, but he anticipates that as more people adopt e-bikes, their health profiles will become more representative of the general population. However, there is no indication that people gain weight from switching to an electric bicycle. Particularly interesting was the observation that even schoolchildren are now using electric bikes. He pointed out that children who were previously driven to primary school by car are more likely to opt for less active modes of transportation later in life. Thus, if these schoolchildren would have otherwise chosen scooters, it might have implications for their future inclination towards motorised vehicles (car, scooter, motor). Moreover, he investigated the effects of e-bike purchase on usage and found that the effects are enduring, rather than confined to the year immediately after purchase. Regarding safety effects, he is unsure whether it is appropriate to equate the safety impacts of e-bikes with those of conventional bicycles. Intuitively, he believes that the safety risks might be higher for e-bikes due to their higher speeds. Notably, there is an increase in older bicycle accident victims who predominantly belong to the category of e-bike users. However, establishing this conclusively is challenging due to underreporting, especially for single-bicycle accidents. He does not expect e-bikes to entirely dominate the bicycle market, as conventional bicycles will remain popular due to their lower cost. Additionally, for some individuals, the willingness to pay for a bicycle is likely to remain lower than the purchase price of an e-bike. Furthermore, many people choose not to use their e-bikes in city centres or around stations due to concerns about theft susceptibility in those areas.

D

Calculations computational model

Financial scheme specific

$$Consumer.surplus = (p_0 - p_1) * q_0 + 1/2 * (p_0 - p_1)(q_1 - q_0) \tag{D.1}$$

$$Km.allowance.cost.companies = additional.km.bicycle_a[km/y] * km.allowance.price[€/km] + remaining.km.bicycle_a[km/y] * increase.km.allowance.price[€/km] - \sum_{s=scheme.type}^{j=mode} (substituted.km_j[km/y] * scheme.price_s[€/km]) \tag{D.2}$$

$$Lease.cost.companies = (partial.reimbursement.price[€/person] * people.partial.reimbursment[person] + lease.price[€/person] * people.fully.reimbursement[person] - \sum_{s=scheme.type}^{j=mode} (subsituted.km_j[km/y] * scheme.price_s[€/km]) \tag{D.3}$$

$$Fietsplan.costs = reimbursement[€/bicycle] * bicycles.sold[bicycles/y] * tax.rate[\%] \tag{D.4}$$

Healthcare

$$Sick.leave.costs = \sum_{a=activity.level} (sick_leave_costs[€/km] * additional.km.bicycle_a[km/y] * effectivenss_a[\%]) \tag{D.5}$$

$$Productivity = \sum_{a=activity.level} (productivity[€/km] * additional.km.bicycle_a[km/y] * effectivenss_a[\%]) \tag{D.6}$$

$$Healthcare.cost.reduction = \sum_{a=activity.level} (healthcare.cost.reduction[€/km] * additional.km.bicycle_a[km/year] * effectivenss_a[\%]) \tag{D.7}$$

$$Disease.burden.reduction = \sum_{a=activity.level} (disease.burden.reduction[€/km]* additional.km.bicycle_a[km/year]* effectivenss_a[\%]) \quad (D.8)$$

$$Reduced.life.expectancy = reduced.life.expectancy.costs[€/km]* additional.km.bicycle_a[km/y] \quad (D.9)$$

$$Health.care.effects.Ebike = \sum_{a=activity.level} (Health.effects[€/MET] * MET.ebike[MET/h]/ speed[km/h] * additional.km.bicycle_a[km/y] * effectivenss_a[\%]) \quad (D.10)$$

$$Health.effects.switch.to.commuting = \sum_{a=activity.level} (additional.activity[€/week/person]* additional.cyclist_a[person] * effectiveness_a[\%] * 52[w/y] \quad (D.11)$$

$$Health.effects.purchasing.ebike = \sum_{a=activity.level} (decreased.activity[€/week/person]* additional.e.cyclist_a[person] * effectivenss_a[\%] * 52[w/y] \quad (D.12)$$

Pollution

$$Noise.pollution = \sum_{j=mode} (Noise.price_j[€/km] * km.subsituted_j[km/y] \quad (D.13)$$

$$GHG.emissions = \sum_{j=mode} (Tank.to.wheel_j[gCO_2 - eq./km]/1000[g/kg] * CO_2.price[€/kgCO_2]* km.subsituted_j[km/y]) \quad (D.14)$$

Infrastructure & maintenance

$$Parking.exploitation.costs = Subsituted.km_car[km/y]* parking.exploitation.costs[€/km] \quad (D.15)$$

$$Infrastructure.costs.reduction = \sum_{j=mode} (Subsituted.km_j[km/y]* marginal.infra.costs_j[€/km] \quad (D.16)$$

$$Infrastructure.costs.bicycle = additional.km_bicycle[km/year]* marginal.infra.costs_bicycle[€/km] \quad (D.17)$$

Travel time

$$LVH = subsituted.km_car[km/y]/total.travelled.km.rush.hour_car[km/y] * Decrease.LVH.per.1\%.increase.traffic_car[\%] * Total.LVH[h] * VOT.commuting_car[€/h] \quad (D.18)$$

Tax

$$Excise.tax = \sum_{i=fueltype} (Fuel.consumption_i[l/km] * share.car_i[\%] * excise.price_i[€/l] * km.subsituted_i[km/y]) \quad (D.19)$$

$$Public.transport.subsidies = \sum_{j=mode} (Subsidy_j[€/km] * km.subsituted_j[km/y] \quad (D.20)$$

Road safety

$$Crash.costs.saved = \sum_{j=mode} (Subsituted.km_j[km/y] * crash.costs_j[€/km] \quad (D.21)$$

$$Crash.costs.bicycle = additional.km_bicycle[km/year] * crash.costs_bicycle[€/km] \quad (D.22)$$

E

Survey Lease-bike

This survey was conducted from 29/03/2023 to 5/18/2023 and received 4639 responses. The questions asked were:

1. What is your age?
2. How long have you owned the lease bike?
3. What type of bike are you leasing?
4. What percentage of your work do you do from home versus on-site?
5. How often do you cycle per week? (Each trip counts as one time)
6. What is your average cycling distance?
7. What is your usual mode of transportation to work? [Primary]
8. What is your usual mode of transportation to work? [Secondary]
9. How many kilometres do you travel for each trip from home to work?
10. Have you increased or decreased your cycling frequency for commuting since owning a lease bike?
    - Focus on commuting: How many more times per week do you choose the bike for commuting?
    - Why?
    - Focus on commuting: How many fewer times per week do you choose the bike for commuting?
    - Why?
11. What financial arrangement applied to you before opting for a lease bike?
12. What was the decisive factor for choosing a lease bike instead of buying one?
13. Does your employer make a monthly financial contribution to your lease bike?
14. Focus on private use: Have you increased or decreased your private cycling since owning the lease bike?
    - Focus on private use: How many more times per week do you choose the bike for private use?
    - Why?
    - Focus on private use: How many fewer times per week do you choose the bike for private use?
    - Why?
15. Does the lease bike replace other modes of transportation? (Private or for commuting)
    - If yes, which mode of transportation does it replace?

- How often does the lease bike replace the other mode of transportation? (per week)

16. Have you noticed a difference in your fitness since owning a lease bike?
17. Have you noticed a difference in your concentration at work since owning a lease bike?
18. Have you noticed a difference in your job satisfaction since owning a lease bike?
19. Have you noticed a difference in your contribution to a better world since owning a lease bike?
20. On a scale of 1 to 10, how would you rate your employer for offering the Bike Lease Plan?

Due to the wording of question 6, the answers provided are not uniformly clear. Question 6 lacks specificity regarding the time frame, whether it refers to one-way or round trips, or possibly the average per day, week, month, or year. As a result, many respondents provided an explanation alongside the numerical value they entered. It appears that most respondents interpreted the answer as referring to a single trip, especially since question 5 asked about the number of one-way trips made per week. To ensure realistic results, all values above 200 km were removed. Some explanations indicated that people still travel around 150 km when going on tours. Furthermore, all responses with explanations were processed to the extent possible, and if processing was not possible, those responses were also removed. This resulted in 4598 remaining responses.

Additionally, question 9 also posed challenges because not everyone uses the lease bike for commuting to work. However, this was not a problem since these answers were not necessary for the data analysis of the distances cyclists travelled to their workplaces. Some individuals had different travel patterns due to visiting clients. When one day's distance was indicated as 1 km and the next day's as 3 km, an average value of 2 km was chosen. If the distance was not specified, these data points were also excluded from the analysis of the average distance travelled for commuting. There were ... data points remaining to determine this distance. However, it was decided to specify these distances by bike type to accurately assess the health effects.

The answers for the bicycle types also required revision, rephrasing, or grouping. For example, touring bikes and hybrid bikes were categorized under "Other." Fatbikes were grouped under "Other E-bikes." As a result, nine categories remained: e-bike, speed pedelec, E-MTB, E-cargo bike, Other E-bikes, City bike, MTB, road bike, and Other. Due to some categories having a very small percentage of respondents, they were not included in the analysis, namely E-MTB (1.4%), Other E-bikes (0.4%), and Other (1.6%). The number of respondents per remaining bicycle type was as follows:

Bicycle type	**Number of respondents**	**Share**
E-bike	3134	68.2%
Speed pedelec	100	2.2%
E-bakfiets	278	6.1%
Conventional bike	408	8.9%
MTB	196	4.3%
Racing bike	323	7.0%

Table E.1: Number of respondents

Per different type of bicycle the average travel distance are established to get a clear picture of the health effects per bicycle type, but also to establish the GHG emission reduction:

Bicycle type	Leisure distance	Commuting distance
E-bike	29,6 km	30,34 km
Speed pedelec	37,2km	23,49 km
E-bike MTB	27,8 km	12,66 km
E-Bakfiets	9,8 km	14,29 km
E-bike Overig	14,4 km	8,79 km
Stadsfiets	9 km	13,25 km
MTB	38,1 km	15,18 km
racingfiets	69,6 km	21,17 km
Overig	34,7 km	18,58 km
Average total average distance	29,9 km	26,33 km

Table E.2: Travel distance per bicycle

Switch km E-bike	Distance	Share
No switch	17,643,058.21	30%
Switch from scooter	1,400,242.72	2%
Switch from car	31,178,737.80	53%
Switch from private bike	4,536,786.40	8%
Switch from Public transport	3,397,922.32	6%
Switch from walk	354,728.15	1%

Table E.3: Travel distance e-bike

Switch km speedpedelec	Distance	Share
No switch	445,036.54	24%
Switch from scooter	18,543.19	1%
Switch from car	1,223,850.48	66%
Switch from private bike	37,086.38	2%
Switch from Public transport	129,802.32	7%
Switch from walk	-	0%

Table E.4: Travel distance speedpedelec

Switch km E-bakfiets	DistanceShare	
No switch	402,403.87	16%
Switch from scooter	8,942.31	0.4%
Switch from car	1,707,980.86	69%
Switch from private bike	187,788.47	8%
Switch from Public transport	125,192.31	5%
Switch from walk	56,653.85	2%

Table E.5: Travel distance e-bakfiets

Switch km conventional bike	DistanceShare	
No switch	1,083,407.68	55%
Switch from scooter	24,291.65	1%
Switch from car	597,574.64	30%
Switch from private bike	131,174.92	7%
Switch from Public transport	111,741.6	6%
Switch from walk	34,008.31	2%

Table E.6: Travel distance conventional bike

Switch km MTB	DistanceShare	
No switch	291,959.17	77%
Switch from scooter	0	0%
Switch from car	67,672.66	18%
Switch from private bike	19,335.04	5%
Switch from Public transport	-	0%
Switch from walk	-	0%

Table E.7: Travel distance MTB

Switch km racing bike	DistanceShare	
No switch	658,354.28	75%
Switch from scooter	2,731.76	0.3%
Switch from car	128,392.74	15%
Switch from private bike	54,635.21	6%
Switch from Public transport	27,317.6	3%
Switch from walk	10,927.04	1%

Table E.8: Travel distance racing bike

Previous scheme	Share
No scheme	25.8%
Lease car	21.5%
Mobility plan	5.2%
Public transport card	9.8%
Kilometre allowance	37.7%

Table E.9: Switch from financial scheme

Bicycle type	Percentage that cycles more often private	Number of times more often	Percentage that cycles more often commuting	Number of times more often
E-bike	78%	3.31	63%	3.14
Speedpedelec	45%	1.52	87%	3.38
E-bakfiets	85%	4.32	37%	2.6
Conventional bike	49%	1.98	32%	3
MTB	74%	1.72	23%	2.26
Racing bike	63%	1.51	26%	2.13

Table E.10: Additional trips