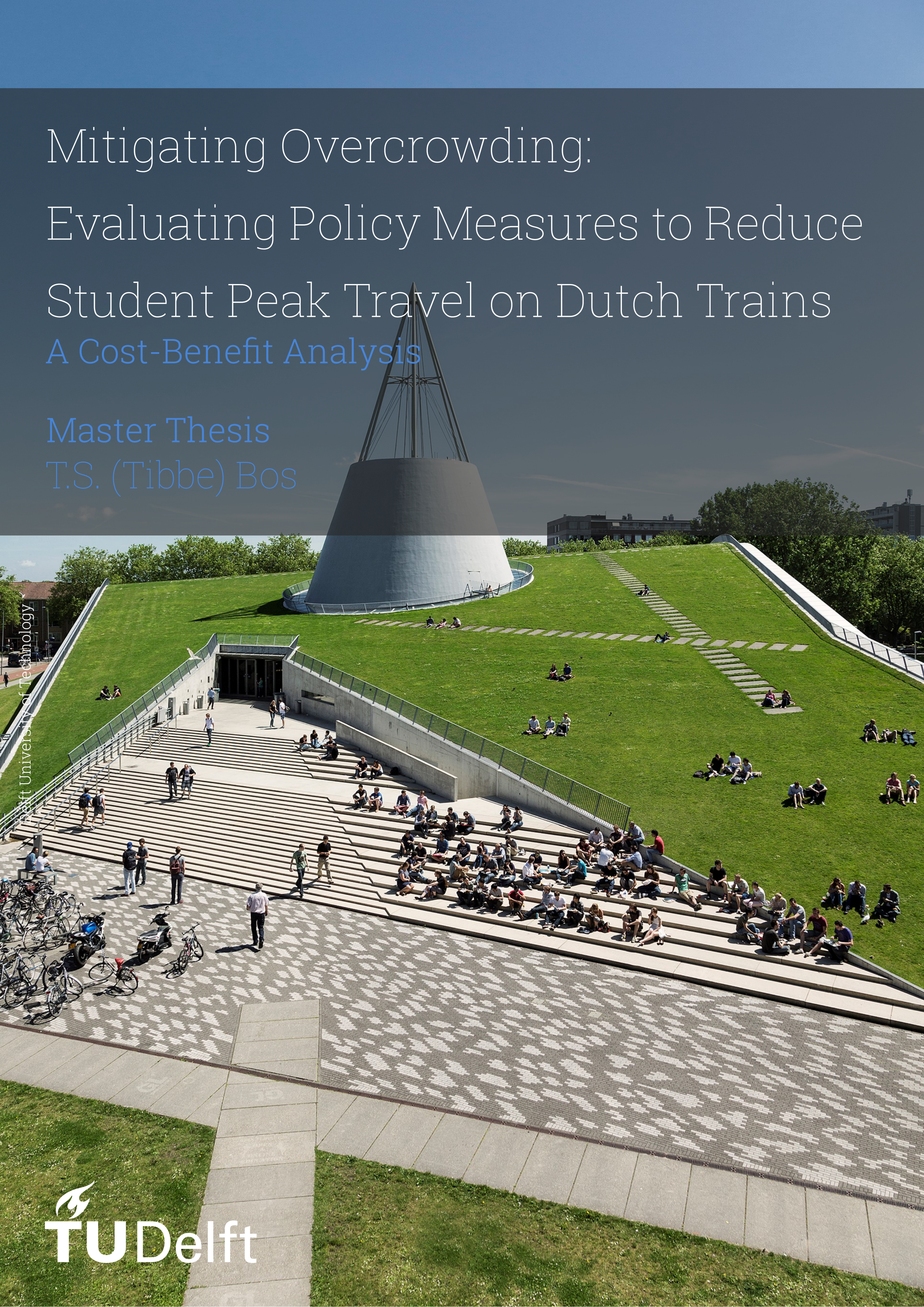
Mitigating Overcrowding: Evaluating Policy Measures to Reduce Student Peak Travel on Dutch Trains

A Cost-Benefit Analysis

Master Thesis

T.S. (Tibbe) Bos



Delft University of Technology

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Mitigating Overcrowding: Evaluating Policy Measures to Reduce Student Peak Travel on Dutch Trains

A Cost-Benefit Analysis

by

T.S. (Tibbe) Bos

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Preface

Dear reader,

I am pleased to present you my thesis report. Over the past six months, I have researched the welfare impact of four policy measures aimed at encouraging students to travel by train to their educational institutions outside peak hours. This study marks the completion of the Master's program in Complex Systems Engineering and Management at Delft University of Technology. As I look back on the memorable years I spent at this university, I would like to take a moment to express my gratitude for all the support I received throughout the thesis.

First, I would like to thank my thesis committee. Dr. Jan Anne Annema, my daily supervisor, was not only consistently available for practical questions about the analysis techniques and the rationale behind the choices made in the research, but he also proved to be a valuable sparring partner for discussing the policy measures and survey questions, thanks to his extensive knowledge of the transport and logistics sector. Dr. Rutger van Bergem, my second supervisor, was not an expert in this field, however his fresh perspective enabled him to provide valuable feedback that enhanced the academic quality of the research and clarified it for scholars outside the discipline. Finally, I would like to thank Professor Van Wee for the inspiration regarding the study topic and, of course, for chairing the committee.

I also owe a debt of gratitude to the respondents of the survey I conducted as part of study. Without the valuable data generated by this survey, making realistic effect estimates would not have been possible. I would also like to thank Dennis Botman, with whom I worked simultaneously on our theses on this topic. In addition to our brainstorming sessions, we periodically checked in with each other and offered support when needed, particularly concerning the graduation process.

Lastly, I am grateful for all the support from my family, my girlfriend, friends, and roommates. A special thanks goes to my roommate Kevin for carefully finding and correcting the final spelling and grammar errors in the thesis.

T.S. (Tibbe) Bos
Delft, October 2024

Executive Summary

With Dutch trains being overcrowded during peak hours and passenger numbers projected to increase, demand for expanding train capacity is growing. However, the current rail network is too congested to accommodate more trains, with opportunities for network expansion being limited by space constraints and the high costs of new infrastructure. To address this issue, policy measures that encourage alternative travel behaviours among students offer a promising alternative for reducing congestion on peak hour trains. While the literature contains numerous studies on measures that reduce peak hour congestion, there is still a lack of insights into the broader societal welfare effects of these policy measures. In addition, there are only limited insights into measures specifically targeting students.

This study addresses this gap by designing and evaluating measures aimed at reducing the number of students travelling by train during peak hours at the national level and applied to MBO, HBO, and university students. The goal of this research is to determine how different measures, aimed at reducing student travel during peak hours, contribute to the overall welfare. The main research question that follows is:

”To what extent are policies, designed to reduce student travel during peak hours on Dutch trains, socially beneficial?”

To address this question, the study is approached using the Cost-Benefit Analysis (CBA), which compares the societal costs of a measure with its societal benefits. During the design phase of this analysis, the literature indicated that measures focused on staggered hours and differential fares were most extensively researched and could significantly reduce peak hour congestion. Based on these findings, four policy alternatives were designed. One alternative requires students to pay the full fare for their travel during peak hours, another shifts lecture start times to later in the day, and the final two alternatives combine a later start for lectures with either a 40% discount on a full peak fare or a morning peak fare with free weekend travel. Table 1 provides a more detailed description of the four alternatives.

Table 1: Overview of Policy Alternatives

Policy Alternative	Description
1. Paid Peak Hour Travel	Requires students to pay the full fare for travelling during peak hours (06:30-09:00 and 16:00-18:30), instead of travelling for free with their student weekday subscription.
2. Shift Lecture Hours	Requires educational institutions to shift the start of lectures to 10:30 or later, with classes extending proportionally longer.
3. 40% Peak Discount + Shift Lecture Hours	Introduces shifted lecture hours, as described in the previous alternative, but also requires students to pay for travel during peak hours. Students receive a 40% discount on the full fare when travelling by public transport between 06:30-09:00 and 16:00-18:30.
4. Weekend + Weekday Free After 09:00 Subscription + Lecture Time Shift	A single subscription is introduced for all students, where they pay the full fare for travelling during the morning peak (06:30-09:00), but travel for free for the rest of the day and during weekends. Additionally, educational institutions also shift their lectures in the same way as described for the ’Shift Lecture Hours’ alternative.

To assess the effects of these measures, it is important to understand how they influence students' travel behaviour. Given the gap in existing literature regarding this behaviour, a rough survey was conducted among students who live outside the city where they study. In the Paid Peak Hour Travel alternative, students reduce their travel to their educational institution by an average of one day per week. In the other three policy alternatives, the average number of visits to the educational institution also decrease, but the reduction is three to five times smaller. In addition to travelling to their educational institution less frequently, students increasingly choose alternative modes of transportation. An increase in car usage is observed in the alternatives with a differential fare, while bicycle usage also increase when lecture times were not shifted. In contrast, in the Shift Lecture Hours alternative, both car and bicycle usage decrease, as more students travel by train than before. However, this increase occurs outside peak hours, as the number of train journeys during peak hours decrease by 20 to 50 percent across all alternatives. Among all modes of transportation, only car usage during peak hours increase, which occurs in the Paid Peak Hour Travel and 40% Peak Discount + Shift Lecture Hours alternatives.

Based on the survey results, which gave a sense of the scale in which students avoid travelling during peak hours, switch to other modes, or reduce their overall travel to campus, the direct, indirect and external effects of the policy alternatives were quantified and monetised. Besides the use of both academic literature and information from government and advisory reports, assumptions were also made due to a lack of information. The key assumptions, given the uncertainty and scale of the effects, are that teaching staff would need to teach an average of two evening hours per week and be compensated at a rate of 150% for these hours when lecture schedules are adjusted. Furthermore, it is assumed that railway companies will only address one-fifth of the demand loss by reducing capacity, and that a year of digital education leads to an decrease of 8% in future salaries.

The results of the CBA are summarized in Table 2, where the values represent the total impact of an effect over the policy period at the 2025 price level. The outcomes indicate that three out of four policy alternatives result in a welfare loss compared to the baseline alternative. The only alternative that generates a welfare gain is the 'Shift Lecture Hours' alternative. The main findings from the table are the remarkably high costs associated with paying teaching staff at educational institutions to provide lectures outside regular working hours, but it is important to note the earlier assumption regarding this effect. Additionally, there is a very strong effect on educational accessibility, which only occurs when students are required to pay for peak travel and keep travelling during peak hours as well. The comfort benefits, resulting from the reduction in overcrowding on trains, and the governmental savings on the Student Travel Product, due to a decrease in the number of kilometers travelled by students, represent the highest benefits among the alternatives. However, in all options where students must pay for peak-hour travel, these benefits never outweigh the costs associated with reduced educational accessibility.

In conclusion, measures requiring students to pay for peak hour train travel do not prove to be socially beneficial, even when classes start later in the morning. Only the alternative of shifting the start of lectures to 10:30 or later is socially beneficial, generating more than half a billion in welfare gains over 15 years.

Based on the scenario analysis, it is concluded that future developments related to financial support for students and the extent of technological innovation and maintenance within the rail network do not affect which alternative maximizes welfare. In none of the scenarios is an alternative, other than the Shift Lecture Hours alternative, that yields a positive NPV. The findings also remain robust despite the knowledge uncertainty regarding the parameters, as well as without taking into account the effects of an overtime policy for teaching staff and digital education, both of which rely on the most uncertain assumptions.

The results of this CBA alone do not provide sufficient grounds to immediately implement shifted lecture hours for this politically sensitive policy. The support among students, teaching staff, and educational institutions for this policy is low. The recommendation from this research is therefore to collaboratively develop the shift in start times in education into a comprehensive set of policy changes that enjoy broad support from students, teaching staff, and educational institutions.

Table 2: Costs-Benefit Overview Table (Present Value)

Effects in million €, price level 2025	**Paid Peak Hour Travel**	**Shift Lecture Hours**	**40% Peak Discount + Shift Lecture Hours**	**Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift**
Costs				
Costs of Student Travel Product Implementation	-2.5	0.0	-2.5	-2.5
Costs of Scheduler Labour	0.0	-0.7	-0.7	-0.7
Costs of Employee Overtime Hours	0.0	-596.1	-596.1	-596.1
Total Costs	**-2.5**	**-596.8**	**-599.3**	**-599.3**
Direct Effects				
Educational Accessibility	-3857.5	0.0	-1883.7	-1165.7
Comfort Benefits	958.3 to 1003.3	749.3 to 784.0	851.5 to 891.2	645.1 to 674.7
Travel Time Reliability	0	0	0	0
Governmental Savings on Student Mobility	2607.6	203.5	796.5	189.5
Benefits of Overtime Education for Employees	0.0	99.4	99.4	99.4
Operational Savings for Railway Companies	10.9 to 17.4	0.5 to 2.5	3.6 to 7.0	0.8 to 2.9
Total Direct Effects	**-280.7 to -229.2**	**1052.6 to 1089.2**	**-132.7 to -89.6**	**-231.1 to -199.3**
Indirect Effects				
Side Job Income	++	+	+	+
Sports	++	+	+	++
Social Activities	+	+	0	+
Impact of Digital Education	-553.7	-171.6	-188.2	-94.1
Mental Health & Wellbeing	-	+	0	0
Total Indirect Effects	**-553.7**	**-171.6**	**-188.2**	**-94.1**
External Effects				
Costs of Traffic Safety Risks	-694.0 to -689.4	372.2 to 374.7	-397.8 to -395.0	-100.6 to -98.6
Costs of Greenhouse Gas Emissions	-41.1 to -163.2	5.1 to 21.0	-26.7 to -106.2	-10.7 to -42.4
Costs of Air Pollution	-9.0 to -21.2	0.5 to 1.2	-7.4 to -17.5	-3.9 to -9.2
Total External Effects	**-744.1 to -873.8**	**377.8 to 396.9**	**-431.9 to -518.7**	**-115.3 to -150.2**
Total Effects	**-1578.5 to -1656.7**	**1258.8 to 1314.5**	**-752.9 to -796.6**	**-440.4 to -443.6**
Net Present Value	**-1581.0 to -1659.2**	**662.0 to 717.7**	**-1352.2 to -1395.9**	**-1039.8 to -1042.9**
Benefit-Cost Ratio	0.69	2.69 to 2.93	0.56	0.47 to 0.48

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1 Introduction

1.1. Overcrowded Trains on the Dutch Rail Network

Although the number of train passengers has not yet returned to pre-COVID levels (Centraal Bureau voor de Statistiek, 2024a), Dutch trains can be extremely crowded during peak hours (Peene, 2022). Not only in 2022, the year after the pandemic, but also in 2023, passenger organization Rover received a record number of complaints regarding overcrowding on trains (Augusteijn, 2023; Peene, 2022). Considering the expected growth in the number of train passengers in the coming years as well (4cast and ABF Research, 2023), expanding capacity seems to be urgently required. However, with a lack of space for infrastructural expansion and its high associated costs (Gemeentelijk Netwerk voor Mobiliteit en Infrastructuur, 2017), it appears unlikely that train capacity can be expanded in the short term to meet the demand. That is unfortunate, because rail transport is one of the most sustainable modes of transportation.

Transport Demand Management (TDM), in contrast to expanding capacity, aims to change travel behaviour (Ferguson, 1990). TDM enhances the efficiency of transportation systems by implementing strategies and policies designed to alleviate crowding (Wachs, 1991). TDM could offer a potential solution to the current issues by limiting peak demand. In addition to an extra peak charge (NOS, 2023), restricting student travel is also one of the measures that has been considered by the NS (Coopmans, 2023). Students not only make up a significant 26% of peak hour train commuters (Wagemans, 2023), they also benefit from free travel if they have a weekly student subscription (Baas, 2023). A study conducted during the COVID pandemic showed that if on campus education was limited to 50% and students would start travelling outside of peak hours, it could result in a 20 to 25 percent reduction in morning peak hour congestion (Van Heest, 2020).

1.2. The Role of the Student Travel Product

The Student Travel Product (Studenten OV) is a travel product for Dutch MBO, HBO, and university students (Dienst Uitvoering Onderwijs (DUO), 2024b). The holder of the Student Travel Product can travel for free or at a reduced rate on trains, buses, trams, and the metro. The Student Travel Product was introduced in 1991, replacing the previous system of travel allowances based on the distance between a student's home and their educational institution (Hermans, 1999). However, this system had become outdated and administratively unmanageable due to the increasing number of students. The new system would also allow for the elimination of travel costs from the student grant, which the Ministry of Education, Culture, and Science expected would lead to lower costs. Finally, the product would familiarize students with sustainable public transportation while ensuring continued accessibility to education.

Over the years, the Student Travel Product has undergone several changes to adapt to evolving needs and policies. A current student can choose between two types of the Student Travel Product (Dienst Uitvoering Onderwijs (DUO), 2024a). With the weekday subscription, the student can travel for free from Monday 04:00 to Saturday 04:00 and receives a 40% discount for weekend travel. With the weekend subscription, the student can travel for free from Friday 12:00 to Monday 04:00, pays the full fare on weekdays between 04:00 and 09:00, and receives a 40% discount on weekday travel after 09:00. For students at MBO levels 1 and 2, the travel product is a grant. For other students, it starts as a loan with interest, which is converted into a grant if they graduate within 10 years.

Immediately after the introduction of the product in 1991, the number of kilometers travelled by students on public transportation doubled (Hermans, 1999). The relatively low occupancy rates on trains at that time increased slightly due to the measure, with students already being the highest users of transportation miles. Today, train occupancy rates are much higher. This is partly due to the fact that the number of students has increased by about 70% compared to back in 1991 (Centraal Bureau voor de Statistiek, 2024c). As a result, concerns have been raised about the sustainability of the current Student Travel Product.

1.3. Research Gap

Several studies in the existing literature have explored methods for spreading peak demand. In chapter 2, the concept of staggered work hours is discussed. O'malley (1975) and Zong et al. (2013) examine the effects on peak traffic volumes and congestion when the start times of businesses or sectors are staggered. The chapter also covers studies on the use of rewards by Ben-Elia and Ettema (2011a) and Ettema et al. (2010), along with an experiment on establishing a permit market by Geng et al. (2023). Following this, chapter 2 explores the most widely researched method in the scientific literature for mitigating peak hour congestion: the differential fare structure. However, none of these studies specifically target measures designed to shift student travel away from peak hours. Additionally, they focus mainly on the extent to which these measures reduce peak congestion, without addressing the potential wider effects.

Measures that increase the costs of peak hour travel for students not only reduce congestion but also affect student mobility and could potentially impact access to education if no additional measures are taken. Students are displeased about the potential restriction of their travel subscription. They are concerned about the potential impact of the measure on their side jobs, sports activities, and participation in their student and study associations (Tsao, 2016; Voermans & Nieuwenhuis, 2016). The LSVb, the National Union of Students in the Netherlands, also argues that such measures undermine the accessibility of higher education and worsen inequality, as it pushes students from lower-income backgrounds out of the public transportation (Landelijke Studentenvakbond, 2016; Wagemans, 2023).

Shifting lecture times, in turn, requires educational institutions to adjust and implement new teaching schedules. According to Utrecht University, it is not feasible for them to move their students out of peak hours, as they do not see any possibilities of adjusting student schedules (De Utrechtse Internet Courant, 2016). Also, Thijs Breukink, a member of the executive board at Wageningen University, considers this not as a suitable solution, as students would still need to come to campus to use the library or computer labs (Ramaker, 2016).

For other train travellers, the measures result in less crowded trains. Commuters, business, and leisure travellers experience greater comfort, potentially making the train a more attractive alternative to the car. The largest railway company in the Netherlands, NS, also supports a reduction in the number of students travelling during peak hours. This helps them alleviate capacity issues and improve their service quality. Additionally, it possibility saves them money that would otherwise be spent on expanding capacity solely to accommodate the peak number of passengers during rush hours.

1.4. Research Objective

In this study, the social costs and benefits of implementing potential measures to reduce the number of students travelling during peak hours are examined. The aim is to determine how measures that reduce the number of students during peak hours contribute to the overall welfare. The key question that follows is:

"To what extent are policies, designed to reduce student travel during peak hours on Dutch trains, socially beneficial?"

By answering this question, the study contributes to the existing literature by specifically examining the costs and benefits that arise from peak demand measures for students. The research not only contributes to the scientific field by testing travel behavioural change among students travelling by train passengers under certain policy measures. It is also socially relevant and may contribute to a future-proof train network in the Netherlands. The research focuses on identifying and quantifying the effects, rather than on assessing whether the policy measures are fair or acceptable. The analytical method that fits well here is cost-benefit analysis (CBA), in which policy options are evaluated against the option of not intervening in the market. The main question can be answered with the CBA, as it evaluates the costs and benefits of the policy measures for the whole society. By examining all associated costs and benefits, the CBA provides insights into the social advantages of a measure. Chapter 3 will provide a detailed discussion of this method's application. By utilizing CBA, the study enables an objective analysis of various policy measures, structured around the following sub-questions:

SQ1: How is peak train crowding going to develop over the next few years without new policies?

SQ2: What policy options could reduce the rush hour travel behaviour of students?

SQ3: What types of costs and benefits are associated to the measures?

SQ4: What impact do the policies have on students?

SQ5: What is the total magnitude of costs and benefits associated with the policy alternatives?

1.5. Applying Complex Systems Engineering and Management to Rail Demand Management

The formulation of the main question and sub-questions indicate that this study concentrates on designing and evaluating various policy measures aimed at changing student travel behaviour to mitigate peak hour crowding on trains. The study will therefore be approached from the perspective of systems engineering, which entails addressing the societal issue of limited train capacity in a multidisciplinary and holistic manner. This perspective aligns well with the addressed societal issue and is in line with the master's program in Complex Systems Engineering and Management (CoSEM). This results from the socio-technical origin of infrastructures, to which rail network also belong. Socio-technical systems include both technical aspects, socio-economic and behavioural elements. Technical aspects within the study are related for example to the rail network, consisting of overhead lines, switches, and a given capacity. But socio-economic and behavioural factors also play a role in these systems, such as passenger demand, travel patterns, and (EU) regulations. Numerous stakeholders are involved in the management and operation of the railway and organisation of higher education, including ministries, municipalities, educational institutions, passenger advocacy groups, railway companies, and infrastructure managers. This complexity results in a multi-actor problem.

1.6. Social Welfare Theory

The principles of the CBA are derived from the social welfare theory. The social welfare theory is the theory behind welfare economics, a branch of economics that studies the evaluation and maximization of the welfare (Shanahan & Ritter, 2013). The theory aligns well with this research, as the study explores whether welfare can be increased by implementing a policy measure that motivates students to travel outside of peak hours. In welfare theory, it is assumed that individuals make rational and disciplined choices based on self-interest to maximize their own welfare (Florio, 2014; Robinson & Hammitt, 2011). This implies that individuals have access to all relevant information and are able to process it effectively to make the best decisions, without any issues or temptations impacting their choice. Additionally, decisions would be made purely in their own interest, without regard for the interests or well-being of others. Equity and distributional effects are not addressed in the theory. The assumptions are therefore relevant for the results of the CBA. In this context, Chapter 11 will address the limitations of the analytical method and Chapter 12 outline which conclusions can and cannot be drawn from the results.

1.7. Structure of Thesis

The thesis structure begins with a review of the literature on reducing peak hour travel in public transport, as outlined in chapter 2. From this review, a knowledge gap was identified, forming the basis of this research. Additionally, chapter 2 explains the rationale behind the selection of the main research question and sub-questions. Chapter 3 then outlines the methods used to address each sub-question. This chapter covers the Cost-Benefit Analysis, including the steps involved and the design of the survey to assess changes in student travel behaviour. In chapter 4 the outcomes of the first step of the CBA are presented. A baseline alternative is outlined, covering overall train passenger behaviour as well as specific behaviour for students across all modes of transport. The research and design process for policy measures aimed at reducing the number of students during peak hours is described in chapter 5. This section covers the literature review, presents a list of identified measures, and explains the selection process. In chapter 6, the report outlines the process of identifying effects. It distinguishes between different types of effects and visualizes them using a conceptual model. Based on the identified effects, a survey was constructed to measure the travel behavioural changes of students, as described in chapter 2. Chapter 7 presents the outline and results of this survey. With these results, the effects can be quantified and monetized. Chapter 8 offers a short summary of the outcomes for each effect, including the underlying justification for these findings. In chapter 9, the CBA table is presented and the results are discussed in detail. Chapter 10 then reviews the results of the sensitivity analysis on the CBA table, highlighting which factors and uncertainties significantly impact the outcomes. Chapter 11 addresses the uncertainties related to both the CBA and the survey. Finally, chapter 12 presents the conclusions drawn from the research.

2

Literature Review

To better understand Transport Demand Management (TDM) strategies aimed at reducing peak hour crowding, this chapter reviews a selection of the written research on this subject. In section 2.1, the chapter first presents how the search for relevant articles was conducted. The findings of the literature review are presented in section 2.2. Through the screening of related articles, it becomes clear which knowledge is already covered in the existing literature and what gaps remain, as concluded in section 2.3. The knowledge gap and main research question, as outlined in chapter 1, align with these findings.

2.1. Search Strategy

A systematic literature review was conducted to analyse existing knowledge on reducing peak hour congestion prior to the research. In Figure 2.1 the screening process of the articles have been illustrated using a PRISMA flow chart. In Table 2.1 the corresponding search strings are provided.

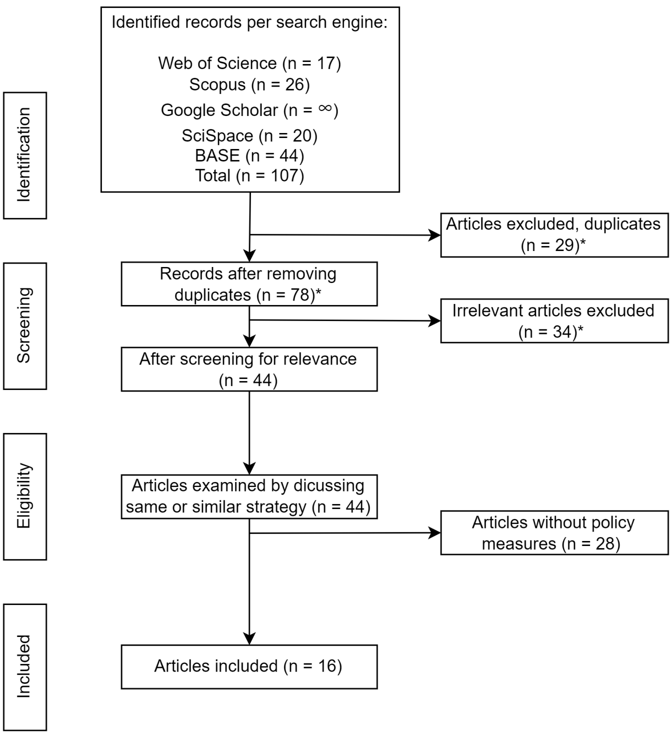


Figure 2.1: PRISMA Flow Diagram of Preliminary Literature Review
**Google Scholar records are excluded*

Table 2.1: Search Strings

Search String	Database Type
student* AND (spread* OR reduc* OR flatten*) AND (peak OR rush) AND "public transport"	Academic
("rush hour" OR "peak hour" OR "rush-hour" OR "peak hour") AND avoid* AND "public transport" AND travel*	Academic

2.2. Literature Findings

Following the identification, screening, and eligibility assessment, a total of sixteen articles were included. Table 2.2 presents these articles, detailing their research titles, references, study areas, and methods of analysis. Additionally, the table outlines the mode of transport the study focused on, the relevant insights derived from the research, and whether the studies include findings related to students. In subsection 2.2.1, subsection 2.2.2, subsection 2.2.3 and subsection 2.2.4 the findings are discussed.

Table 2.2: Scientific Literature Overview Table

Research Title	Reference	Study Area	Method/Analysis	Mode of Transport	Relevant Insights	Finding about Students
Rewarding rush-hour avoidance: A study of commuters' travel	(Ben-Elia & Ettema, 2011a)	The Hague	Mixed discrete choice model	Car	The use of rewards to change commuters' behaviour works on the short run, influenced mainly by socio-demographical characteristics.	No
Changing commuters' behaviour using rewards: A study of rush-hour avoidance	(Ben-Elia & Ettema, 2011b)	The Hague	Longitudinal techniques and mixed logistic regression	Car	Compared to credits for earning a smartphone, monetary reward is a gain with diminishing sensitivity, influenced by external factors.	No
Exploring the Impact of the 'Free Before 7' Campaign on Reducing Overcrowding on Melbourne's Train	(Currie, 2009)	Melbourne	Real experiment, survey	Train	Free pre-peak ridership led to 23% of passengers shifting their departure time, decreasing peak demand by 1.2-1.5%.	No
Quick and effective solution to rail overcrowding: Free early bird ticket experience in Melbourne, Australia	(Currie, 2010)	Melbourne	Stated preference	Train	A free pre-peak ticket reduced peak demand by 1.2-1.5%, but demand growth outweighed the effect.	No
Using incentives as traffic management tool: Empirical results of the "peak avoidance" experiment	(Ettema et al., 2010)	The Hague	Logistic regression models	Car	Positive incentives can reduce peak traffic by up to 60%, with shifts in trips before and after peak.	No
The impact of tradeable rush hour permits on peak demand: evidence from an on-campus field	(Geng et al., 2023)	Beijing	Nested logit models	None	Tradeable rush hour permits reduced rush-hour breakfasts by 20%.	Yes
Time-dependent pricing strategies for metro lines considering peak avoidance behaviour of commuters	(Huan et al., 2022)	Beijing	Stated preference	Metro	A peak charge has more impact than an off-peak discount, but could lead to loss of ridership.	No
Evaluating off-peak pricing strategies in public transportation with an activity-based approach	(Lovrić et al., 2016)	Singapore	Activity based model	MRT and buses	Ridership during free pre-peak policy reduced by 3.5% for the MRT-only scenario.	Yes
Impact and assessment of "Free" Public Transport measures: lessons from the case study of Brussels	(Macharis et al., 2006)	Brussels	Survey, Social Cost-Benefit Analysis	Tram, bus, and metro	The implementation of a free public transport card for students increased public transport use, influenced by more factors than price.	Yes
Work Schedule Changes to Reduce Peak Transportation Demand	(O'Malley, 1975)	New York	Survey	All	Staggered work hours resulted in a 26% reduction of peak congestion at busy subway stations.	No
Train commuters' scheduling preferences: Evidence from a large-scale peak avoidance experiment	(Peer et al., 2016)	The Netherlands	GPS observations and MNL model	Train	The reward experiment was successful in reducing peak trips by 22%.	No
Implications of congestion charging for departure time choice: Work and non-work schedule flexibility	(Saleh and Farrell, 2005)	Edinburgh	Stated choice	Car	Congestion charging likely shifts departure times to less congested times, influenced by work and non-work activities.	No
Understanding peak avoidance commuting by subway: an empirical study in Beijing	(Wang et al., 2018)	Beijing	Stated Preference	Metro	Financial incentives have a slightly stronger effect on peak hour avoidance than non-financial incentives.	Yes
Modelling the impact of alternative fare structures on train overcrowding	(Whelan and Johnson, 2004)	North of England	Demand model	Train	Increased peak fare significantly impacted peak loading, while decreased off-peak fare had negligible differences.	No
Managing rail transit peak hour congestion with a fare-reward scheme	(Yang & Tang, 2018)	Hong Kong	Transit bottleneck model	Metro	Best performance of a fare-reward scheme achieved when 50% of commuters travel free during shoulder periods.	No
Examination of staggered shifts impacts on travel behaviour: A case study of Beijing, China	(Zong et al., 2013)	Beijing	Departure time choice and travel duration models	All	The program, starting governmental and service industry hours one hour later, reduced peak traffic volumes by 15.2%.	No

2.2.1. Staggered Work Hours

One of the oldest academic papers in this area is about an experiment in Manhattan, which started in 1970 (O'malley, 1975). Here, numerous businesses were convinced to adjust their working hours by a minimum of 30 minutes from the traditional 9 to 5 schedule. As a consequence, over 200 thousand employees shifted their commuting times, resulting in a remarkable 26% reduction in peak congestion during the morning rush hour. The success of differential starting times proved effective, prompting Zong et al. (2013) to investigate whether this approach would also be successful in Beijing using a departure time choice model. Based on four programs, with varying starting times for different industries, the reduction in traffic volumes was determined for the morning peak. Program B, in which only the starting time for governmental and service industries changed from 08:00 to 09:00, had the highest impact and reduced peak traffic volumes with 15.2%. This research is unique in its kind as it did not use an incentive for the employees, but instead prominent businessmen were convinced to cooperate.

2.2.2. Permits and Rewards

In other research on shifting travel times, an incentive is used to persuade travellers to depart earlier or later. In the 13-week Dutch study called "Spitsmijden", travellers were rewarded for avoiding peak hour travel by car (Ben-Elia & Ettema, 2011a; 2011b; Ettema et al., 2010). One part of the participants was receiving a monetary reward between 3 and 7 euros for each day they did not drive to work in the morning rush. The other part received credits to earn a phone at the end of the experiment. The results of the experiment showed that all rewards result in a reduction of peak car trips. The highest reduction was found for the monetary reward of € 7, which reduced the share of car travel during rush hour from 50% to 20%. The reduction of the group which received credits for a phone was slightly lower, it decreased from 43% to 15%. However, while the sensitivity to the monetary reward decreased during the study period, this did not apply to the group receiving credits for a smartphone.

A few years later a comparable study has been conducted, however in this experiment researchers looked at the train commuter instead (Peer et al., 2016). Based on both the commuting distance and either a low or high reward system, the participants could be rewarded between 1.5 and 4.5 Euros per off-peak trip. In the high reward category, a 22% reduction was found of trips made during the peak hour. Moreover, half of the reduction was still detected in the post-measurement phase, during which participants did not receive a reward. An alternative way of rewarding has been proposed by Yang and Tang (2018). They suggest a fare-reward scheme in which rail commuters are rewarded with a free off-peak trip after a certain number of paid trips during peak hours. By developing a transit bottleneck model, they find that the optimum is found when 50% of the commuters travel for free in the off-peak periods. This results in a 25% reduction in total time costs and a 20% reduction of average equilibrium trip costs.

Another new and experimental incentive could be the use of tradeable rush hour permits, as experimented by Geng et al. (2023). During the experiment participants were required to use a permit to collect their free breakfast during canteen rush hour. Participants were able to buy and sell permits via a web application. An algorithm was used to set the price. The findings of the experiment showed that by using a tradeable permit scheme, about 20% of the rush hour pick-ups were avoided. From the survey among the participants it also turned out that more than 70% of them were satisfied with the tradeable permit scheme.

2.2.3. Differential Fare Structures

Despite the demonstrated success of rewards and permits in reducing rush hour travel, the most commonly used instrument in academic literature is the implementation of a differential fare. Research by Wang et al. (2018) on metro commuters shows that the impact of a differential fare is bigger compared to other non-financial rewards. In their stated preference experiment, four hypothetical incentives were presented to the respondents. They were asked how their commute would change in the following scenarios: 1) an additional 50% peak hour fare, 2) a 50% off-peak hour price reduction, 3) free Wi-Fi, food, and beverage coupons during off-peak hours, and 4) earning credits by avoiding peak hour travel to receive a phone. The results show that for the two financial rewards a quarter of the respondents would certainly avoid peak hour travel. For the non-financial incentives, the percentages of respondents who would certainly avoid peak hour travel were lower, with 17% for earning credits towards a phone and 21% for the additional services.

Additionally, the results from Wang et al. (2018) indicate that commuters are more sensitive to a peak hour price increase than to an off-peak hour price reduction. An observation which aligns with principles of behavioural psychology, emphasizing that individuals tend to be more sensitive to losses than to gains. This observation is supported by the research from Huan et al. (2022) as well in which a bi-level optimisation model is used to test peak avoidance behaviour on an empirical case study of a metro line. In this model the upper-level optimization model generates pricing strategies, balancing the operator and commutes surplus and minimising the peak ridership. The lower-level model estimates travel demand based on the pricing strategies and provides feedback to the upper-level model for accurate evaluation. The model showed that an extra peak charge could reduce peak ridership by 13.3%, while an off-peak discount only results in a 9.0% reduction.

Similar impact differences are observed in the outcomes of the PRAISE rail operations model developed by Whelan and Johnson (2004). In this model the probability for an individual commuter for a particular journey is computed, considering the evaluation of journey attributes and their corresponding elasticities. An increase of either 10% or 30% in peak fare resulted in a decrease in peak loading, from 130% to 126% and 119%, respectively. On the other hand, a reduction of either 10% or 30% in off-peak fare only resulted in a marginal decrease, from 130% to 129% and 127%, respectively.

Nevertheless, a discount during off-peak hours proves to have its advantages too. Combining the off-peak discount with the peak charge results in an even larger decrease in peak ridership, making it the most effective method to shift commuters away from peak hours (Wang et al., 2018). A 14.0% reduction has been observed with a combination of both a peak charge and an additional off-peak discount, compared to a 13.3% reduction with only the peak charge (Huan et al., 2022). The availability of the discount motivates more travellers to choose off-peak hours, reducing the likelihood of them changing their mode of travel (Huan et al., 2022). Another advantage is the fact that this is also revenue-neutral policy option (Whelan & Johnson, 2004).

Further research extends the off-peak discount approach by introducing a completely free pre-peak period (Currie, 2009; 2010; Lovrić et al., 2016; Macharis et al., 2006). However, the results of those studies are somewhat disappointing. In Singapore, the peak was reduced by 3.5% after the launching of the free pre-peak policy (Lovrić et al., 2016). In Melbourne, the free pre-peak travel resulted in 23% of passengers shifting their departure times to avoid peak hours (Currie, 2009; 2010). However, this did not lead to a significant reduction of peak demand, which only decreased between the 1.2% and 1.5%. With free-peak travel available until 07:00, the trains between 07:00 and 08:00 experienced a decrease in congestion, but the critical peak between 08:00 and 09:00 saw little change.

Although rewards, permits, and price incentives can contribute to reducing rush hour congestion, it appears that other factors also come into play when striving for substantial behavioural changes (Ben-Elia & Ettema, 2011b). Research by Saleh and Farrell (2005) indicates that both non-work activities and work schedule flexibility have an impact on the choice of departure time for the journey to work.

2.2.4. Grey Literature

The scientific literature does not cover any studies where peak measures only target students. Consequently, we broaden our scope by including various non-academic reports and publications addressing the implementation and experimentation of policies targeting students.

Shortly after the student public transport pass was divided into weekday and weekend passes, Kroes and Wilbrink (1995) conducted research to examine how students' travel behaviour had changed under the new system. It was found that this change had no short term effect on the average number of weekly trips, but students increasingly chose for bicycles, mopeds, or cars. They reduced their public transport usage, with the impact being more pronounced on local and city transportation than on trains.

The follow-up study on the student public transport card by P. Bakker and Wortelboer-van Donselaar (2014) took a different approach; the governing parties aim to save costs on the card and request an assessment of the effects of converting the then-existing card into a discount pass. The interesting aspect of their research was their differentiation between peak and off-peak hours. The alternative, in which students receive a 100% discount outside peak hours and no discount during peak hours, halved the number of student passenger kilometers travelled during peak times. And even in the alternative where students only received a 50% discount during peak hours, a peak reduction of over 30% could be expected. Upon the introduction of a route card, which offers a free choice of routes and provides a 40% discount during off-peak hours for other routes, the decline was already significantly lower at 15%. However, even this reduction could potentially have a considerable impact on the current issues.

Not only encouraging students to travel outside peak hours, but also distributing student travel more evenly during peak times can help lighten the congestion. In Nijmegen, three educational institutes on the Heyendaal Campus coordinated the starting hours of lectures with each other (EU Urban Mobility Observatory, 2019). By staggering the starting times in fifteen-minute intervals, the number of train passengers at the peak time of 08:15 decreased by 22%.

During the pandemic, COVID-19 measures shifted most education online in 2020 and 2021 (Ministerie van Onderwijs, 2020), leading to a sharp decline in student travel. Trains suddenly became nearly empty, leading railway companies to cut services from their schedules. Despite this change was expected to have more long-term effects, student travel behaviour quickly returned to pre-COVID levels. Research by De Haas (2023) shows that by 2022, student train usage had already recovered to 90–94 percent of 2019 levels.

2.3. Conclusion

With the literature review complete, it is now possible to reflect on the key findings from existing research. The existing academic literature has explored numerous incentives aimed at reducing peak hour congestion in both road traffic and public transport. Despite the significant number of students using public transport and the interesting fact that they have access to free travel (chapter 1), no specific research has been conducted on measures aimed at this group. The grey literature does contain research on this topic. It has assessed how many students reduce their travel during and outside peak hours under different measures, but the report lacks insight into the broader social impacts of these measures. A previously written thesis covers this broader perspective, but the evaluated measures do not cover other conditions of the Student Travel Product, opting instead to explore the implementation of soft measures.

It is clear that the literature does not yet provide enough knowledge to assess the social benefits of hard measures aimed at reducing the number of students travelling during peak hours. It remains unclear what social effects a Student Travel Product with different conditions might have, as well as the extent of the costs and benefits of such a measure. This knowledge gap in the literature will be addressed in this research, which will examine the social effects and their magnitude.

3 Method

This research applies the Cost-Benefit Analysis (CBA). The CBA is an economic appraisal tool for evaluating policies (Mouter et al., 2015). A CBA assesses both the cost to implement a policy measure, as well as the effects which result from it. The ratio between the costs and benefits helps in evaluating the desirability of the policy (Mouter et al., 2021). To address the main research question, the study is divided into five sub-questions:

SQ1: How is peak train crowding going to develop over the next few years without new policies?

SQ2: What policy options could reduce the rush hour travel behaviour of students?

SQ3: What types of costs and benefits are associated to the measures?

SQ4: What impact do the policies have on students?

SQ5: What is the total magnitude of costs and benefits associated with the policy alternatives?

In this chapter, the research method for each sub-question is explained. This starts with describing the process of developing a baseline alternative in section 3.1, to use as a reference for the policy measures. In section 3.2 the process of designing policies to reduce student peak travel is discussed. Following the design process of these policy alternatives, section 3.3 outlines how the effects are identified. Since some of the necessary data is missing, section 3.4 describes the process of creating a survey to estimate these effects. Finally, section 3.5 details how the effects will be calculated. The described research phases are visualized in Figure 3.1. Broadly speaking, the approach aligns with the General Guidance for Cost-Benefit Analysis provided by Romijn and Renes (2013). Where applicable, explicit references to this guide are made.

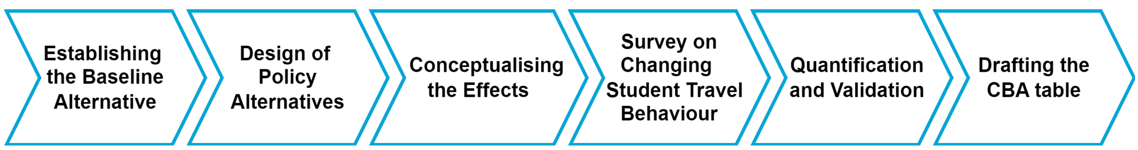


Figure 3.1: Research Phases

3.1. Envisioning Future Rail Mobility

In a CBA, the policies under evaluation are compared to a reference situation, known as the baseline alternative. Romijn and Renes (2013) define the baseline alternative as the alternative which describes the most likely scenario without the introduction of any new policy initiatives. To address the sub-question 'How is peak train crowding going to develop over the next few years without new policies?', an overview is provided of how the problem and its context are evolving. Based on this, it have been assessed whether the problem will remain relevant in the future and to what extent it will improve or worsen. The study follows the methodology outlined by Romijn and Renes (2013). In essence, this involves analyzing trends and forecasts related to key markets and the external factors that influence them. Trends and forecasts are primarily discussed in government reports from ministries, statistical agencies, and planning bureaus. Therefore, a grey literature review have been conducted. The advantage of this approach is that it used a fact-based foundation for developing the baseline alternative. Data from grey literature is often more current and designed for practical application (Griffith & Ré, 2023). However, predictions in grey literature are also based on assumptions not made in scientific literature. Additionally, grey literature is not peer-reviewed before it is made publicly available (Soldani, 2019). The designed baseline alternative is described in chapter 4.

3.2. Design of Policy Alternatives

For the second sub-question, 'What policy options could reduce the rush hour travel behaviour of students?', the aim is to identify potential measurements aimed at reducing the number of students taking the train during peak hours. In a CBA, those options are called policy alternatives. A policy alternative contains the smallest possible set of measures that are technically, legally, and economically feasible to solve the identified problem (Romijn & Renes, 2013). The approach was twofold: firstly, exploring existing solution ideas in the literature, and secondly, brainstorming to develop innovative new measures to tackle this problem.

The first part requires a literature review. Both scientific literature and grey literature have been searched for experiments where policy instruments have resulted in decreased peak congestion. For the search process the following websites were used: Scopus, Web of Science, Google, and Google Scholar. A literature review is crucial for mapping out the current landscape of existing knowledge (Linnenluecke et al., 2020). It supports this research by generating policy alternatives that are not previously tested using the same analysis (Leenaars et al., 2021), and serves as an inspiring or comparative source for designing the policy alternatives (Berressem, 2019). However, a drawback is that a literature review can be time-consuming due to the large number of potential sources (Knopf, 2006; Pautasso, 2013). Grey literature has also been included in the literature review, enhancing its completeness, since many projects and initiatives on this topic are not covered in the scientific literature (Paez, 2017).

After a preliminary literature review, an incomplete inventory of existing measures have been compiled. To supplement this list of policy measures, brainstorming sessions have also been conducted to generate straightforward or innovative new measures. Dennis Botman and I, both working on this topic for our theses, have done a half an hour brainstorm session using the Round Robin technique. Each of us wrote down one idea on a card and then passed it to the other (Smart, 2024). The receiver subsequently wrote down a new idea based on the one written on the card. This process can continue as long as new ideas emerge, or can be restarted any point in time. The technique enables to generate many ideas, which will be evaluated afterwards (Collins & Rogoff, 1991).

As it required more work than the time we have available, not all ideas have been addressed in the remainder of the study. By making a rough selection based on the extent of impact reported in the literature, only four policy alternatives have been designed for further analysis.

3.3. Conceptualizing Costs and Benefits

With both the baseline and policy alternatives defined, the next step in the research approach was to identify the impacts of the measures proposed in the policy alternatives. This addresses the sub-question: 'What types of costs and benefits are associated with the measures?'. The identification was the first step in determining the effects of the policy measure, followed by quantification and valuation (Romijn & Renes, 2013). Effects have been identified by analyzing the relevant markets affected by the policy measure, following the same approach as described in section 3.1 (Romijn and Renes, 2013). However, this part of the analysis goes beyond just the directly affected markets and also considered effects that arise in other markets as a result of the impacts in the direct markets. The identification process included the identifying of side effects of the measure as well.

For the identification of the direct effects, the results of the literature review conducted for section 3.2 were reused. This broad selection of literature already describes many effects, and reusing it saves time, allowing more time to properly conduct a survey and CBA. Indirect and external effects have been identified through targeted searches in scientific literature. To structure the identification and clarify the causal relationships between direct- and indirect effects, a conceptual model have been used which illustrates the causal connections between various factors (Van Wee et al., 2014).

3.4. Surveying Students

As chapter 2 suggests, the amount of research conducted on the elasticity of student travel behaviour is very limited. However, this information is crucial for further determining the effects of the measures. By answering the sub-question 'What impact do the policies have on students?' we have tried to estimate this effect.

Within transportation research, stated choice experiments are popular to measure travel behaviour for hypothetical conditions that cannot be observed in real markets (Hensher, 1994). Something that is also the case for the measures that are yet to be designed. In stated preference research, the respondent is presented with several choice sets based on the chosen experimental design, from which they must select the most preferred option (Rose & Bliemer, 2009). A stated choice experiment would thus be suitable for collecting the missing data on students' changing travel behaviour. A proper execution of a stated choice experiment is, however, a study in itself.

Within the scope of this research, there was no time to conduct a stated preference experiment to accurately determine changes in student travel behaviour. Instead, a more simple approach has been applied. Students were asked directly whether they expect to travel less, more, or the same during peak hours as a result of the proposed measures. According to Liu and Charles (2013) this method is known as the stated opinion approach. By using the stated opinion approach instead of a stated preference experiment, the results may be less precise, yet they still offer a valuable insight into the order of magnitude of the effects. It have been acknowledged that this also reduced the overall accuracy and increases the uncertainty of the research results.

A survey was selected as the tool for conducting the stated opinion approach. A survey has relatively low costs, a quick response time of respondents and gives access to a broad population (Story & Tait, 2019). Nevertheless, the tool is also associated with potential risks such as technical issues, concerns about the privacy of collected data, and low response rates (Story and Tait, 2019). Moreover, it is crucial how the questions are phrased and what answer options are provided, as both factors significantly influence the outcomes of the survey (Krosnick, 1999). To formulate specific survey questions, the target audience for the survey have been defined in subsection 3.4.1. Additionally, subsection 3.4.2 addresses how the survey is distributed.

3.4.1. Participant Recruitment

The objective of the survey research was to map the changed travel behaviour resulting from the four selected policy measures, so that this could be used to determine the social costs and benefits of these measures. The policy measures directly influence the frequency, mode choice, and timing of students' travel to their educational institutions. However, the changed travel behaviour of students can, in turn, lead to the attraction of new travellers. Therefore, a comprehensive survey would need to include the entire travelling population. Nonetheless, the survey's target group have been limited to students who do not live in the city where they study. They are the only ones who experience the direct impact of the policy measures, making the effects of the measures most pronounced for them.

The students in this target group included those in MBO, HBO, and university education, as all three groups are entitled to the current type of Student Travel Product and thus contribute to peak hour congestion in the trains. There was no requirement for a minimum distance between the place of residence and the city of study.

3.4.2. Survey Administration

Although the survey research did not aim for statistical significance, efforts were still be made to achieve the highest possible number of respondents within the limited time, budget, and resources of the study. This was done by recruiting respondents not only through social media but also by actively approaching potential respondents. The survey link have been distributed through WhatsApp groups with many students, including those of study and sports associations. Additionally, the research has shared a link to the survey via LinkedIn.

Active recruitment of respondents took place at Delft Station. The researcher was present for one to two hours at the end of the afternoon for three days, holding a QR code to ask travellers to complete the survey. The choice of this location and time was related to the survey's target audience: students living outside their study city. A significant portion of these students travels home by train in the late afternoon. Additionally, people who are waiting are more likely to be willing to complete a survey.

Before the survey was launched, it was be tested by fellow students and reviewed by the thesis supervisor. Any necessary adjustments have been made based on their feedback.

The results of this survey are uncertain. This uncertainty arises not only from the limited number of students surveyed, which may hinder the ability to obtain a representative sample, but also from the possibility that some students might provide strategically biased responses. Despite these limitations, this data remains the most accurate available for assessing the effects, as no further information is found in the literature. It is important to note that this significantly impacts the uncertainty of the results, and therefore, chapter 11 will provide additional attention to this.

3.5. Assessing Costs and Benefits of Policy Alternatives

Using the survey data as a basis for understanding how student travel behaviour changes under the policy alternatives, the final two steps for determining the effects of the policy measures were carried out. These steps involved quantifying and valuing the effects identified in section 3.3. By completing these two steps, the final sub-question 'What is the total magnitude of costs and benefits associated with the policy alternatives?' was answered.

Quantifying the effects means determining the extent of change in the policy alternative compared to the baseline alternative (Romijn & Renes, 2013). This was partly based on the percentage changes reported in the survey for the policy alternatives. For example, the number of kilometers travelled by students during peak hours was calculated by multiplying the percentage decrease reported in the survey by the number of kilometers travelled in the baseline alternative. Based on the number of kilometers, emissions were calculated using index numbers from governmental reports. Other costs and effects have been assessed using secondary sources from both grey and scientific data concerning expenses for education and train staff, rail equipment, and educational performance. For each effect, efforts have been made to find usable data for quantification. Although this process have been time-consuming, a CBA based largely on assumptions is not reliable. The search began with scientific literature, followed by government and consultancy reports. If necessary, other grey sources have also been consulted. For some effects, there has been insufficient information to make a reliable quantitative assessment, so these effects have been described qualitatively (Romijn and Renes, 2013). These effects have been represented in the CBA using -, - -, 0, +, or ++. A single dash (-) represents a slight negative effect, whereas a double dash (–) indicates a more pronounced negative impact. A zero (0) signifies either no effect or a negligible one. A single plus (+) represents a mild positive effect, while a double plus (++) indicates a significant positive impact.

Valuation, also known as monetization, involves expressing the quantified effect in monetary terms by calculating it based on households' willingness to pay (Romijn and Renes, 2013). The willingness to pay represents the maximum amount someone is willing to spend to gain a positive benefit or to avoid a negative impact (Romijn and Renes, 2013). Some effects, such as cost savings, were already expressed in monetary terms and therefore did not require further monetization. Other effects have been valued using specific metrics. For instance, travel time valuation converts travel time into monetary terms, while an efficient CO_2 price translates greenhouse gas emissions into monetary value. To find metrics for valuing non-monetary effects, a targeted literature search was conducted in scientific and grey literature via Scopus, Web of Science, Google, and Google Scholar. The identified metrics were recorded in Excel files to facilitate the conversion from effects to monetized values.

Even after assessing the costs and benefits of the policy measures, Romijn and Renes (2013) provide several steps for effectively presenting the results of the analysis. First, the effects across the time horizon have been discounted back to the base year. These effects were then aggregated and presented in the CBA table, along with the Net Present Value (NPV) and the benefit-cost ratio. Detailed explanations of these terms and the steps taken can be found in chapter 9. Subsequently, the results presented in chapter 9 underwent a scenario and sensitivity analysis. The scenario analysis tested whether the CBA outcome is sensible for changes in the baseline alternative. The sensitivity analysis on the other hand examined whether the CBA outcomes remain robust in the face of incorrect assumptions, index numbers, or the discount rate. Those analysis are further described in chapter 10. The Research Flow Diagram, as presented in Appendix A, offers a clear visual representation of the research approach.

4 Baseline Alternative

As we formulated our problem in the problem analysis in Chapter 1, it is now time for the follow-up step of the CBA. This chapter describes the baseline alternative. Romijn and Renes (2013) have defined the baseline alternative as the alternative which describes the most likely scenario without the introduction of any new policy initiatives. The baseline alternative is used as reference alternative to the policy alternatives, which will be designed in the next chapter.

In the baseline alternative, we describe the current situation and outline how this situation is expected to develop without the introduction of new policies. The description is based on the relevant markets related to the problem. First, the growth in passenger kilometers by train is discussed in section 4.1. Next, in section 4.2 it is described how many kilometers students will travel per mode of transport. And finally, section 4.3 examines to what extent rail infrastructure is a limitation for passenger railway capacity.

4.1. Passenger Kilometers by Train

The rail market is at the heart of the problem. To predict how the rail market will evolve, the forecast for the number of passenger kilometers by train is one of the key factors considered. The number of passenger kilometers by train is the sum of all kilometers travelled by train over a year in the Netherlands. In the past years various forecasts on travel behaviour by train have been published by Rijkswaterstaat, KiM and the joint efforts of CPB and PBL (Hamers, 2022; Hamersma & Moorman, 2023; Hilbers et al., 2020; Manders & Kool, 2025; Rijkswaterstaat WVL, 2024). Some reports provide short-term forecasts, while others make predictions for 2040 and 2050. One thing is clear, the forecasts present different views on the extent to which the number of passenger kilometers by train in the Netherlands will increase in future years.

The differences between the forecasts are due to the varying methods and data used. The COVID-19 pandemic has increased the uncertainties surrounding the forecasts even further. On the short term the pandemic resulted in a decrease in passenger kilometers by train. In the years following the pandemic, researchers have sought to forecast the extent to which behavioural changes will be long-lasting. The research by Van Der Werff et al. (2023) concludes that the negative perception of public transport in relation to health will not have a long-term impact on its usage. On the other hand some respondents in the research by Van Hagen and Van Oort (2021) specify that they bought a E-bike or car, which may indicate a long term mode shift. Furthermore, even after the pandemic, the number of hours people work from home has continued to rise. In 2023, employees averaged 6.8 hours of remote work per week, compared to just 2.6 hours in 2019 (Oude et al., 2021).

The passenger kilometers by train in this baseline alternative are grounded in the most recent forecast publications. This approach avoids relying on the steep upward trend seen before the COVID-19 pandemic, while also steering clear of the uncertain and more pessimistic perspective that emerged immediately after the pandemic. The trend line for the number of passenger kilometers by train, as will be used in this baseline alternative, is shown in Figure 4.1. For short-term passenger behaviour (2028), the report "Mobiliteitsbeeld 2023" by Hamersma and Moorman (2023) has been used. For the medium-term (2040) and long-term (2050) projections, the forecasts outlined in the "Hoofdrapport Referentieprognoses 2024" by Rijkswaterstaat WVL (2024) were utilized. Between the forecast years a linear trend is assumed. The total number of passenger kilometers was then divided into morning peak (33%), evening peak (27%), and off-peak (40%), as observed by Knockaert et al. (2013).

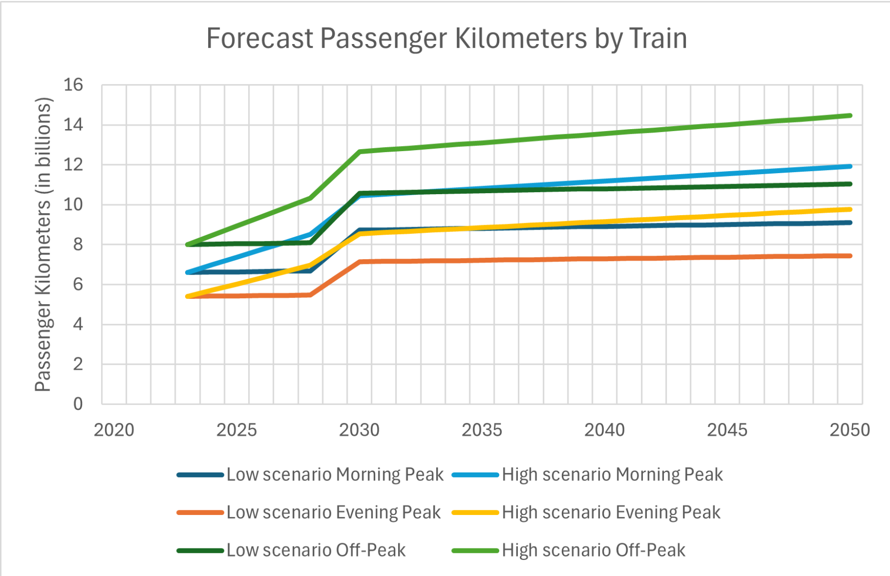


Figure 4.1: Forecast Passenger Kilometers by Train

4.2. Student Travel Behaviour

With students identified as the target group to reduce overcrowded peak hours, forecasting their travel behaviour is crucial to evaluating how different policy alternatives could mitigate the issue. The impact of student travel behaviour is also influenced by its volume. Therefore, we begin by examining the projected growth of the student population in the coming years.

The Ministry of Education, Culture and Science publishes each year a forecast of the number of students per level of higher education (Ministerie van Onderwijs, 2024a; 2024b; 2024c), see Figure 4.2. Their data indicates that the number of university students will rise until 2030, after which it will decline below the current levels around 2038. The number of students at HBO is already in decline, a trend that will continue in the coming years, but at a slower pace. The number of MBO students will also start to decline after a period of limited growth, leading to an overall decrease in the student population in the future. The decline in the student population is driven by an aging population, reduced government funding, and policies affecting the admission of international students (Loesberg et al., 2023).

This shrinking student population is also increasingly taking classes from home. The COVID-19 pandemic accelerated a rapid transition and innovation in online learning (Versteeg & Kappe, 2021). Although on-campus education has once again become the standard following the pandemic (Kloosterman & Van Loosbroek, 2022), an increasing number of educational activities are now offered in hybrid or blended formats (NOS, 2022b). As a result, there is less need to travel to educational institutions.

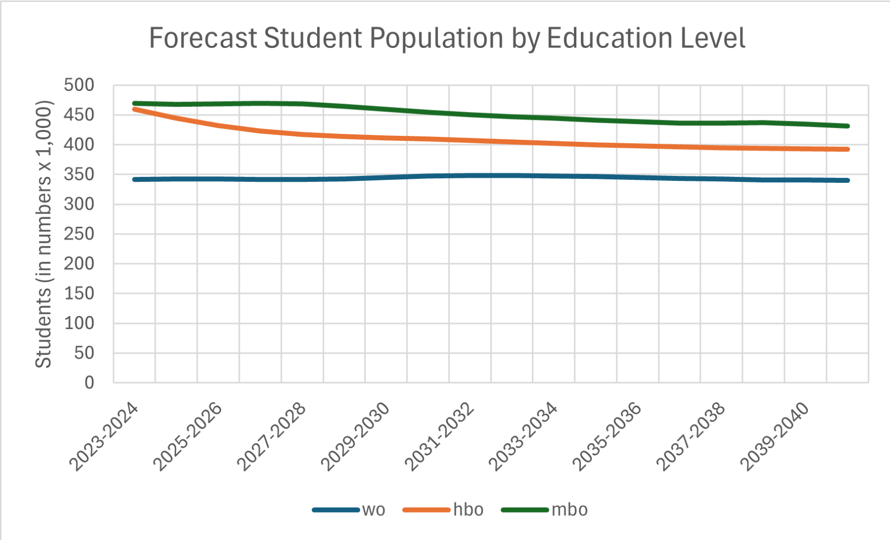


Figure 4.2: Forecast Student Population

Students' future travel behaviour will also be influenced by their expected living situation. The National Student Housing Monitor by Hooft van Huijsduijnen et al. (2023) outlines the forecast on this topic. They predict that the availability of student housing will grow in the coming years due to ongoing construction plans for new student accommodations. Alongside the increase in supply, demand for student housing is also rising, partly due to the reintroduction of the basic grant (Hooft van Huijsduijnen et al., 2023). Despite the decrease in student numbers, the demand for student housing is growing faster than its availability. While the number of students living away from their parents home is expected to increase by 6 to 7 percent relative to current levels, the housing shortage is projected to rise from 23,700 units in 2022-2023 to between 39,600 and 56,700 units by 2030-2031.

4.2.1. Student Kilometers by Train

While there are many different forecasts for the total number of passenger kilometers by train, there are no specific forecasts available for student travel behaviour. Data on current student travel behaviour is also limited. As a result, the baseline for student passenger kilometers will be based on broad assumptions. As a starting point, the revision report on the Student Travel Product by Jonkers et al. (2023) was used. This report provides the number of free passenger kilometers reported per time period for the academic year 2022-2023. The study is thus grounded in data collected immediately after the COVID-19 pandemic. This set of data was then reallocated, with time periods categorized into morning peak, evening peak, and off-peak. However, this data also included trips by bus, tram, and metro (BTM), as well as free passenger kilometers for weekend subscription holders. As the report also detailed the free kilometers for each mode of transport and the proportion of those kilometers travelled on weekdays, it was possible to convert this data into the free number of weekday train kilometers, segmented into morning peak, evening peak, and off-peak periods. These values represent the base year for the baseline.

For coming years it is assumed that the number of student passenger kilometers will decrease proportionally with the number of students. Additionally, it is assumed that travel during weekdays will decrease due to the higher proportion of students living away from their parents home. As the proportion of students living away from their parents home increases by 6 to 7 percent, it is assumed that the number of weekday passenger kilometers will decrease by 6.5% in 2030-2031 for both peak morning, peak evening, and off-peak periods. The forecast does not specifically adjust for the proportion of online education. It is assumed that the share of online education will remain consistent with that of 2022-2023, given the lack of concrete evidence to suggest otherwise. The established forecast is shown in Figure 4.3

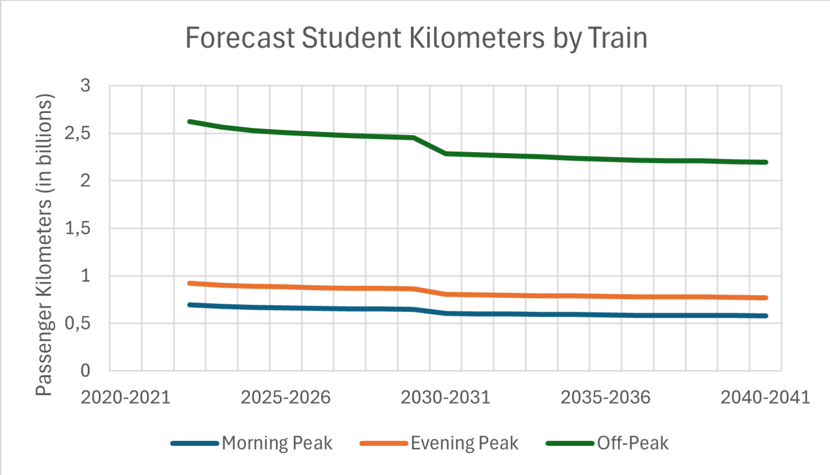


Figure 4.3: Forecast Student Travel Behaviour

4.2.2. Student Kilometers by BTM

Student travel behaviour by bus, tram, or metro (BTM) is also based on the revision report concerning the Student Travel Product by Jonkers et al. (2023). While in subsection 4.2.1 the kilometers travelled by BTM were filtered out, for this forecast, the number of train kilometers has been filtered out instead. By doing so, it was possible to construct the number of free weekday kilometers by BTM for the base year. It is again assumed that the number of kilometers increases in proportion to the student population, as outlined in subsection 4.2.1, with adjustments for the rising share of students living away from home. Figure 4.4 illustrates that while the number of passenger kilometers by students in BTM is lower than for trains, a similar distribution is observed across morning, evening, and off-peak hours.

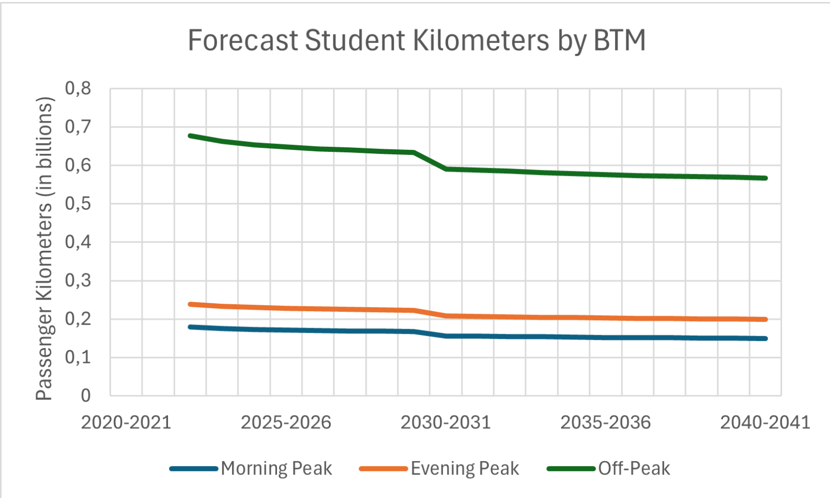


Figure 4.4: Forecast Student Travel Behaviour BTM

4.2.3. Student Kilometers by Car

The report by Jonkers et al. (2023) is limited to kilometers travelled using the Student Travel Product, meaning that a different source had to be consulted for the forecast of kilometers travelled by students by car. No forecast specific to students was available for this either, so the trend for the baseline was developed based on a number of assumptions. It is assumed that students travel an average of 31 km by car between their home address and the institution (Oskamp & Hoppesteyn, 2003), that their travel time is 30 minutes, and that there are 7,000, 5,000, and 2,000 transport movements per half-hour during the morning, evening, and off-peak periods, respectively (De Haas, 2020). By multiplying this number of kilometers by 5 study days per week and 40 education weeks a year, an estimate was made of the total number of kilometers for the morning, evening, and off-peak periods. To make a relevant comparison with student travel behaviour using the Student Travel Product, the change in the number of car kilometers over the time horizon is also assumed to be proportional to the change in the student population. In Figure 4.5 it can be seen that the difference between the number of car kilometers during peak and off-peak times is relatively smaller compared to trains and public transport, particularly for the morning peak.

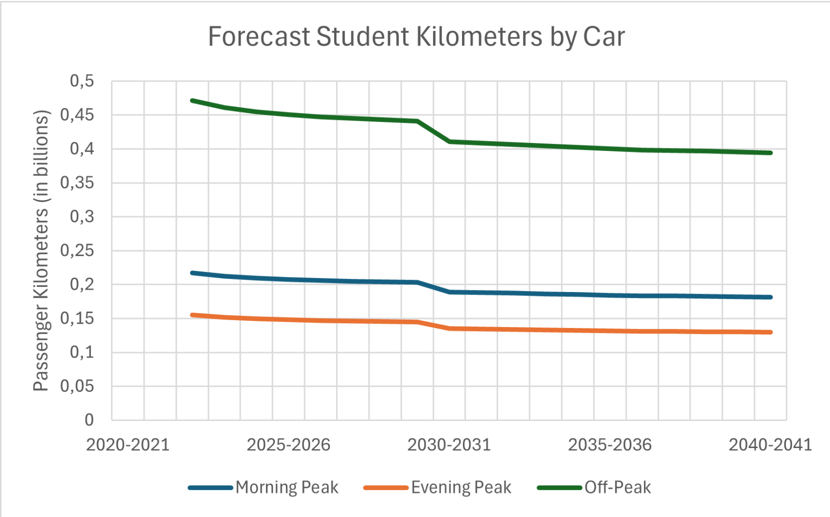


Figure 4.5: Forecast Student Travel Behaviour Car

4.2.4. Student Kilometers by Bicycle

According to the survey conducted, as detailed in Chapter 7, a small proportion of 4.7% of students living at their parents commute to the educational institution by bicycle. In estimating the annual number of cycled kilometers by students, this percentage is used to make a forecast based on the total student population. Furthermore, the average distance for students who cycle was estimated to be 10 kilometers, assuming that these students live closer to the educational institution compared to those who travel by car. Based on the student numbers presented in Figure 4.2 and the fact that students who cycle visit their institution an average of 4.06 days per week according to the survey, the forecast is provided in Figure 4.6.

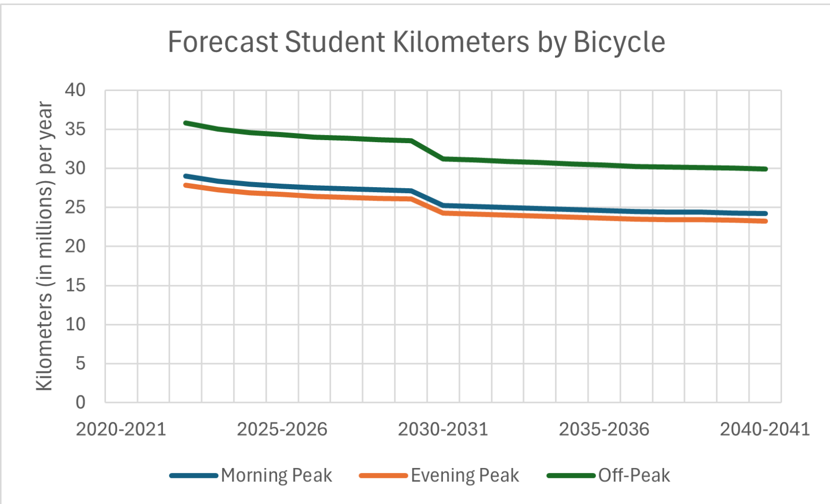


Figure 4.6: Forecast Student Travel Behaviour Bicycle

4.3. Forecast Rail capacity

Although it cannot be viewed in isolation, it is essential to consider the available rail capacity alongside predictions of passenger behaviour. The infrastructure, managed by ProRail, is key to determining how many trains can operate. The railway companies, with NS as the concession holder for the Main Rail Network(HRN), provide the equipment and personnel needed to keep the trains running. As discussed in chapter 1, expanding rail infrastructure is inherently expensive. Additionally, the extensive development throughout the country, including areas close to existing rail lines, further complicates the process and adds to the challenge of adding new tracks. Despite these challenges, capacity expansions have been implemented in the past. In 2007, the rail capacity between Amsterdam and Utrecht was increased (Infrasite, 2021), and in 2023, the number of tracks between Rijswijk and Delft Campus was doubled (ProRail, n.d.). In the coming years, ProRail will continue to work on expanding the rail network. As part of the High-Frequency Rail Transport Program (PHS), various bottlenecks will be addressed, sections of track will be widened, and new safety systems and improved traffic control systems will be installed (ProRail, 2024). Despite the planned expansions, there were growing concerns before the COVID-19 pandemic that the rapid rise in passenger kilometers would surpass the available transportation capacity. This anticipated mismatch between demand and capacity raised alarms about potential overcrowding and service limitations. Due to the more modest growth expectations compared to those projected before the COVID-19 pandemic, potential infrastructure constraints in this baseline alternative are considered outside the scope. Similarly, ProRail's impact on rail capacity is regarded as less significant compared to that of NS, further emphasizing the focus on other factors.

Based on the insights presented above, a conclusive answer can be formulated to the sub-question: How is peak train crowding expected to evolve over the next few years without the implementation of new policies? This baseline alternative indicates that the overall number of passenger kilometers travelled by train is expected to rise in the coming years, see Figure 4.1. The low scenario forecasts a growth of around 25% by 2050, whereas the high scenario anticipates an increase of approximately 75%. The travel behaviour of students reflects a different trend, influenced by a slight decrease in the student population. The total distance travelled by students in the baseline alternative is projected to decrease. Figure 4.3 illustrates a decline of approximately 15%. In summary, while train congestion is unlikely to diminish, the effectiveness of measures aimed at students will be reduced due to the declining proportion of student travellers.

5 Policies

As the baseline alternative is described in the previous chapter, the next step is designing policy alternatives. For this purpose, potential measures are initially identified in scientific literature, news articles, as well as governmental and consultancy reports. The search process is described in section 5.1. Next, in section 5.2, the measures are categorised in two main categories and several sub categories. In section 5.3, a selection is made of which measures will be evaluated through the survey. And finally, the four policy alternatives are presented in section 5.4.

5.1. Systematic Literature review

To identify potential policy measures that reduce the number of students travelling during peak hours, a literature review was conducted. The search process consisted of two parts. First, articles were sought in the academic databases Scopus, Web of Science and Google Scholar, followed by a search for reports and news articles in the grey literature using Chrome. In Figure 5.1, the combined results of the search process are visualised according the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram.

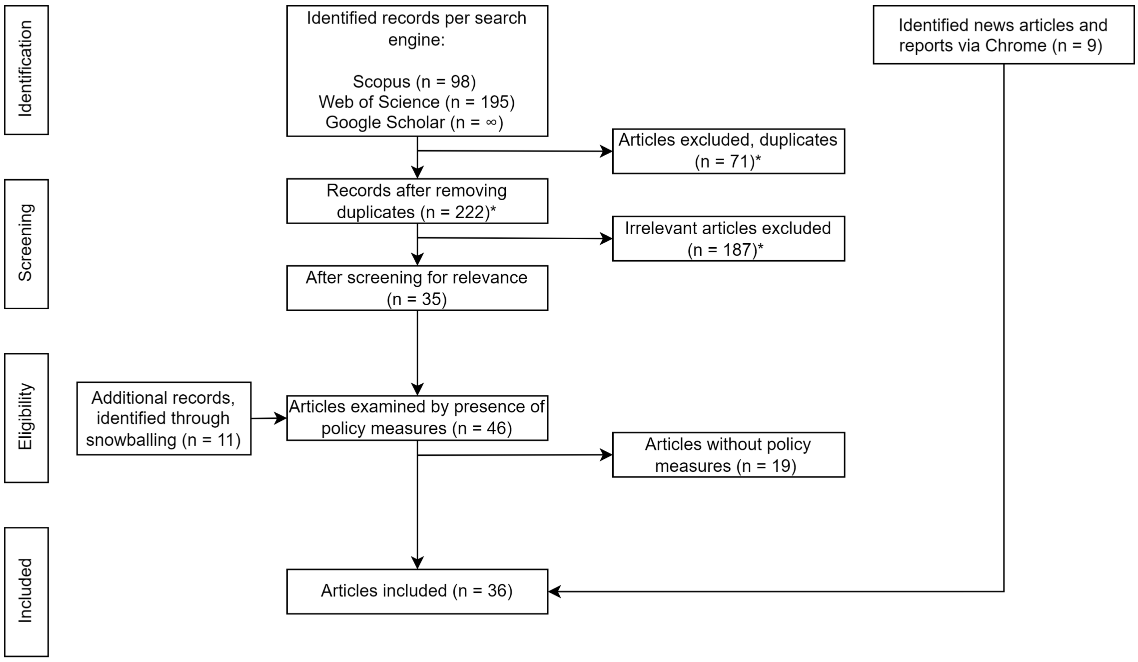


Figure 5.1: PRISMA Flow Diagram for Policy Identification
**Google Scholar records are excluded*

For the identification process, four academic and two non-academic search strings were used, as listed in Table 5.1. In the Scopus database, searches were conducted within the title, abstract, and keywords, whereas in Web of Science, searches were conducted across all fields.

Table 5.1: Search Strings

Search String	Database Type
student* AND travel* AND (peak OR rush) AND (spread* OR reduc* OR flatten*)	Academic
student* AND (public transport* OR train*) AND (peak OR rush AND spread* OR reduc* OR flatten*)	Academic
student* AND (spread* OR reduc* OR flatten*) AND (peak OR rush) AND ”public transport”	Academic
(”rush hour” OR ”peak hour” OR ”rush-hour” OR ”peak hour”) AND avoid* AND ”public transport” AND travel*	Academic
studentenreisproduct rapport spits	Non-academic
student spits college	Non-academic

5.2. Identification

In Table 5.2 an overview of the identified potential measures to reduce peak demand is presented. The measures are divided into two categories and several subcategories. The two main categories distinguish financial measures from non-financial measures. The financial measures, the most widely used type in literature, are measures that directly impact the fare or the traveller’s budget. Non-financial measures, on the other hand, aim to influence traveller behaviour through alternative means. Furthermore, the table specifies whether each measure is specifically intended for or tested on students, indicated with ’Yes’ or ’No’ in the ’Student Context’ column.

Within the category of financial measures eight distinct types can be identified. Firstly, the traveller may be asked for a contribution. Both options of this type are specifically intended for students who currently travel for free or at a 40% discounted rate. Additionally, students can be offered a route-specific travel subscription, allowing free travel exclusively on a fixed route and with a 40% discount applied for travel outside this route. In the ’Budget’ subcategory, the student receives an allocated amount of money. This budget can be either spend freely, be restricted to public transport only, or be applicable to both public transport and shared mobility. The largest subcategory is differential pricing. Here, the traveller pays a variable amount for the journey, depending on the travel time. This can be taken to an extreme by assigning a period during which travel is entirely free, as is done in the ’Free off-peak’ subcategory.

In addition to charging a higher or lower fare, travellers can also be motivated to travel outside peak hours by rewarding them. In Dutch research by Ettema et al. (2010) and Peer et al. (2016), changes in traveller behaviour by car and train were measured by providing them with a reward of a few euros for avoiding peak hours. The seventh type of financial measure includes various options for pre-selling seats or spots in public transport. This can be achieved through either a tradeable rush hour permit, a reservation system, or auctioning. Lastly, students could be incentivized to travel off-peak by increasing the basic grant, thereby providing them with more budget to afford accommodation.

The non-financial measures can also be categorised. The most frequently mentioned alternative here is the staggering of hours. By staggering the start and end times of work or school days, the distribution of travellers over time can be more evenly spread. Other types of measures include ’Extra Service’ and ’Non-Financial Rewards’. An ’Extra Service’ improves the quality of the journey by improving the frequency and reliability of transport or by providing the traveller with Wi-Fi, food or beverage. ’Non-Financial Rewards’ is a subcategory of measures that incentivizes peak avoidance by awarding credits. These credits can be saved to purchase items such as a Netflix subscription, an (e-)bike, or a phone.

Other measures to encourage students to travel less or at different times include partially offering online education, as seen in the ’Blended Learning’ alternative. Additionally, making it easier and more affordable for students to live on campus can be achieved by increasing the availability of housing on or near campus and providing (greater) subsidies for student rentals.

Table 5.2: Policy Measures and Their Contexts

Category	Sub Category	Policy Measure Inventory	Student Context	Effect	Source
Financial	**Contribution**	Current subscription + €20 contribution	Yes	Low	(P. Bakker & Wortelboer-van Donselaar, 2014)
		Current subscription + €75 contribution	Yes	Low	(P. Bakker and Wortelboer-van Donselaar, 2014)
	Route-Specific Travel Subscription	Route of choice free, 40% discount outside peak hours	Yes	Moderate	(P. Bakker and Wortelboer-van Donselaar, 2014)
	Budget	Mobility budget €60	Yes	Moderate	(P. Bakker and Wortelboer-van Donselaar, 2014)
		Free budget €60	Yes	Moderate	(P. Bakker and Wortelboer-van Donselaar, 2014)
		MaaS budget for public transport and shared mobility	Yes	-	(OV magazine, 2023)
	Differential Pricing	+10% peak hour fare	No	Low	(Whelan & Johnson, 2004)
		+30% peak hour fare	No	Moderate	(Whelan and Johnson, 2004)
		+50% peak hour fare	No	High	(Wang et al., 2018)
		-10% off-peak hour fare	No	Low	(Whelan & Johnson, 2004)
		-30% off-peak hour fare	No	Low	(Whelan and Johnson, 2004)
		-50% off-peak hour fare	No	High	(Wang et al., 2018)
		+52% peak hour fare, -42% off-peak hour fare	No	Moderate	(Huan et al., 2022)
		Peak surcharge + surcharge refundable in shoulder period	No	-	(Tang et al., 2020)
		-25% pre-peak fare	No	Low	(Halvorsen et al., 2020)
		Full peak fare, free off-peak	Yes	High	(P. Bakker & Wortelboer-van Donselaar, 2014)
		50% peak fare, free off-peak	Yes	High	(P. Bakker and Wortelboer-van Donselaar, 2014)
		50% fare (both peak and off-peak)	Yes	Moderate	(P. Bakker and Wortelboer-van Donselaar, 2014)
		Triangular fare structure	No	Moderate	(Kamel et al., 2020)
		Three level structure; peak, shoulder, off-peak	No	Moderate	(Weesie et al., 2009)
		Weekend subscription, free after 09:00	Yes	High	(Groningen Bereikbaar et al., 2018)
	Free Off-Peak	Free travel before 7:00	No	Low	(Currie, 2009; 2010)
		Free travel before 7:45	No	Low	(Lovrić et al., 2016)
	Reward	€1.5 - €4 per trip	No	Moderate	(Peer et al., 2016)
		€3 per trip	No	Moderate	(Ettema et al., 2010)
		€4 per trip	Yes	-	(Broer, 2015)
		€7 per trip	No	High	(Ettema et al., 2010)
	Tradeable Slots	Tradeable Rush Hour Permit	No	Moderate	(Geng et al., 2023)
		Reservation System	No	-	(Hörcher et al., 2022)
		Auctioning	No	-	(Hörcher et al., 2022)
	Student Grant	Student grant	Yes	Moderate	(Overkleeft, 2020)
Non-Financial	**Staggered Hours**	15-Minute Start Time Intervals between institutes	Yes	Moderate	(EU Urban Mobility Observatory, 2019)
		30-Minute Work Hour Adjustment	No	Moderate	(O'malley, 1975)
		1-Hour Work Hour Adjustment	No	Moderate	(Zong et al., 2013)
		30-Minute Two-Sloted Start Hours	Yes	-	(Rérat, 2021)
		Weekly Spreading	Yes	-	(Daniels & Mulley, 2013)
		Reduced number of travel days	Yes	-	(Taskforce beter benutten onderwijs en openbaar vervoer, 2015)
		Reschedule 9:00 classes	Yes	-	(Daniels & Mulley, 2013)
		Start of lectures to 09:45	Yes	Moderate	(Brons, 2024)
		Start of lectures to 11:00	Yes	-	(Van Heest, 2018)
		Half of the students starting one hour later	Yes	High	(Owen Jansson Anders Ljungberg, 2009)
		Half an hour staggered start of lectures	Yes	High	(2009)
		Extended opening hours for shops and leisure facilities	No	-	(Saleh & Farrell, 2005)
	Extra Service	Wi-Fi, food, and beverage coupons	No	Moderate	(Wang et al., 2018)
		Increased off-peak service quality, frequency and reliability	Yes	-	(Daniels & Mulley, 2013)
		Student Lines	Yes	-	(C. Ding et al., 2020)
	Non-Financial Reward	Credits saving for Netflix subscription	Yes	-	(Broer, 2015)
		Credits saving for bicycle	Yes	-	(Broer, 2015)
		Credits saving for e-bike discount	Yes	-	(Broer, 2015)
		Credits saving for a phone	No	High	(Ettema et al., 2010)
		Free off-peak trip	No	-	(Yang & Tang, 2018)
	Alternative Learning	Blended learning	Yes	Moderate	(Overkleeft, 2020)
	Housing	Increased Student Housing on Campus	Yes	-	(Daniels & Mulley, 2013)
		Subsidised Student Housing	Yes	-	(Voss, 2015)
	Travel Information	Real Time Crowding Information	No	Moderate	(Drabicki et al., 2023)
	Voluntary Off-Peak Commute	Encouraging voluntary off-peak commute	No	-	(Shimizu et al., 2024)
	Combi	Reduced Student Transport Subscription + adjusted class schedules	Yes	-	(Verrips & Hilbers, 2020)

5.3. Selection

Within the scope of this study, conducting a detailed analysis of all potential measures and their combinations, as well as designing a respondent-friendly survey for all of them, is unfeasible. The same applies for calculating the associated costs and benefits. This asks for selecting a few measures to include in the survey and CBA.

The selection of alternatives is done in a rough manner. Nevertheless, the measures are not chosen entirely at random. As each measure has the potential to achieve a positive welfare effect in the cost-benefit analysis, every measure is worth further analysis. The literature indicates however that certain measures show little effect or even significant negative effects. For instance, introducing an own contribution to the current Student Travel Product (P. Bakker & Wortelboer-van Donselaar, 2014), offering free travel during the morning rush hour (Currie, 2009; 2010), or implementing only an off-peak fare reduction have minimal impact on rush hour congestion (Halvorsen et al., 2020; Lovrić et al., 2016; Whelan & Johnson, 2004). Moreover, measures such as consistently rewarding travellers entail high costs (Broer, 2015; Ettema et al., 2010; Peer et al., 2016). Increasing student housing on and around campus, creating separate student lines, and improving off-peak quality, frequency, and reliability are measures that are very challenging to implement (C. Ding et al., 2020). There are also measures that have already been (partially) implemented, which may prevent or significantly reduce the desired effects described in the literature. For instance, the basic student grant has been reintroduced (De Minister van Onderwijs Cultuur en Wetenschap, 2023), blended learning opportunities are expanding, real-time crowding information is now available in the NS app (Nederlandse Spoorwegen, 2018), and the government encourages voluntary off-peak travel.

To simplify the selection of alternatives, the impact of each measure was assessed. The abstract, introduction, and conclusion of each scientific article was reviewed to determine the magnitude of the effect. The 'Effect' column in Table 5.2 specifies whether, and to what extent, the literature indicates that a measure has a noticeable impact. The magnitude of the effect is classified as low, moderate, or high. If the effect on train congestion is unclear or not explicitly mentioned, the effect has been marked with a '-'. In Table 5.2 two subcategories stand out significantly in terms of the number of policy measures compared to the other subcategories. Much research has been conducted on differential pricing measures and staggered hours, and the findings of both are promising. Therefore, these categories of measures are used to design the policy alternatives.

Within differential pricing, there are various policy measures, as shown in Table 5.2. Those identified as having a high impact on train congestion include a '+50% peak hour fare', a '-50% off-peak fare', a 'full peak fare with free off-peak travel', a '50% peak fare with free off-peak travel', and finally, a 'weekend subscription with free travel after 09:00'. The '+50% peak hour fare' and '50% peak fare with free off-peak travel' measures are essentially the same in the context of a weekday subscription with free travel. Moreover, the '-50% off-peak fare' measure is not feasible due to the free travel, as it would result in a negative fare, essentially turning it into a reward for the traveller. For the design of the policy alternatives, the decision was made to continue with the 'full peak fare with free off-peak travel', the 'weekend subscription with free travel after 09:00' and a 40% peak fare discount compared to the full fare. This was chosen because the full peak fare represents a more extreme policy measure compared to the (+)50% peak fare. Additionally, the 'weekend subscription with free travel after 09:00' differs significantly from both the (+)50% and full peak fare. A 40% peak discount is also more in line with the current discount rate of 40% than a 50% discount rate.

Also within the staggered hours subcategory, the focus was on measures identified as having a high impact on the train congestion. The measures 'Half of the students starting one hour later' and 'Half an hour staggered start of lectures' were indicated as having a potentially high impact, as presented in Table 5.2. It was decided to combine the two measures and extent the later start time of lectures for all students to one and a half hours. As it is assumed that with the later start time, fewer students will still need to travel during peak hours despite the adjusted lecture times, as they have a travel time of more than an hour.

5.4. Policy Alternatives

In the CBA, four policy alternatives will be evaluated. Each policy alternative should represent the smallest feasible set of measures that are technically, legally, and economically feasible, as outlined in section 3.2.

In the first policy alternative, starting from the 2025-2026 academic year, the 'full peak fare with free off-peak travel' is introduced to the current Student Travel Product. Weekday subscription holders no longer have free travel on weekdays between Monday 04:00 and Saturday 04:00. When travelling between 06:30-09:00 and 16:00-18:30. However, travel on weekdays outside of these peak hours remains free. Weekend subscription holders, who currently receive a 40% discount during evening rush hours in the baseline alternative, also pay the full fare between 06:30-09:00 and 16:00-18:30.

In the second policy alternative, lecture times are shifted one and a half hours later. Beginning in the 2025-2026 academic year, classes at MBO, HBO, and universities start at 10:30 or later. The total number of teaching hours per day remains unchanged, so lectures run correspondingly later to accommodate the delayed start.

As Verrips and Hilbers (2020) mention in their article, the combination of a differential fare and staggered hours can reinforce each other. I also believe this approach is more fair for students, as it avoids imposing higher costs for a trip they must take to attend their lectures. Since the measures were tested separately in the previous two alternatives, they are permitted to be combined in this case according to Romijn and Renes (2013). The following two alternatives have been developed from this.

In the third policy alternative, weekday subscription holders pay the 40% discount fare for travel between 06:30-09:00 and 16:00-18:30 starting from the academic year 2025-2026. Additionally, from this year, teaching times in MBO, HBO, and universities will be adjusted to start at 10:30, as in alternative 2, and will extend proportionally longer.

In the fourth and final alternative, all students will receive the same subscription. This subscription allows for free travel on weekdays and weekends, with the exception of the morning rush hours. Between 06:30 and 09:00, all students will pay the full fare. In this alternative, teaching times are also shifted to a later hour, as explained in alternative 2.

The names and descriptions of the four policy alternatives are presented clearly in Table 5.3.

Table 5.3: Overview of Policy Alternatives

Policy	**Description**
1. Paid Peak Hour Travel	Under this policy, both weekday and weekend subscription holders must pay the full fare when travelling by train between 06:30-09:00 and 16:00-18:30.
2. Shift Lecture Hours	All lectures and scheduled educational activities start no earlier than 10:30. Lectures will be extended by the same duration they are delayed. The conditions of the student travel subscription do not change.
3. 40% Peak Discount + Shift Lecture Hours	Weekday subscription holders pay a 40% reduced fare when travelling by train between 06:30-09:00 and 16:00-18:30 and travel for free outside peak hours. No change for students with a weekend subscription. Lectures begin at 10:30 and end later, as in policy 2.
4. Weekend + Weekday Free After 09:00 Subscription + Lecture Time Shift	All students receive a subscription for free weekend travel and weekday travel after 09:00, but pay full fare during the morning peak (06:30-09:00). Lecture times shift to start at 10:30, as described in policy 2.

6
Identification

Now that four policies have been selected for further analysis, this chapter will take the first step towards determining the effects of these policy measures. The goal of this chapter is to identify all relevant policy effects, so that they can be quantified and monetized in chapter 8. Some effects will also be tested in the survey, as will be discussed in chapter 7.

6.1. Types of Effects

Since it is impractical to investigate all the consequences of a policy measure, it is helpful to categorize the effects into different types. Firstly, the literature distinguishes effects on existing markets, referred to as priced effects, and effects on missing markets, known as non-priced effects or externalities (Romijn and Renes, 2013). An existing market is the market for all priced goods and services, while a missing market is a non-existing market for goods and services which are not priced (Romijn and Renes, 2013). This distinction is not crucial for identification, but it will certainly play a role in valuing the effects as non-priced effects need to be monetized.

The more important distinction for identifying effects, is whether they are direct or indirect results of the policy measure. The direct effects of a measure are the effects in the market where the measure intervenes and include direct cost and benefits during the measure's lifetime (Romijn and Renes, 2013). Direct effects lead to impacts on other markets, these secondary impacts are referred to as indirect effects. The distinction is crucial because it is necessary to first identify the direct effects before investigating the effects that arise from them. Direct and indirect effects can both occur in existing and missing markets (Romijn and Renes, 2013).

6.2. Conceptualization of Effects

To understand the potential effects of the policy alternatives presented in section 5.4, the articles on differential fares and staggered work hours were revisited again. These articles identified various effects; however, to further explore additional impacts and the effects of those effects, multiple scientific and grey literature searches were conducted. After identifying numerous effects, it became apparent that a simple list was insufficient to describe the causal relationships and underlying connections between them. The conceptual framework outlined by Van Wee et al. (2014) offered a structured model for organising the effects and establishing connections between them. The conceptual model helps to better understand how certain effects arise. Effects expected to have a significant impact are included in the conceptual model, as shown in Figure 6.1 within the ovals. In subsection 6.2.1, additional details are provided regarding the costs that will be incurred. Section 6.2.2 outlines the direct effects included in the conceptual model. Indirect effects are discussed in subsection 6.2.3, while subsection 6.2.4 presents the external effects of the policy alternatives.

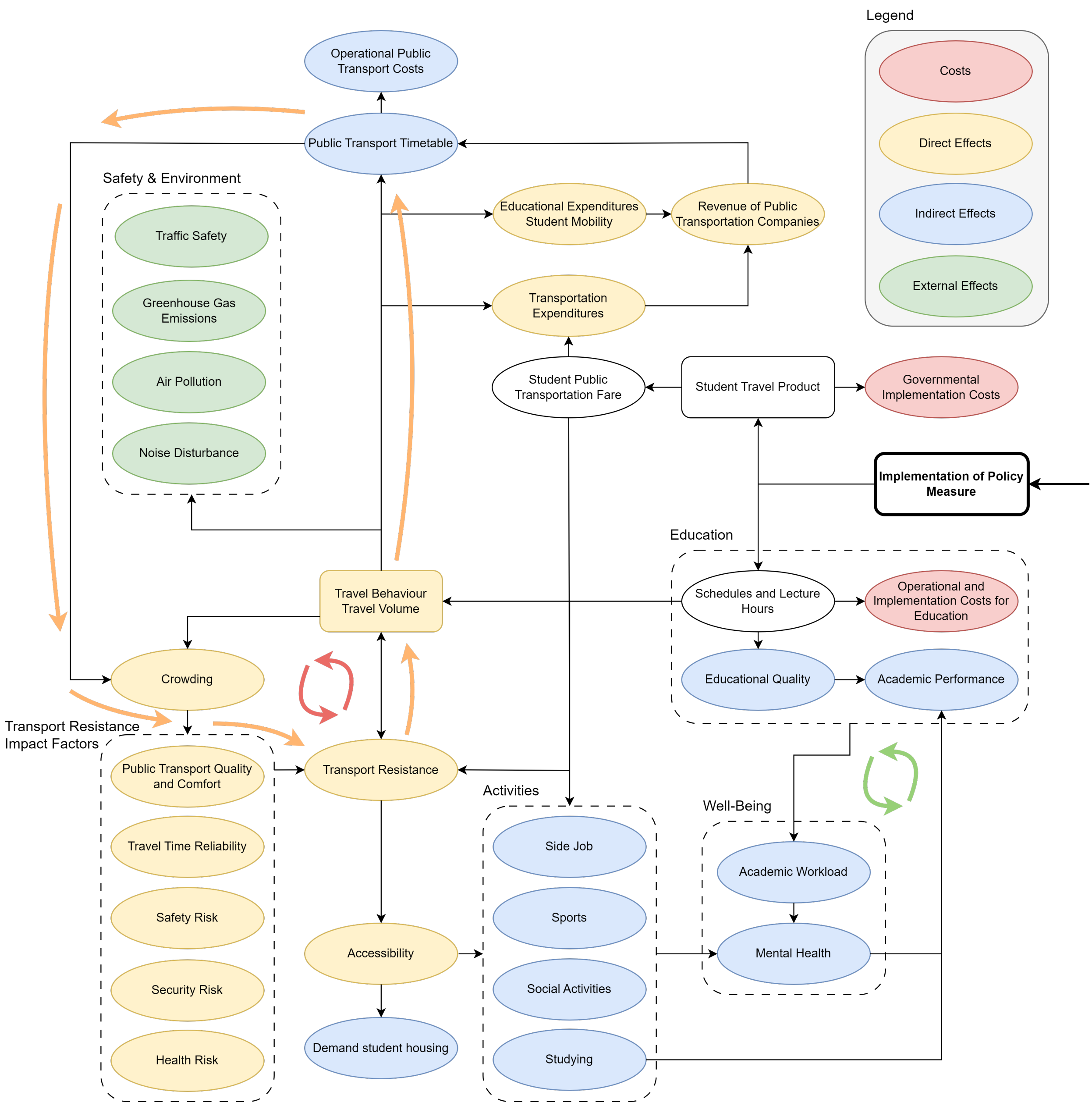


Figure 6.1: Conceptual Model of Effects

6.2.1. Costs

To implement the policies outlined in the policy alternatives, various costs will be incurred. According to the General Guidance by Romijn and Renes (2013), these costs represent the resources needed to implement and maintain the measures. In Figure 6.1, the cost items are highlighted in red. In the right side of this figure is shown that the implementation of the policy measures requires adjustments to either the Student Travel Product, the schedules and lecture hours in education, or both of them. Implementing 'new' public transportation fares for the Student Travel Product requires a one-time investment from the Ministry of Education, Culture and Science to modify the legislation, inform students, and update the product digitally. Adjusting schedules and lecture times at MBO's, HBO's, and universities also incurs costs, as schedulers need to create a new timetable with updated start and end times and then implement it for each program. Furthermore, the education sector incurs annual costs to compensate teachers for the hours they work beyond 18:00.

6.2.2. Direct Effects

The direct effects of the four policy measures occur within the markets they target, namely the rail market and the education market. In Figure 6.1, these effects are highlighted in yellow. While the shift of lectures to a later time reduces the need for most students to travel during peak hours, the adjustment of fares results in higher transport resistance and thus provides a financial incentive to actually avoid peak hour travel. In this way, the two policy aspects reinforce each other and influence students' travel behaviour, as shown in Figure 6.1. The increased transport resistance also impacts the accessibility of education. There is a loss in utility because students who previously travelled for free now have to pay for peak hour travel. This results in some students travelling outside peak hours or not travelling at all on certain days.

When the measures achieve their desired impact, it will be more quiet during peak times on the train. The quality, comfort and travel time reliability of the journey will improve, and reduced crowding will also lower safety, security, and health risks. This will reduce transportation resistance for commuters, attracting new passengers who might have otherwise chosen alternative activities or locations. Both existing and new passengers will have comfort benefits from this improvement. However, as new passengers are attracted, the trains become a bit more packed again. A feedback loop emerges, as indicated in figure Figure 6.1 using the red circular arrows. This feedback loop causes train congestion to partially stabilize at an equilibrium.

In the policy alternatives, the number of kilometers travelled by students will change. As the reimbursement paid by the Ministry of Education, Culture, and Science depends on this number of kilometers (Dijkgraaf, 2023b), the educational expenditures on student mobility will also change. This, in turn, will affect the revenue of public transportation companies. However, these companies will gain an additional revenue stream from students who pay to travel during peak hours. The total revenue determines how much public transport the transportation companies can offer in their timetable. The timetable subsequently affects the level of crowding in public transport, which influences the transport resistance factors and thus the transport resistance. This creates a feedback loop, as the transport resistance subsequently impacts passenger behaviour and the realised volume. This feedback loop is indicated in Figure 6.1 with the orange arrows.

6.2.3. Indirect Effects

The direct changes in the rail and education markets impact other markets, such as the housing market, the time allocated to different activities and the student well-being. Together, they represent the indirect effects of the policy measures. In Figure 6.1 the indirect effects are shown in blue. The impact on accessibility affects the location and timing of activities (Van Wee et al., 2014). This can relate to studying, working, sports, and social activities. Accessibility also affects the demand for housing locations. As transportation costs increase, more students may feel forced to live closer to the educational institution.

The time spent on and the quality of education together influence students' academic performance. However, the timing can also play a role. For example, according to (Bhalerao & Atabey, 2022), studying in the morning is more productive, but students tend to sleep more if classes start later in the day (Dikker et al., 2020). The organization and execution of education as a whole affect the academic workload experienced by students. A high academic workload leads to mental stress, which in turn results in poor mental health. Since this also impacts academic performance, it creates a feedback loop. This feedback loop is indicated in Figure 6.1 with the green circular arrows.

6.2.4. External Effects

In the policy alternatives, the frequency and choice of transportation by students may change. Commuters also adjust to the new travel behaviour of students. The total combined transportation volume throughout the day is crucial for traffic safety and its environmental impact. The latter effect can be further divided into greenhouse gas emissions, air pollution, and noise disturbance. The green circles in Figure 6.1 represent the external effects of the policy measures.

7 Adapted Student Travel Behaviour

In accordance with the research approach as outlined in Chapter 3, a survey was conducted with students living outside their study city. The survey consisted of a set of closed-ended questions, presented to the respondents in a fixed sequence. This chapter substantiates the choice of the survey questions (section 7.1) and discusses the survey results (section 7.2). The survey results will be used as input in calculating the relevant market effects for the policy options being assessed in Chapter 8.

7.1. Survey Outline

The survey consisted of 69 closed-ended questions, not all of which were visible to respondents. The questions shown to respondents depended on their earlier answers in the survey. For example, a respondent studying at a HBO institution did not need to select their institution from a list that also included universities and MBO institutions. Similarly, respondents were not required to indicate peak time travel frequency for transportation modes they did not use.

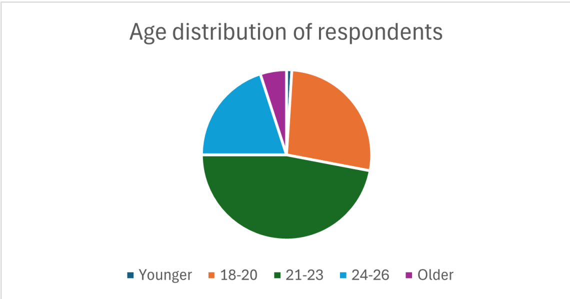
The design of the survey questions was done with the survey's purpose in mind. The primary objective is to ascertain the extent to which peak hour train commuting decreases under the proposed policy measures. Furthermore, we seek to determine whether the policy measures could potentially influence the modal choice of the respondents. Finally, the goal is to measure changes in time allocation to other activities and to assess policy acceptance for reflection afterwards.

The online survey begins with the opening statement on the start page. In the opening statement, the researcher introduces himself, discusses the purpose of the survey, and informs the respondent on how their data will be used and stored. By proceeding to the next page of the survey, the respondent agrees to participate and consents to the described data processing. Mandatory approval from the TU Delft ethics committee on the opening statement and data management of the survey was obtained. The letter of approval is attached in Appendix C.

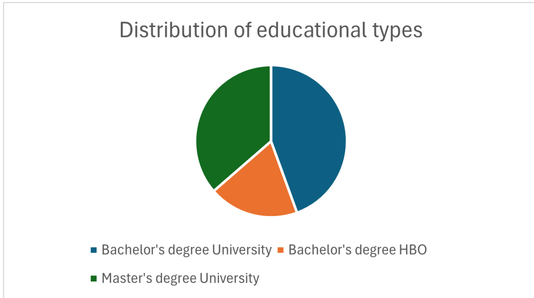
In the first set of questions, the student is asked about their age, place of residence, type of education, educational institution, and whether they have a Student Travel Product (Student-OV). In the second set of questions, the respondent is asked how often they travel to their educational institution, what mode of transportation they primarily use for this journey, and how often they travel during the morning and evening peak with this mode. Next, the respondent is presented with the four policy measures through a brief description. In the subsequent four sets of questions, the respondent is asked how often they expect to travel to their educational institution under each policy, what mode of transportation they would use, and how often they would travel during the morning and evening peak hours. Additionally, the student is asked to estimate the change in the number of hours per week they expect to spend on their side job, sports, and social activities. Finally, they rate the acceptability of each policy measure on a 5-point scale from very unacceptable to very acceptable. The complete questionnaire of the survey can be found in Appendix B.

7.2. Survey Results

Throughout the survey's duration, responses were recorded from 143 respondents. However, not all respondents completed the survey; only 91 respondents reached the end of it, of whom 88 answered all the questions. Nearly half of these respondents were aged between 21 and 23 years old, as shown in Figure 7.1. With 44% of respondents pursuing a university bachelor's degree and 36% pursuing a university master's degree, the majority of respondents are university students. The remaining 19% of respondents are enrolled in a bachelor's program at an HBO institution. As shown in Figure 7.2, nearly all respondents own a student weekly subscription. This finding was expected as the survey only included students who do not live in the city where they study. Those students typically benefit more from a weekly subscription as they often commute to their institution multiple times during the week.



(a) Age



(b) Type of Education

Figure 7.1: Distribution of Age (a) and Type of Education (b) Among Survey Respondents

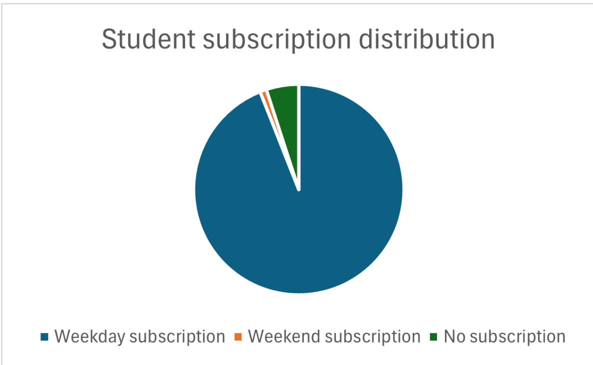


Figure 7.2: Student Subscription Shares

7.2.1. Current Travel Behaviour Among Students

The survey results indicate that, on average, students currently commute to their educational institution 3.63 days per week. Three-quarters of the students primarily use the train for the majority of their journey, 15% use the bus, tram or metro, while the rest goes by bicycle or car, as illustrated in Figure 7.3.

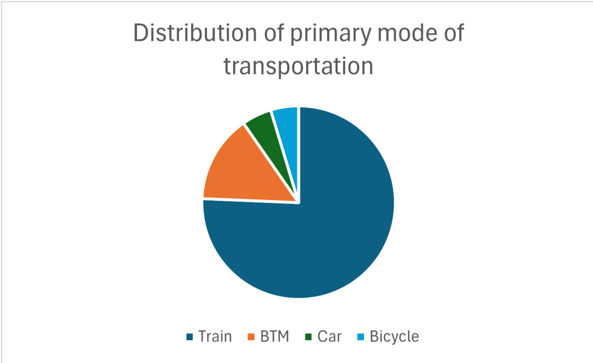


Figure 7.3: Mode of Transport

Students travelling by train visit their institution on average 3.56 days a week, as shown in Table 7.1. Nearly three-quarters of the trips to the institution occur during the morning peak. For the return trips in the evening peak, this proportion increases to four-fifths. Regarding other modes of transport, students who travel by bus, tram, or metro visit their educational institution most frequently, whereas those who use a car do so the least often. Furthermore, students using BTM travel more often during peak hours compared to car users.

Table 7.1: Transportation Statistics

Mode of Transport	Avg. Days to Institution	% Travel Morning Peak	% Travel Evening Peak
Train	3.56	72.8%	80.9%
BTM (Bus, Tram, Metro)	4.24	86.8%	70.3%
Car	3.00	33.3%	41.7%
Bicycle	4.06	62.6%	60.1%

7.2.2. Travel Behaviour in Four Policy Scenarios

Next, the survey presented the respondents with the four measures chosen in chapter 5. Once again, their travel behaviour was assessed. Across all policy measures, there was a decrease in the average number of days travelled to the institution, as shown in Table 7.2. With the introduction of Paid Peak Hour Travel, respondents would, on average, commute one day less to their educational institution, whereas the reduction with the other policy measures would be considerably smaller. Students may reduce their trips to the educational institution, choosing to attend only on days when they have several or more significant lectures due to the higher transport costs. On one hand, this could indicate that students are skipping some classes. On the other hand, some education will probably be followed online.

Table 7.2: Impact of Policy Measures on Average Days to Institution

Policy Measure	Change in Avg. Days to Institution (%)
Paid Peak Hour Travel	-27.6%
Shift Lecture Hours	-8.5%
40% Peak Discount + Shift Lecture Hours	-9.4%
Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift	-4.7%

The policy measures also impact the choice of transportation mode, as shown in Table 7.3. In policy scenarios where students face higher fees for train travel during peak hours, a decrease in the choice of this mode of transport is observed. This effect is also observed for the BTM transportation mode. Although our survey does not specify that higher costs will apply for BTM in the policy scenarios, respondents likely assumed so given the current form of the subscription. The choice to commute to the institution by car actually increases in most scenarios, because the costs for other modes of transport have risen. As a result, the car has become relatively cheaper, leading students who find it more comfortable to travel by car to choose this option more frequently. Only in the 'Shift Lecture Hours' alternative does car usage decrease, which may indicate that some students choose to drive during peak hours, while opting for public transport outside of these times. There are notable changes in bicycle usage in two scenarios. In the Paid Peak Hour Travel scenario, bicycle usage increases substantially. These students might live within cycling distance but prefer to travel by public transport for convenience, especially since it's free. However, in the scenario where the public transport subscription includes both weekday and weekend travel but paid peak hour travel, bicycle usage decreases. This is due to the fact that students who would normally choose to cycle are less inclined to do so under this alternative, as public transport is more often free.

Table 7.3: Impact of Policy Measures on Mode of Transport

Policy Measure	Train	BTM	Car	Bicycle
Paid Peak Hour Travel	-11.2%	-13.7%	116.6%	57.0%
Shift Lecture Hours	2.9%	-5.7%	-30.0%	-3.6%
40% Peak Discount + Shift Lecture Hours	-2.4%	-5.7%	50.0%	-3.6%
Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift	-0.2%	-1.2%	10.0%	-25.1%

Shifting lecture times and increasing the cost of peak hour travel also contribute to changing travel patterns throughout the day. Table 7.4 shows how the number of trips during peak times changes under the policy measures. Paid Peak Hour Travel leads to a reduction in peak hour travel on trains and BTM, with a more pronounced decrease observed during evening peak. In contrast, the policy measure sees an increase in the number of car trips during peak hours. The number of bicycle trips during peak hours shows minimal change, with a slight increase observed during the evening peak. When public transport prices remain unchanged but lecture times shift, a different outcome emerges. A greater decrease is observed in the number of trips during the morning peak for train and BTM. The number of trips during the evening peak also declines, but much less than for the measure of Paid Peak Hour Travel. This policy scenario also results in a decrease in the number of car trips during peak hours. The most significant percentage decline is observed in the number of bicycle trips during the morning peak, whereas a slight increase is observed during the evening peak.

For the policy measures involving increased costs for peak hour travel and shifted lecture hours, we observe somewhat similar outcomes for the usage of train and BTM. Here, the decrease in the number of trips during the morning peak is smaller than with the 'Shift Lecture Hours' policy measure. This trend is also reflected in the number of train trips during the evening peak, whereas for bus, tram and metro trips a slight increase is shown. The use of cars during peak hours differs between these two policy measures. With '40% Discount + Shift', car use increases by 30 to 50 percent compared to the current situation. When travelling at full fare during peak hours but with free weekend travel and shifted lecture times, car use remains almost the same during the morning peak, while it decreases during the evening peak. Finally, both measures show a decrease in the number of bicycle trips during peak hours.

Table 7.4: Percentage Change of Trips During Peak Hours for each Mode of Transport

Policy Measure	Peak Time	Train	BTM	Car	Bicycle
Paid Peak Hour Travel	Morning Peak	-34.4%	-22.3%	116.0%	-0.4%
	Evening Peak	-45.8%	-27.2%	65.6%	17.2%
Shift Lecture Hours	Morning Peak	-50.6%	-32.6%	-20.0%	-59.8%
	Evening Peak	-30.6%	-12.1%	-20.0%	9.4%
40% Discount + Shift	Morning Peak	-47.5%	-24.2%	55.0%	-69.3%
	Evening Peak	-36.1%	-8.4%	33.6%	-31.6%
Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift	Morning Peak	-47.1%	-26.1%	1.0%	-83.5%
	Evening Peak	-20.8%	3.0%	-32.8%	-18.4%

7.2.3. Well-being and Acceptability

As described in section 7.1 , the survey also attempts to roughly capture the changes in students' well-being. This is assessed by examining changes in the time spent on side jobs, sports, and social activities. Students report that, on average, they will spend more time on their side jobs, sports, and social activities under the policy measures, as shown in Table 7.5. The average number of hours that students expect to spend on their side jobs increases the most across all policy scenarios. The policy measure 'Paid Peak Hour Travel' leads to the highest expected increase, with more than 2 additional hours per week. Students also expect to spend, on average, an additional 30 to 45 minutes per week on sports. The average time students expect to spend on social activities changes the least, with the most significant increase occurring when students can travel for free on weekends.

Table 7.5: Avg. Hourly Change of Time Spent on Side Job, Sports and Social Activities

Policy Measure	Side Job	Sports	Social Activities
Paid Peak Hour Travel	2.26	0.75	0.27
Shift Lecture Hours	1.04	0.31	0.26
40% Peak Discount + Shift Lecture Hours	1.27	0.35	0.07
Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift	1.53	0.71	0.82

Although it falls outside the scope of the study, we also measured acceptance of the policy measures. Policy measure 'Paid Peak Hour Travel' faces the most resistance from students. For almost 90% of students this measure is unacceptable. Additionally, the implementation of the 40% peak hour discount and the adjustment of lecture times are not well-received by students. The majority consider these measures unacceptable. The policy allowing students to travel for free on weekdays outside peak hours and on weekends, along with shifting lecture times, receives the most positive rating. For nearly half of the students this measure is acceptable. Finally, for the policy measure involving only shifting lecture times, about an equal number of students find it acceptable as those who do not.

Table 7.6: Acceptability of Policy Measures

Policy Measure	Very Unacceptable	Unacceptable	Neutral	Acceptable	Very Acceptable
Paid Peak Hour Travel	63%	26%	9%	2%	0%
Shift Lecture Hours	13%	26%	24%	32%	6%
40% Peak Discount + Shift Lecture Hours	13%	42%	26%	18%	1%
Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift	5%	25%	24%	30%	17%

A final important note is that the results presented in this chapter are subject to significant uncertainty. The limitations associated with this are further elaborated in chapter 11. However, these limitations do not pose a problem for this study, as the survey was designed to provide insight into the extent of changes in student travel behaviour.

8 Effects

The survey results presented in the previous chapter now provide data to calculate the identified effects of chapter 6. This chapter outlines the estimated impacts of the policy measures (chapter 5) compared to the baseline alternative, as described in chapter 4. These effects will also be monetized, assigning a monetary value to non-monetary impacts. The chapter begins with an analysis of the costs of the policy (section 8.1), followed by an examination of the direct effects in section 8.2. Indirect effects are discussed in section 8.3 and finally, section 8.4 explores the external effects. In Appendix E, a table is included with the inputs for each effect.

8.1. Costs

To implement the policies in the policy alternatives, costs will first be incurred. These include initial costs for implementation, which can be regarded as investment costs. Additionally, there will be ongoing annual costs to maintain the policy.

8.1.1. Costs of Student Travel Product Implementation

The introduction and implementation of the 'new' Student Travel Product entails costs, as shown in the conceptual model in Figure 6.1. The estimate will be a rough approximation, as no data is available for the specific policy implementation of these forms of the Student Travel Product. The initial costs have been estimated based on Dijkgraaf (2023a), concerning the transition of the Student Travel Product from the OV-chipkaart to an OV-pass (OV-pay). It is assumed that the initial implementation costs for changing the travel product are the same for each alternative, as shown in Table 8.1.

Table 8.1: Costs of Student Travel Product Implementation (in million €)

Policy Measure	Initial Costs
Paid Peak Hour Travel	-2.5
Shift Lecture Hours	0.0
40% Peak Discount + Shift Lecture Hours	-2.5
Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift	-2.5

8.1.2. Costs of Scheduler Labour

In the last three policy alternatives, there is a shift in lecture times. With a start time of 10:30 or later, all universities begin their lectures later than they did before. However, in these policy alternatives, lectures also run proportionally longer, meaning no additional teaching spaces are needed compared to the baseline alternative. According to Adviesteam Slim Reizen (2023) changing the schedule should not incur significant extra costs, apart from the implementation process and the required labour hours. It became evident during the pandemic that schedulers worked extra hours to arrange the more complex online and on-campus classes (Lambeets, 2021). Due to a lack of data on the costs of shifting lecture times, a rough estimate has been made. The assumption is that there are only initial costs for creating a new schedule, which require 0.5 FTE for a year on 25.000 students. Based on the number of students, as described in chapter 4, and an average annual FTE salary of €27,585 (talent.com, 2024), the cost of this item has been estimated, as shown in Table 8.2.

Table 8.2: Costs of Scheduler Labour (in million €)

Policy Measure	Initial Costs
Paid Peak Hour Travel	0.0
Shift Lecture Hours	-0.7
40% Peak Discount + Shift Lecture Hours	-0.7
Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift	-0.7

8.1.3. Costs of Employee Overtime Hours

A shift in lecture times also leads to a change in working hours for employees at the educational institutions. Although not all employees have the same contract, the cost estimation is based on the collective labour agreement for Dutch universities (Universiteiten van Nederland (UNL), 2023). According to this agreement, employees who work overtime on weekdays (after 18:00) receive 150% of their regular salary for the additional hours worked. In the policy alternatives, it is assumed that employees work an average of 1 hour of overtime on two out of five working days due to the adjusted lecture schedules. The total number of overtime hours is based on the number of FTEs in MBO (MBO raad, 2023), HBO (Vereniging Hogescholen, 2023), and WO (Puylaert, 2023), and adjusted over the time horizon to account for changes in student numbers. The hourly costs are derived from the minimum salaries of lecturers in MBO (Onderwijsloket, 2024) and HBO from 2023, and WO from 2022 (Hoger Onderwijs Persbureau, 2019). Those salary have also been adjusted to the base year 2025 with an average annual salary increase of 3.85% (Centraal Bureau voor de Statistiek, 2019a). The costs of overtime hour by educational employees is about 50 million euros per year, as shown in Table 8.3.

Table 8.3: Yearly[a] Costs of Employee Overtime Hours (in million €)

Policy Measure	Costs
Paid Peak Hour Travel	0.0
Shift Lecture Hours	-46.1
40% Peak Discount + Shift Lecture Hours	-46.1
Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift	-46.1

[a] Based on the year 2030.

8.2. Direct Effects

Following the implementation of the policies from the policy alternatives, direct effects emerge in both the transportation and education markets. Subsection 8.2.1 describes how students adapt their travel behaviour. Changes in accessibility to education are covered in subsection 8.2.2. Next, subsection 8.2.3 details the comfort benefits for travellers, while subsection 8.2.4 addresses travel time reliability. Finally, subsection 8.2.5 examines the reduced costs from the Ministry of Education, Culture, and Science for the Student Travel Product.

8.2.1. Student Travel Behaviour

A first direct effect observed in three policy alternatives is the increased 'Transport Resistance' for travelling during (morning) peak hours, as shown in Figure 6.1. In these alternatives, students pay more for their peak trips compared to the baseline alternative. Additionally, transportation demand throughout the day shifts as lectures move to a later time. Together, these changes result in different travel behaviour for students. Figure 8.1 shows the share of trips per mode of transport during the morning peak in the baseline alternative. The academic year 2030-2031 was used for the graph, as it falls in the middle of the time horizon.

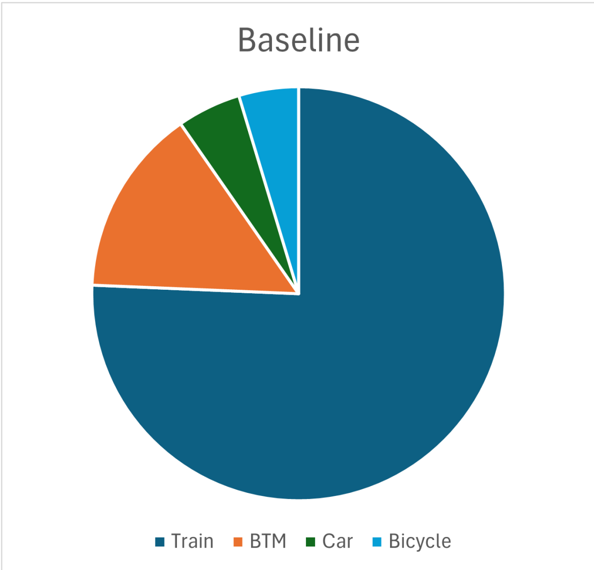


Figure 8.1: Morning Peak Mode Shares in Baseline

Figure 8.2 till 8.5 illustrate how this share of trips during the morning peak changes across the policy alternatives. This change is determined based on the percentage increases and decreases in transport modes reported in the survey and the changes in the number of peak hour trips students make with each mode of transport. Finally, it is assessed how many of these trips occur outside peak hours or are avoided entirely by examining the average reduction in the number of days students travel to their educational institution. The graphs also highlights the share of morning peak trips from the baseline alternative that are no longer made. For these trips, the student either no longer travels to the educational institution at all or travels outside the morning peak hours. Different travel behaviour is also observed during the evening peak and off-peak times. Appendix D includes graphs that illustrate the changes in passenger kilometers per mode of transport during the morning peak, evening peak, and off-peak periods for each policy alternative.

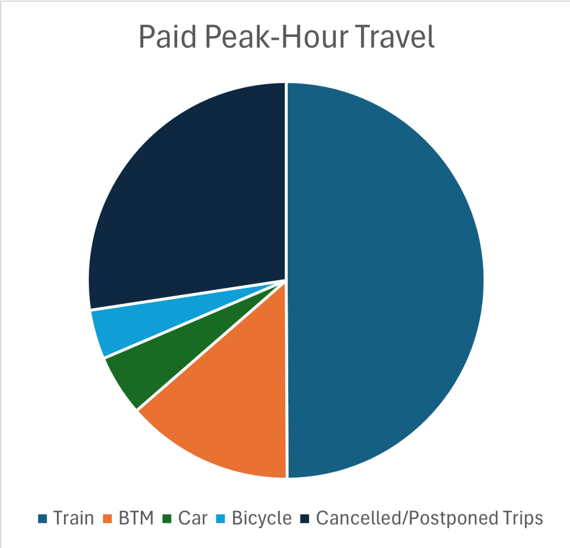


Figure 8.2: Morning Peak Mode Shares in Paid Peak Hour Travel

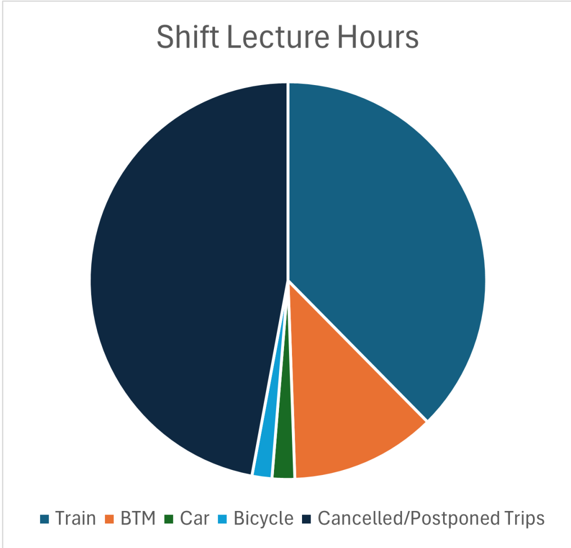


Figure 8.3: Morning Peak Mode Shares in Shift Lecture Hours

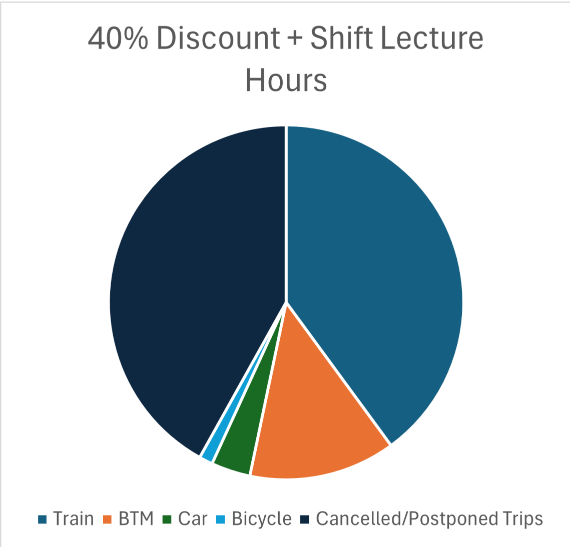


Figure 8.4: Morning Peak Mode Shares in 40% Discount + Shift Lecture Hours

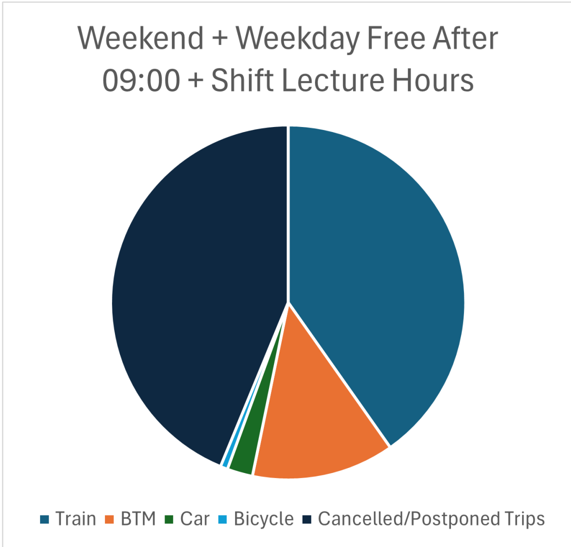


Figure 8.5: Morning Peak Mode Shares in Weekend + Weekday Free After 09:00 + Shift Lecture Hours

8.2.2. Educational Accessibility

The higher 'Transport Resistance' during peak hours, due to price increases in public transport, also reduces 'Accessibility' for students travelling to their educational institution, as described in chapter 6. The accessibility loss in this analysis is measured by the loss of consumer surplus. This reflects the gap between what students are willing to pay and what they actually pay for their travel (Kozlik, 1941). When prices increase, this gap narrows, as this is a loss of utility for the students. The decrease in consumer surplus occurs both for travellers who continue to use public transport during peak hours after the price increase (persisting travellers) and for those who choose to travel outside peak hours or use a different mode of transport (dropped-out travellers) (Romijn & Renes, 2013).

The calculation of the loss in consumer surplus is based on average kilometer fare from 2023: €0.23 for bus and metro, €0.35 for trams, and €0.14 for trains (Autoriteit Consument & Markt (ACM), 2021). And have been adjusted to the base year 2025, based on an assumed annual increase of 2.7% in public transport fares between 2009 and 2019 (Centraal Bureau voor de Statistiek, 2019b). The loss in surplus for persisting travellers in the policy alternatives can be calculated by multiplying the difference in tariff compared to the baseline alternative by the number of kilometers travelled in the policy alternative. In the 'Paid Peak Hour Travel' alternative, the tariff difference equals the average kilometer tariff, as students travel for free in the baseline alternative. With only a shift in lecture hours, the tariff remains unchanged, resulting in no loss of consumer surplus. For the alternative where students receive a 40% discount during peak hours, the kilometer tariff is reduced by 40%. Lastly, the final policy alternative applies the same pricing as 'Paid Peak Hour Travel'. The first three policy alternatives assess the number of kilometers travelled during both morning and evening peak hours, as reported in section subsection 8.2.1, while the last alternative considers only the kilometers travelled during the morning peak.

For dropped-out travellers, the loss in consumer surplus is calculated using the rule of half. This means that the loss in consumer surplus is equal to half of the surplus for the persisting travellers (Infrastructure Australia, 2021). The consumer surplus for the dropped-out travellers can then be calculated by multiplying the difference in travelled kilometers between the policy alternative and the baseline alternative by half the tariff, as discussed above. By adding the consumer surplus for both train and BTM, as well as for persisting and dropped-out travellers, the total loss in consumer surplus, or the loss in accessibility, can be calculated. In Table 8.4 the loss is presented for the year 2030.

Table 8.4: Yearly[a] Educational Accessibility Loss (in million €)

Policy Measure	Costs
Paid Peak Hour Travel	-299.5
Shift Lecture Hours	0.0
40% Peak Discount + Shift Lecture Hours	-143.6
Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift	-88.0

[a] Based on the year 2030.

8.2.3. Comfort Benefits

In the policy alternatives, there is a smaller and more balanced number of passenger kilometers per train throughout the day. This results in a higher seat opportunity and fewer passengers per square meter, thereby enhancing overall travel comfort. This not only results in comfort benefits but also attracts new passengers. To estimate the improvement in comfort, a multiplier of the value of travel time is applied. The magnitude of the multiplier depends on the level of crowding and varies between seated and standing passengers. Additionally, the increase in new train passengers is taken into account.

Given a seat availability of 94.7% during peak hours on NS trains in 2023 (Nederlandse Spoorwegen, 2024a), an estimate is made of the number of hours passengers spend in crowded trains, in which they experience reduced comfort. It is assumed that 5.3% of passenger kilometers during peak hours in the baseline alternative are travelled by standing passengers in conditions where all seats are occupied and some passengers are standing. Moreover it is assumed that 25% of the passenger kilometers during peak hours are travelled as seated passenger in those same conditions. The corresponding multipliers are presented in Table 8.5 (Kouwenhoven et al., 2023). By using the average train speed of 69.3 km/h (Planbureau voor de Leefomgeving (PBL), 2018), including station stops, the number of passenger kilometers can be converted into travel time.

Table 8.5: Crowding Multipliers (2023)

Crowding Level	Sit	Stand
100% of the seats occupied, people are standing everywhere (1 person per square meter)	1.18	1.93

In the policy alternatives, it is assumed that the number of standing and seated passengers in crowded trains decreases proportionally with the increase in available passenger kilometers. Additionally, a correction has been made for a reduced timetable, as will be explained in subsection 8.2.7. For calculating comfort benefits, a differentiation is made between existing and new train passengers. The benefits for existing passengers are determined by multiplying the value of travel time by their travel time. For new passengers, the calculation follows the rule of half, as described in subsection 8.2.2. This involves multiplying the value of travel time by the travel time of new passengers and then dividing the result by two.

The societal benefits of the comfort improvements are detailed in Table 8.6. The differences between the alternatives are relatively minor. The 'Paid Peak Hour' alternative provides the greatest benefits, as it is most effective in reducing the number of passengers on the train.

Table 8.6: Yearly [a] Societal Comfort Benefits for Train Travel (in million €)

Policy Measure	Low	High
Paid Peak Hour Travel	77.0	80.6
Shift Lecture Hours	60.2	63.0
40% Peak Discount + Shift Lecture Hours	68.4	71.6
Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift	51.8	54.2

[a] Based on the year 2030.

8.2.4. Travel Time Reliability

As crowding levels in trains decrease, fewer trains will face delays caused by the heavy congestion during boarding and deboarding at stations. This can improve the reliability of travel time. However, there are no official figures indicating how many delays and disruptions are due to overcrowded trains or what proportion they represent. Overcrowding as a cause of delays is often not mentioned at all (Nederlandse Spoorwegen, 2024b). In the disruptions reported by passengers, only 7 instances of overcrowding were recorded over the past 2 years (Rijden de Treinen, 2024). This effect is not included because a realistic estimation of its impact cannot be made, and based on the number of reported disruptions, its overall effect is likely to be negligible.

8.2.5. Governmental Savings on Student Mobility

The reimbursement paid by the Ministry of Education, Culture and Science to transport providers for the Student Travel Product is recalibrated every three years based on the average number of travel kilometers per student (Dijkgraaf, 2023b; Jehoram, 2024). As described in subsection 8.2.1, students in the policy alternatives travel fewer kilometers by train and BTM. Therefore, the reimbursement will be lower in the policy alternatives, providing a benefit for the Ministry as it reduces its annual costs. The reimbursement for each academic year is based on the number of kilometers travelled three years earlier. Consequently, the compensation will remain consistent with the baseline alternative until the academic year 2027-2028. The savings for the Ministry are calculated based on a compensation of 1 billion euros for the number of kilometers travelled in the base year 2023-2024 (Hoger Onderwijs Persbureau, 2023). This calculation does not distinguish between kilometers travelled during peak hours and those travelled off-peak. Results are shown in Table 8.7.

Table 8.7: Yearly[a] Governmental Savings on Student Mobility (in million €)

Policy Measure	Effect
Paid Peak Hour Travel	272.2
Shift Lecture Hours	21.2
40% Peak Discount + Shift Lecture Hours	83.2
Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift	19.8

[a] Based on the year 2030.

8.2.6. Benefits of Overtime Hours for Employees

While it incurs costs for the university to pay teaching staff for hours worked beyond their regular hours (subsection 8.1.3), it can provide benefits for teachers who are willing to work during these hours. For this effect it is assumed that each teacher has a specific willingness to pay to avoid working outside their regular hours. This willingness to pay can vary based on several factors, including personal preferences, family dynamics, and involvement in evening hobbies. While the origin of the willingness to pay is not the primary concern, it is important to note that some teachers may have a lower willingness to pay than the compensation they receive for their overtime hours. These teachers thus benefit from giving lectures in the evening.

To estimate how much benefit this provides to the teachers, it has been assumed that the willingness to pay for not having to teach in the evening is lower for one-third of the teachers than the compensation they receive for it (NOS Nieuws, 2017). Based on the same number of teachers and their salaries as mentioned in subsection 8.1.3, it can be calculated how much benefit this generates for the lecturers. It is also assumed that the benefits for this one-third group of teachers increase linearly, meaning that an average teacher receives half of the benefits from the compensation they receive for it. The result is presented in Table 8.8.

Table 8.8: Yearly[a] Benefits of Overtime Hours for Employees (in million €)

Policy Measure	Effect
Paid Peak Hour Travel	0.0
Shift Lecture Hours	7.7
40% Peak Discount + Shift Lecture Hours	7.7
Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift	7.7

[a] Based on the year 2030.

8.2.7. Operational Savings for Railway Companies

As students shift away from public transport in the policy alternatives, particularly during peak hours, trains become less crowded. In subsection 8.2.3 is quantified how this reduction improves the comfort for both existing and new train passengers. Rail operators will also notice the impact on their trains. While they appreciate the enhanced comfort for their passengers, they also recognize that operating less crowded trains comes with higher costs. As a result, they will make selective reductions to the timetable, carefully avoiding a return to crowded trains. This section of the chapter provides a detailed explanation of how the estimation of this effect was developed.

The operational benefit is achieved by requiring fewer trains, leading to lower depreciation costs. Additionally, maintenance and personnel costs change due to an increase or decrease in the total number of train kilometers in the policy alternatives. To assess the change in train kilometers compared to the baseline alternative, the analysis focused on the passenger kilometers during the morning peak, when transport demand is at its highest. The change in train kilometers was calculated based on the difference in passenger kilometers between the baseline alternative and the policy alternatives, assuming an average of 500 seats per train (Nederlandse Spoorwegen, 2016) and a peak occupancy rate of 40% (Nederlandse Spoorwegen, 2024c). The analysis further assumed that for every 5 kilometers decrease in passenger kilometers, train kilometers are reduced by 1 kilometer. Which is a rough, non-source-based assumption.

The avoided depreciation costs were then estimated based on material costs ranging from 5 to 10 million per train (nu.nl, 2023; Verlaan, 2017), an average lifespan of 40 years per train (Nederlandse Spoorwegen, 2022), and an average distance of 225 km travelled by a train during the morning rush hour (Hilhorst, 2012). To estimate maintenance costs, we considered the total difference in train kilometers during morning, evening, and off-peak hours. This estimate was derived from data in Poppeliers et al. (2022), which indicates that maintenance costs typically range from 0.40 to 1.00 euros per train kilometer. The avoided or extra personnel costs are based on the assumption that each train requires one driver and two conductors. To estimate these costs, we consulted again data from Poppeliers et al. (2022), which provided annual personnel costs. This information was then converted to determine the total personnel costs per train for one timetable hour (DRU). The yearly benefit of both depreciation, maintenance and personnel costs are presented below in Table 8.9.

Table 8.9: Yearly[a] Operational Savings for Railway Companies (in million €)

Policy Measure	Low	High
Paid Peak Hour Travel	1.1	1.8
Shift Lecture Hours	0.1	0.2
40% Peak Discount + Shift Lecture Hours	0.4	0.7
Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift	0.1	0.3

[a] Based on the year 2030.

8.3. Indirect Effects

The direct effects in the rail and education market result in indirect effects in other markets. In this section the impact on activities, education and railway operations are described.

8.3.1. Activities

In the policy alternatives, students travel fewer days per week to their educational institution. This saves them travel time, and the flexibility of digital education allows them to organize their activities more freely. The survey, as presented in chapter 7, align with that and show that on average students will spent more time on both side jobs, sports and social activities. This results in benefits. With increased work, students earn more income, allowing them to better meet their needs. More exercise leads to improvements in health, work and on social aspects (Peters et al., 2021). And social activities, including those organized by study and student associations, are attended for the enjoyment and networking opportunities they offer. Membership in a student association is often linked to better career prospects, thanks to the networks established during their involvement (Emmer, 2017; Roelofsen & Peters, 2017).

Moreover, students who are members of a student association tend to complete their studies more quickly and have a lower dropout rate (De Gruijter, 2006).

The increase in these three activities is expected to result a higher average student income, better health, improved work and study performance, and enhanced social enjoyment. Nevertheless, these benefits are not included quantitatively in the analysis because the cause-and-effect relationship is hard to establish, and quantifying the effects is quite challenging. The three activities are therefore evaluated qualitatively, as outlined in chapter 3. The results are shown in Table 8.10 and will also be reflected in the CBA account.

Table 8.10: Qualitative Effect of Side Job, Sports and Social Activities

Policy Measure	Side Job	Sports	Social Activities
Paid Peak Hour Travel	++	++	+
Shift Lecture Hours	+	+	+
40% Peak Discount + Shift Lecture Hours	+	+	0
Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift	+	++	+

8.3.2. Impact of Digital Education

With students travelling to campus less frequently in the policy alternatives, it can be argued that some of the in-person education is missed. To estimate the impact of this, it is assumed that this education will be followed online. During the COVID-19 pandemic, it became evident that online education comes with both benefits and drawbacks. Benefits include reduced travel time, increased flexibility in choosing where and when to study, and the ability to control one's own learning pace (Dankbaar, 2012; Goes-Daniëls & Van der Klink, 2021). However, the drawbacks include the fatigue of attending classes via a screen, social isolation, and lower motivation (2021; Van der Gulden et al., 2021). As a result, this analysis assumes reduced effectiveness of knowledge transfer in online education (A. Bakker et al., 2020).

The impact of online education is measured in terms of future lost income, with an additional year of education resulting in an 8% higher income (Ter Weel et al., 2020; Van Heest, 2020). The percentage of education lost each year due to COVID-19 was used as a reference on the proportion of missed credits per year. HBO students missed an average of 22.5% of their study credits per year, while university students missed 19.2% (Warps & Van den Broek, 2020). To make the estimate more realistic, it is necessary to adjust these percentages for the proportion of practicals or laboratory work of the study credits (33,3%) (Warps and Van den Broek, 2020), for which students will most likely travel to the educational institution in the post-pandemic period. It is also assumed that the quality of online education has improved and that the educational activities still attended in person are more important to attend physically. This effect is assumed to improve digital education by 50%. Based on the percentage decrease in days that students typically travel to their educational institution, as reported in chapter 7, an estimate has been made of the amount of education missed each year.

The average decrease in income per student per year was then estimated based on the proportion of educational loss per year, an average study duration of 5 years and a median gross income of €40,000 per year in 2023 (Klees, 2024). This latter was adjusted to the base year 2025 through the average annual income increase of 1.95%. (Centraal Bureau voor de Statistiek, 2024b). The yearly income loss, based on the year 2030, is presented in Table 8.11.

Table 8.11: Yearly[a] Income Effect of Online Education (in million €)

Policy Measure	Income Effect
Paid Peak Hour Travel	-68.6
Shift Lecture Hours	-21.3
40% Peak Discount + Shift Lecture Hours	-23.3
Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift	-11.7

[a] Based on the year 2030.

8.3.3. Mental Health & Wellbeing

Alongside the benefits of increased side-job work, engaging in sports, and participating in social activities through study and student associations, there is also the indirect impact of later class times and paying for public transport during peak hours on overall well-being. This relationship is illustrated in the conceptual model in Figure 6.1. While there are metrics available to quantify well-being (D'Acci, 2011), monetizing it remains a significant challenge. As a result, the decision was made to evaluate this effect qualitatively rather than quantitatively. Initially, the discussion will focus on the impact of starting classes at 10:30 on well-being, followed by an exploration of how paying for peak time travel affects wellbeing.

Shifting class times to 10:30 or later allows students to sleep longer. The literature includes various studies that discuss the direct or indirect impact of this change on student wellbeing through academic performance. Numerous studies in the literature explore how this shift indirectly affects student well-being, particularly through its influence on academic performance, as shown in chapter 6 in Figure 6.1. A significant positive relationship was found between a later start time and the amount of sleep students receive (Marx et al., 2017; Wheaton et al., 2016). However, the effects on academic performance, measured by grades and test scores, were either negligible or mixed (Biller et al., 2022; Onyper et al., 2012). And the same applies to the effects on absenteeism and student alertness (Marx et al., 2017). Nevertheless, the studies emphasize the expected positive impact that improved sleep has on cognitive performance and learning (Biller et al., 2022). While a direct correlation with academic performance remains unproven, better sleep could alleviate study-related stress, which in turn would benefit overall wellbeing.

While there is considerable literature on the negative impact of long commuting times on wellbeing (P. Ding & Feng, 2022; P. Ding et al., 2023), studies exploring the impact of travel costs on wellbeing are relatively scarce. In Foster et al. (2024), an effort is made to establish this relationship through existing literature. However, the available studies are limited, heterogeneous, and lack example studies, making a causal assessment difficult. Nevertheless, they all indicate that reduced public transport costs have a positive impact on mental health and wellbeing. This is due to its ability to reduce the risk of social isolation while enhancing opportunities for social interaction and physical activity (Foster et al., 2024). Can we conclude that raising costs in the policy alternatives decreases wellbeing? Not necessarily, as this study did not specifically target students. Crowding in public transport is also a factor, as it negatively affects passenger wellbeing (Tirachini et al., 2013). In the proposed policy alternatives, public transport is expected to become less crowded, both during and outside peak hours. Furthermore, it may have an indirect effect on well-being by affecting student attendance. Although free transportation is typically expected to improve attendance, some studies show the opposite: free transport can actually negatively impact attendance and increase absenteeism (Edwards, 2024; Garcia-Munoz & Sandoval, 2022).

Despite the limited evidence in the literature, an estimation is made regarding the impact of the policy alternatives on mental health and wellbeing. The relevant studies indicate that a shift in lecture hours primarily has a positive effects on wellbeing, while negative effects do not emerge directly in the literature. In contrast, the studies regarding the impact of higher public transport costs often report negative effects. Therefore, it is assumed that shifting lecture hours has a small positive effect on student well-being, whereas the increased costs have a small negative impact. The total effect for each policy measure is shown in Table 8.12.

Table 8.12: Qualitative Effect of Mental Health & Wellbeing

Policy Measure	Income Effect
Paid Peak Hour Travel	-
Shift Lecture Hours	+
40% Peak Discount + Shift Lecture Hours	0
Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift	0

8.4. External Effects

In the policy alternatives, a change in the travelled kilometers per mode of transport was observed. The conceptual model in Figure 6.1 illustrates that this results in external effects, as the levels of traffic risks and emissions differ across various modes of transport, thereby influencing their societal valuation. This chapter will address the costs associated with traffic accidents (subsection 8.4.1), greenhouse gas emissions (subsection 8.4.2), air pollution (subsection 8.4.3) and noise disturbance (subsection 8.4.4).

8.4.1. Costs of Traffic Safety Risks

Participation in traffic carries risks. As travel behaviour shifts across the policy alternatives, the statistical probability of accidents changes as well. The external costs for each policy alternative have been calculated based on the reduction or increase in student kilometers travelled per mode of transport. The total effect of all modes of transport is presented in Table 8.13.

The external accident costs were calculated using the total average external accident costs per 1000 passenger kilometers in the Netherlands as reported by Schroten et al. (2022). For cars, the calculation considered the small reduction in kilometers driven due to the shift of commuters from car to train (Jonkeren & Huang, 2024). For the train, a small increase in the number of kilometers travelled was accounted accordingly. For tram and metro, it was assumed that the external accident costs are equivalent to those of the bus.

Table 8.13: Yearly[a] External Accident Costs (in million €)

Policy Measure	Low	High
Paid Peak Hour Travel	-55.3	-54.6
Shift Lecture Hours	30.8	31.2
40% Peak Discount + Shift Lecture Hours	-31.7	-31.3
Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift	-7.7	7.4

[a] Based on the year 2030.

8.4.2. Costs of Greenhouse Gas Emissions

Based on the previously calculated travel behavioural effects in the policy alternatives (subsection 8.2.1), an estimate has been made of the changes in greenhouse gas emissions. In this analysis, the greenhouse gas emissions are determined using the average CO_2-equivalent per kilometer (Leestemaker et al., 2023). This includes the total impact of CO_2, CH_4, and N_2O, converted into CO_2 units. The increase or decrease in emissions for each policy alternative was calculated by multiplying the CO_2 equivalent with the difference in passenger kilometers for each mode of transport compared to the baseline alternative. To determine the value of this effect, the number of tons of CO_2 equivalent was multiplied by the efficient CO_2 price for 2030 (De Bruyn et al., 2023). The valuation including all modes of transport for each policy measure is shown in the Table 8.14.

Table 8.14: Yearly[a] External Costs of Greenhouse Gas Emissions (in million €)

Policy Measure	Low	High
Paid Peak Hour Travel	-3.3	-13.0
Shift Lecture Hours	0.4	1.9
40% Peak Discount + Shift Lecture Hours	-2.1	-8.4
Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift	-0.8	-3.3

[a] Based on the year 2030.

8.4.3. Costs of Air Pollution

In addition to greenhouse gas emissions that negatively impact the climate, travelling by car, train, and public transport also releases substances that affect air quality. Air pollutants have a particularly local impact (Leestemaker et al., 2023), affecting the areas around roads and railway lines. The calculation considered three types of combustion emissions: NO_x, $PM_{2.5}$, and PM_{10}. For each substance, the emissions in the policy alternatives were calculated by multiplying the number of kilometers per mode of transport by the average emission of each substance per kilometer for each type of vehicle (Leestemaker et al., 2023). The number of grams of NO_x, $PM_{2.5}$, and PM_{10} was then multiplied by the environmental price for each respective substance, as provided in De Bruyn et al. (2023). The result of this analysis is presented in Table 8.15.

Table 8.15: Yearly[a] External Costs of Air Pollution (in million €)

Policy Measure	Low	High
Paid Peak Hour Travel	-0.7	-1.7
Shift Lecture Hours	0.0	0.1
40% Peak Discount + Shift Lecture Hours	-0.6	-1.4
Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift	-0.3	-0.7

[a] Based on the year 2030.

8.4.4. Costs of Noise Disturbance

Ultimately, changes in transportation patterns can result in either increased or decreased noise disturbance. However, unlike other external effects, noise effects do not occur linear to the number of kilometers travelled. For instance, adding another car kilometer to an already congested road results in minimal additional noise disturbance for nearby residents. None of the alternatives involve the construction of new infrastructure or the improvement or demolition of existing infrastructure. This means that no new groups of citizens will experience noise disturbances as a result of the policy alternatives. Additionally, since the focus is primarily on a change in student travel behaviour, which represents only a small portion of total traffic, it is assumed that the magnitude of the effect across the four policy alternatives is negligible. Consequently, this effect is not included in the CBA.

9 Results

With all identified effects now quantified and monetized, this chapter presents an overview of the results. The results of the CBA provide a clear answer to the sub-question: What is the overall magnitude of costs and benefits associated with the policy alternatives? This chapter first explains in section 9.1 how individual effects have been translated into a comprehensive overview of costs and benefits across the time horizon. Following that, section 9.2 presents and discusses the CBA table.

9.1. Discount Rate

To effectively present both the monetized and qualitatively described effects from chapter 8 in a CBA table, separate tables are created for each alternative. In these tables, the various effects will be arranged vertically, while the years of the time horizon will be displayed horizontally. Implementation costs, such as adjusting class schedules and making technical modifications to the public transport card, occur in the early years of the time horizon. In contrast, several effects, such as the reduction of the ministry's budget for transport providers and the consequences of increased online education, take place much later in the time horizon. In a CBA, both inflation and the preference for immediate value over future value are considered (Romijn & Renes, 2013). Adjustments for future effects are made through the application of a discount rate, which is used to reflect their present value.

The discount rate is an interest rate applied to future effects to convert them into present values (Broughel, 2020). In this CBA, a discount rate of 2.9 percent has been adopted, following the recommendation by Werkgroep discontovoet 2020 (2020) for benefits that exhibit strong non-linearity. The decision to not apply the standard discount rate of 2.25 percent is due to the lack of a clear linear relationship between the costs incurred in the policy alternatives and the generated benefits. It is also noted by Werkgroep discontovoet 2020 (2020) that non-linear benefits arise when considering travel time benefits. In this CBA, comfort benefits are calculated using a multiplier applied to the travel time benefits. If educational institutions start even later, the overtime costs for staff will increase. However, the comfort benefits will see only a modest rise, as many students are already travelling outside peak hours due to the current adjustments. The impact on educational accessibility and the effects of digital education do not have a linear relationship with the costs either.

The 2.9 percent discount rate is applied based on the base year of 2025, which marks the first year that costs will be incurred for implementing the policy alternatives. Additionally, this is the year when the adjusted Student Travel Product will come into effect, as it is set to be introduced in the academic year 2025-2026, as detailed in chapter 5. The projected effects in the years 2026 up to and including 2040 have been adjusted using the discount rate to reflect the price level of 2025.

9.2. CBA table

Once the discount rate has been applied, the total effects for the forecast period are aggregated. Table 9.1 displays these totals in million euros for each policy alternative. The table presents all costs and benefits in the first column, categorized into costs, direct effects, indirect effects, and external effects. The four adjacent columns detail the magnitude of costs and benefits for each policy alternative. Costs and negative benefits are represented as negative numbers, while savings and positive benefits are shown as positive numbers. At the end of the chapter, Table 9.2 presents an additional CBA table, showcasing also the non-monetized effects as prescribed by Koopmans (2004).

In the upper section of the table, the costs are outlined. The total costs associated with the 'Paid Peak Hour' alternative are significantly lower than those for the other three policy alternatives, as this alternative does not involve any costs for scheduler labour and employee overtime hours. The lecture times remain unchanged in this alternative. For the remaining three policy alternatives, it can be observed that the total costs are primarily driven by employee overtime expenses. The reason that the costs for teaching staff are so high is due to the fact that they must be paid each year for the hours they work after 18:00. Moreover, the teaching staff for MBO, HBO, and universities consists of tens of thousands of FTEs. In the 'Shift Lecture Hours' alternative, there is, in contrast to the other alternatives, no change to the Student Travel Product, resulting in no costs for the Student Travel Product Implementation.

Table 9.1: Costs-Benefit Overview Table (Present Value)

Effects in million €, price level 2025	Paid Peak Hour Travel	Shift Lecture Hours	40% Peak Discount + Shift Lecture Hours	Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift
Costs				
Costs of Student Travel Product Implementation	-2.5	0.0	-2.5	-2.5
Costs of Scheduler Labour	0.0	-0.7	-0.7	-0.7
Costs of Employee Overtime Hours	0.0	-596.1	-596.1	-596.1
Total Costs	**-2.5**	**-596.8**	**-599.3**	**-599.3**
Direct Effects				
Educational Accessibility	-3857.5	0.0	-1883.7	-1165.7
Comfort Benefits	958.3 to 1003.3	749.3 to 784.0	851.5 to 891.2	645.1 to 674.7
Travel Time Reliability	0	0	0	0
Governmental Savings on Student Mobility	2607.6	203.5	796.5	189.5
Benefits of Overtime Education for Employees	0.0	99.4	99.4	99.4
Operational Savings for Railway Companies	10.9 to 17.4	0.5 to 2.5	3.6 to 7.0	0.8 to 2.9
Total Direct Effects	**-280.7 to -229.2**	**1052.6 to 1089.2**	**-132.7 to -89.6**	**-231.1 to -199.3**
Indirect Effects				
Side Job Income	++	+	+	+
Sports	++	+	+	++
Social Activities	+	+	0	+
Impact of Digital Education	-553.7	-171.6	-188.2	-94.1
Mental Health & Wellbeing	-	+	0	0
Total Indirect Effects	**-553.7**	**-171.6**	**-188.2**	**-94.1**
External Effects				
Costs of Traffic Safety Risks	-694.0 to -689.4	372.2 to 374.7	-397.8 to -395.0	-100.6 to -98.6
Costs of Greenhouse Gas Emissions	-41.1 to -163.2	5.1 to 21.0	-26.7 to -106.2	-10.7 to -42.4
Costs of Air Pollution	-9.0 to -21.2	0.5 to 1.2	-7.4 to -17.5	-3.9 to -9.2
Total External Effects	**-744.1 to -873.8**	**377.8 to 396.9**	**-431.9 to -518.7**	**-115.3 to -150.2**
Total Effects	**-1578.5 to -1656.7**	**1258.8 to 1314.5**	**-752.9 to -796.6**	**-440.4 to -443.6**
Net Present Value	**-1581.0 to -1659.2**	**662.0 to 717.7**	**-1352.2 to -1395.9**	**-1039.8 to -1042.9**
Benefit-Cost Ratio	0.69	2.69 to 2.93	0.56	0.47 to 0.48

The direct effects, as shown in Table 9.1 include educational accessibility, comfort benefits, travel time reliability, governmental savings on student mobility, benefits of overtime education for employees and operational savings for railway companies. Educational accessibility represents the largest negative direct effect in most policy alternatives and arises when students have to pay for their travel to educational institutions. In the alternatives 'Paid Peak Hour Travel,' '40% Peak Discount + Shift Lecture Hours,' and 'Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift,' students continue to travel during peak times despite having to pay for it compared to the baseline alternative.

The comfort benefits are the largest positive direct effect. Comfort benefits arise due to reduced crowding in trains, as the number of students travelling during peak hours decreases. The 'Paid Peak Hour Travel' alternative has the greatest comfort benefits because, in this alternative, the highest number of students stop travelling during peak hours on the train. In the 'Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift' alternative, these benefits are minimized, as the focus in this alternative is exclusively on decreasing the number of students during the morning peak, rather than addressing the evening peak.

Travel time reliability remains at zero for all policy alternatives, as there is no evidence to suggest that it will improve with reduced train crowding.

The governmental savings from the Student Travel Product are the largest benefits for the 'Paid Peak Hour Travel' alternative. As the number of student travel kilometers declines, the Ministry of Education, Culture, and Science will ultimately reduce the allowance to transport providers for the Student Travel Product. The other policy alternatives also generate savings for the ministry, as each alternative leads to a reduction in the total number of student travel kilometers.

In the policy alternatives, benefits arise for teaching staff who do not object to evening lectures but are compensated for their overtime hours. In the 'Paid Peak Hour Travel' alternative, these benefits do not exist, as there is no shift in lecture times. In the other three alternatives, the benefits are the same for each alternative since they involve the same number of students and the same shift in lecture times.

Lastly, operational savings for railway companies arise as a direct effect. Peak hours are critical in determining the necessary train capacity. With the decrease in congestion during peak times, companies will operate slightly fewer trains. However, this reduction does not occur in a one-to-one ratio with the drop in congestion, as they seek to prevent overcrowding on trains. As a result, the operational savings for railway companies represent the smallest direct effect.

The indirect effects from the policy alternatives are the side job income, sports, social activities, impact of digital education and the mental health & wellbeing. Most of these effects could not be quantified. However, it is important that they are also included in Table 9.1. The effects on side jobs, sports, and social activities are based on how much extra time students would spend on these activities. In the 'Paid Peak Hour Travel' alternative, the number of hours students spend on their side jobs clearly increases more than in the other policy alternatives. There are also positive effects due to the increased time spent on sports, particularly in the first and last policy alternatives. The positive effect of social activities is generally lower because the expenditure on this activity increases less, and furthermore, this activity also yields fewer benefits.

The impact of digital education is the only indirectly quantified effect. This effect arises because students travel less to the educational institution in the policy alternatives. Assuming that students make up for these study hours digitally and that the quality of digital education is lower, a negative effect occurs. This effect is most significant in the 'Paid Peak Hour Travel' alternative, as this is where the largest decrease occurs in the number of days students travel to the educational institution. In contrast, the impact in the other policy alternatives is at least three times smaller, with the 'Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift' maintaining the highest number of on-campus study hours.

The impact on mental health and wellbeing is assessed qualitatively. The 'Paid Peak Hour Travel' alternative negatively affects mental health and well-being, as students face increased financial stress due to the need to travel during peak hours for their studies. In contrast, 'Shift Lecture Hours' has a positive effect; a later start time allows students to get more sleep, often resulting in a longer night's rest. For the last two alternatives, there are both increased public transport costs, which can lead to financial stress, and the benefit of extended sleep. These conflicting effects balance each other out, leading to no overall impact on mental health & wellbeing.

The final category of effects includes externalities related to the costs of traffic safety risks, greenhouse gas emissions, and air pollution. The costs associated with traffic safety risks are negative for the 'Paid Peak Hour Travel,' '40% Peak Discount + Shift Lecture Hours', and 'Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift' alternatives. In these scenarios, there is an shift from travel by train and BTM to travel by car and bicycle. Trains and public transport result in fewer accidents per kilometer travelled compared to cars and bicycles. In the 'Shift Lecture Hours' alternative, the shift is in general reversed, leading to a positive effect on the traffic safety risks in this scenario. The increase in car usage also leads to higher emissions of greenhouse gases and air pollution. Therefore, costs are again associated with the alternatives 'Paid Peak Hour Travel,' '40% Peak Discount + Shift Lecture Hours,' and 'Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift'.

Considering the magnitude of the total effects of each policy alternative, it becomes clear that only one policy alternative results in a positive welfare effect: the 'Shift Lecture Hours' alternative. The 'Paid Peak Hour Travel' alternative has the largest negative impact. However, the other policy alternatives, which require students to pay more for travel during peak hours, also show negative effects. The positive total effect of 'Shift Lecture Hours' is mainly due to the positive direct effects of this measure. The comfort benefits stand out significantly as the largest benefit component. Additionally, the ministry achieves a saving of 200 million euros spread over 15 years. However, the most important reason is that, compared to the other three alternatives, there are no negative impacts on the accessibility of education. Ultimately, this measure stands out as the only alternative with positive external effects. It prevents students to switch to cars, thereby mitigating the risk of injury from accidents and reducing greenhouse gas emissions and air pollution.

The 'Paid Peak Hour Travel' alternative has the largest total negative effect. While this option enables the ministry to save more than ten times the amount on the Student Travel Product compared to the 'Shift Lecture Hours' alternative and offers enhanced comfort benefits, it also leads to several considerable negative effects. This policy alternative reduces the accessibility of education, resulting in a loss of nearly 5 billion euros within the time horizon. Additionally, it is also the alternative where the impact of online education is the biggest, as students travel to the educational institution least often. When they do make the journey, they are more likely to go by car, worsening the negative external effects associated with this measure.

Table 9.2: CBA table including non-monetised (left) and monetised effects (right) per policy alternative

	Unit of Measurement	Non-Monetised Policy Effects				Net Present Value in million €			
		Paid Peak Hour Travel	**Shift Lecture Hours**	**40% Discount + Shift Lecture Hours**	**Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift**	**Paid Peak Hour Travel**	**Shift Lecture Hours**	**40% Discount + Shift Lecture Hours**	**Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift**
Costs									
Costs of Student Travel Product Implementation	*M€*	-2.5	0.0	-2.5	-2.5	-2.5	0.0	-2.5	-2.5
Costs of Scheduler Labour		0.0	-0.7	-0.7	-0.7	0.0	-0.7	-0.7	-0.7
Cost of Employee Overtime Hours		0.0	-953.0	-953.0	-953.0	0.0	-596.1	-596.1	-596.1
Total Costs						-2.5	-596.8	-599.3	-599.3
Direct Effects									
Educational Accessibility	*M€*	-6027.5	0.0	-2924.5	-1803.6	-3857.5	0.0	-1883.7	-1165.7
Comfort Benefits	*M hours*	99.8 to 100.1	78.1 to 78.2	88.7 to 88.9	67.2 to 67.3	958.3 to 1003.3	749.3 to 784.0	851.5 to 891.2	645.1 to 674.7
Travel Time Reliability	*+/-*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Governmental Savings on Student Mobility	*M€*	3336.9	260.4	1019.3	242.4	2607.6	203.5	796.5	189.5
Benefits of Overtime Education for Employees	*M€*	0.0	158.8	158.8	158.8	0.0	99.4	99.4	99.4
Operational Savings for Railway Companies	*M€*	13.9 to 22.3	0.6 to 3.1	4.6 to 9.0	1.0 to 3.7	10.9 to 17.4	0.5 to 2.5	3.6 to 7.0	0.8 to 2.9
Indirect Effects									
Side job income	*+/-*	++	+	+	+	++	+	+	+
Sports	*+/-*	++	+	+	++	++	+	+	++
Social Activities	*+/-*	+	+	0	+	+	+	0	+
Impact of Digital Education	*income in M€*	-889.6	-275.8	-302.5	-151.2	-553.7	-171.6	-188.2	-94.1
Mental Health & Wellbeing	*+/-*	-	+	0	0	-	+	0	0
External Effects									
Costs of Traffic Safety Risks	*M€*	-49.3 to -49.2	8.4	-23.0 to -22.9	-3.6 to -3.5	-694.0 to -689.4	372.2 to 374.7	-397.8 to -395.0	-100.6 to -98.6
Costs of Greenhouse Gas Emissions	*Mton CO2-equivalent*	1.9	-0.2 to -0.3	1.3	0.5	-41.0 to -163.2	5.1 to 21.0	-26.7 to -106.2	-10.7 to -42.4
Costs of Air Pollution	*kg of NOx, PM2.5, and PM10*	0.3	0.0	0.2	0.1	-9.0 to -21.2	0.5 to 1.2	-7.4 to -17.5	-3.9 to -9.2
Total Effects						-1578.5 to -1656.7	1258.8 to 1314.5	-752.9 to -796.6	-440.4 to -443.6
Balance						-1581.0 to -1659.2	662.0 to 717.7	-1352.2 to -1395.9	1039.8 to 1042.9

10

Scenario and Sensitivity analysis

The previous chapter outlines the results of the CBA by presenting concrete figures for estimated effects. As will be discussed in chapter 11, the CBA relies on assumptions and general index numbers, which leads to uncertainty in its results. This chapter therefore discusses the three types of uncertainties as distinguished by Romijn and Renes (2013). It also testes the outcomes of the CBA against two of those types of uncertainties. In section 10.1, the chapter begins by explaining the concept of uncertainty regarding future developments. Following that, section 10.2 presents the scenario analysis. Next, section 10.3 discusses the concept of knowledge uncertainty. Section 10.4 presents the results of the sensitivity analysis on several CBA effects. And finally, in section 10.5, the chapter discusses the final form of uncertainty: Policy Uncertainty.

10.1. Uncertainty about Future Developments

In chapter 4, an attempt has been made to outline the future of the rail and education markets. The effects of the policy alternatives, as presented in chapter 9, are based on this described future scenario. However, the future remains uncertain, and so are the outcomes of the CBA. Romijn and Renes (2013) call this type of uncertainty 'uncertainty about future developments' and includes both macroeconomic uncertainty and specific risks related to the policy measure. Uncertainty about Future Developments is incorporated in the CBA within the baseline alternative, which outlines an as accurate as possible future, based on typical average developments of key factors. However, there is uncertainty about how the existing and missing market will actually evolve, while students, commuters, and other transport consumers make their choices and derive their welfare based on these market conditions. For instance, will affordable electric cars or new trains with increased passenger space become available? How will the job market develop, and will educational institutions begin to include remote study days into their schedules?

10.2. Scenario Analysis

To address the uncertainty about future developments, this section of the report performs a scenario analysis. The sensitivity of the CBA is tested for future uncertainty, using four future scenarios. Future developments in the rail and education markets are likely to have the most significant impact on the outcomes of the policy alternatives. Consequently, the four scenarios have been crafted based on two potential trajectories for these markets, as shown in Figure 10.1.

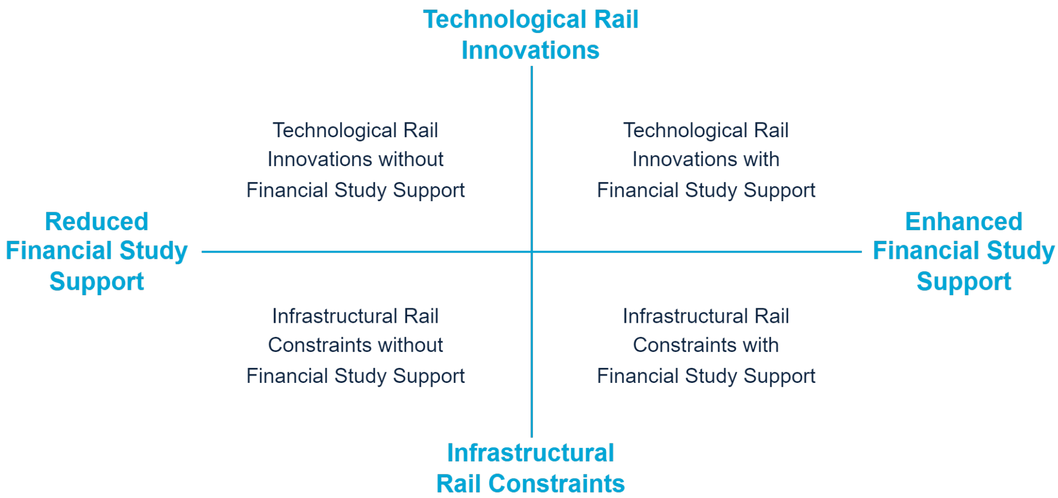


Figure 10.1: Visualization of the Four Future Scenarios

Firstly, as illustrated on the x-axis, financial support for students can be either reduced or increased. This includes a range of government programs designed to support students, including the basic grant, student loans, and student housing, among others. But it also includes policies which make studying less attractive, such as interest on student loans, the long-term study penalty, and the binding study advice (BSA). It remains uncertain to what extent future politics will prioritize the encouragement of studying, as well as the degree to which regulations will be abolished or expanded. Depending on the regulations in place, more or less young people will choose to study, potentially leading to different developments of the issue in the future, as described in chapter 1. Developments in the rail market can also take two distinct paths, as shown in Figure 10.1 on the y-axis. On one hand, technological breakthroughs may enable the rail network to create more capacity, think of technologies like the European Rail Traffic Management System (ERTMS), automated train operations (ATO), or optimized timetabling. On the other hand, insufficient investments in rail infrastructure might lead to issues such as structural deficiencies in rail bridges, ground subsidence, or an unreliable power supply. This, in turn, could cause more frequent disruptions and prolonged maintenance periods, potentially reducing the reliability and capacity of the rail network in the future.

In practical terms, the enhanced financial study support is translated into a 10% increase in the number of students compared to the baseline alternative, while the reduced financial study support corresponds to a 10% decrease in the number of students. The technological rail innovations, in turn, lead to 10% more trains, with a 4% increase during peak hours. Conversely, the Infrastructural rail constraints result in 10% fewer trains, including a 4% reduction during peak hours. The summarized results of the scenario analysis are shown in Tables 10.1 till 10.4, while the full CBA tables are presented in Appendix F.

10.2.1. Costs

Table 10.1 and Table 10.2 show that the total costs of the policy alternatives involving a shift in lecture times have increased. This is due to the increase in student numbers, which demands more teaching staff. Consequently, this also leads to a rise in the absolute number of overtime hours that need to be worked. In Table 10.3 and Table 10.4 the opposite trend is observed. The sharper reduction in the future student population compared to the baseline alternative from chapter 4 leads to lower staffing costs, as fewer overtime hours will need to be paid.

10.2.2. Direct Effects

The scenarios also influence the total of all direct effects. In the 'Technological Rail Innovations with Financial Study Support' scenario (Table 10.1), the cumulative direct effect for policy alternatives involving a differential fare declines further into the negative. The full CBA table in Appendix F indicates that this outcome results from multiple direct effects. The impact on educational accessibility continues to decline due to the increasing number of students. In absolute terms, a larger number of students is experiencing decreased accessibility due to the pricing set in the policy alternatives. Furthermore, comfort benefits experience a slight decrease as a result of greater capacity among transport providers. The governmental savings on student mobility and the operational savings for railway companies compensate for a small portion of this decline. Governmental savings increase due to an absolute rise in the number of students who travel less, while railway companies increase savings by operating a absolute smaller number of trains.

In Table 10.2, the 'Infrastructural Rail Constraints with Financial Study Support' scenario presents a contrasting outcome. The total direct effect of all policy alternatives increases compared to the CBA in Table 9.1 of chapter 9. The increase is due to the rise in comfort benefits, governmental savings on student mobility, and operational savings for railway companies across all four policy alternatives, despite the fact that educational accessibility decreases by the same amount as in Table 10.1. Comfort benefits increase because, in this baseline scenario, more students are expected to travel with reduced train capacity compared to the baseline alternative described in Chapter 4. This leads to a greater crowding problem, making the measures in the policy alternatives relatively more effective. The governmental savings increase for the same reasons mentioned in 'Technological Rail Innovations with Financial Study Support.' Due to the larger number of students, fewer kilometers are travelled in absolute terms when the policy measures are implemented. The operational savings for railway companies are significantly higher than those indicated in Table 9.1 and Table 10.1. This increase is due to the fact that in a scenario with a greater number of students and limited train capacity, a larger portion of that scarce capacity is utilized by students. Consequently, when the students travelling during peak hours are decreased, the resulting absolute savings become much more substantial compared to a scenario with fewer students.

In the 'Infrastructural Rail Constraints without Financial Study Support' scenario shown in Table 10.3, there is also an observed increase in the total direct effects. However, this increase is not driven by governmental savings on student mobility or operational savings for railway companies. With fewer students in this future scenario, the government experiences lower savings related to student mobility. Furthermore, the policy measures shift a smaller number of students from peak hours, meaning railway companies do not significantly reduce their operational expenditures. The scenario does see an increase in comfort benefits, however, this increase is lower than that in Table 10.2. The reason is that there are fewer students in this scenario who can be removed from peak hours by the policy measures. The decline in total direct effects can be attributed to the reduced educational accessibility effects. While the previous two scenarios saw an decrease in educational accessibility effects due to a higher number of students, this scenario's fewer students lead to a increase of this effect. Specifically, there are simply fewer students impacted by the new fare policy in absolute terms.

In the fourth and final scenario, ”Technological Rail Innovations without Financial Study Support,” the total direct effect decreases, just as in the first scenario. The only effect that improves is educational accessibility, as fewer students experience the negative impacts of the policy measures. Although the effects on educational accessibility improves in this scenario, they do not compensate for the reduction in comfort benefits, government savings on student mobility, the benefits of extended education hours for employees, and the lower operational savings for railway companies. Comfort benefits decline because the reduction of an absolute smaller group of students travelling during peak hours, combined with increased train capacity, this leads to a significantly smaller effect of the policy measures. Additionally, governmental savings on student mobility also decrease, as there are fewer students changing their travel behaviour. Moreover, operational savings drop to zero because the higher train capacity, alongside a lower number of students, does not result in less equipment being deployed.

10.2.3. Indirect Effects

Within the indirect effects, the scenarios did not revise the impact of side job income, sports participation, social activities, or mental health & wellbeing. It is assumed that a 10% change in the student population does not significantly affect the qualitative scales of these factors. The impact of digital education is the only effect that does change in the four scenario’s compared to the CBA table of chapter 9. The impact of digital education is only affected by the number of students, and not by the innovations or constrains in the rail sector. With the increase in the number of students in scenarios featuring enhanced financial study support, the negative impact of the policy measures on the effectiveness of digital education becomes more bigger. In absolute terms, there are more students engaged in digital education. Conversely, in scenarios with no or limited financial study support, the student population decreases, leading to a reduction in the impact of digital education.

10.2.4. External Effects

Finally, Tables 10.1, 10.2, 10.3 en 10.4 illustrate how the total external effects evolve across the scenarios. In the scenarios where the number of students increases due to better financial support, the effect becomes stronger. This means that, on one hand, the costs in policy alternatives with costs rise further, while on the other hand, the benefits for alternatives with benefits also increase. In scenarios where the student population decreases, the opposite effect occurs. Here, costs decline, but the benefits of the ’Shift Lecture Hours’ alternative also drop. The cause of this is that with a 10% increase in students, there are in absolute numbers more students who will travel by car in the policy alternatives. However, if 10% more students take the train, there will also be absolute greater safety and environmental benefits. The percentage change in the three different external effects is consistent as they all based on the travelled kilometers per mode of transport, as also illustrated in the appendix in Appendix F.

10.2.5. Conclusion

The results of the scenario analysis show that, despite future uncertainties, the ’Shift Lecture Hours’ alternative stays the only policy option with a positive welfare balance. The results of the analysis show that this alternative is robust within the tested scope of future uncertainty. The NPV remains significantly above zero in all four scenarios, and the benefit-cost ratio also stays well above 1.00.

Table 10.1: Technological Rail Innovations with Financial Study Support (Present Value)

Effects in million €	Paid Peak Hour Travel	Shift Lecture Hours	40% Peak Discount + Shift Lecture Hours	Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift
Total Costs	**-2.5**	**-656.5**	**-659.0**	**-659.0**
Total Direct Effects	**-420.0 to -368.2**	**1094.6 to 1131.4**	**-234.8 to -191.8**	**-294.3 to -261.8**
Total Indirect Effects	**-609.0**	**-188.8**	**-207.1**	**-103.5**
Total External Effects	**-821.7 to -974.5**	**417.0 to 442.0**	**-475.3 to -571.2**	**-125.6 to -160.5**
Net Present Value	**-1854.1 to -1954.1**	**666.3 to 728.3**	**-1576.1 to -1629.1**	**-1182.4 to -1184.8**
Benefit-Cost Ratio	0.67 to 0.66	1.79 to 1.86	0.46 to 0.45	0.42

Table 10.2: Infrastructural Rail Constraints with Financial Study Support (Present Value)

Effects in million €	Paid Peak Hour Travel	Shift Lecture Hours	40% Peak Discount + Shift Lecture Hours	Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift
Total Costs	**-2.5**	**-656.5**	**-659.0**	**-659.0**
Total Direct Effects	**115.0 to 298.1**	**1544.9 to 1709.0**	**258.3 to 430.4**	**115.1 to 272.9**
Total Indirect Effects	**-609.0**	**-188.8**	**-207.1**	**-103.5**
Total External Effects	**-818.2 to -960.2**	**415.8 to 437.4**	**-475.1 to -570.5**	**-126.6 to -164.5**
Net Present Value	**-1314.7 to -1273.7**	**1115.4 to 1301.1**	**-1082.9 to -1006.2**	**-774.0 to -654.1**
Benefit-Cost Ratio	0.77 to 0.78	2.32 to 2.54	0.63 to 0.66	0.62 to 0.68

Table 10.3: Infrastructural Rail Constraints without Financial Study Support (Present Value)

Effects in million €	Paid Peak Hour Travel	Shift Lecture Hours	40% Peak Discount + Shift Lecture Hours	Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift
Total Costs	**-2.5**	**-537.1**	**-539.6**	**-539.6**
Total Direct Effects	**-29.6 to 26.3**	**1132.2 to 1173.8**	**84.4 to 132.3**	**-43.4 to -7.2**
Total Indirect Effects	**-498.3**	**-154.5**	**-169.4**	**-84.7**
Total External Effects	**-670.3 to -787.5**	**340.2 to 357.9**	**-388.7 to -466.8**	**-103.6 to -134.6**
Net Present Value	**-1200.6 to -1262.0**	**780.8 to 840.1**	**-1013.4 to -1043.5**	**-771.3 to -766.2**
Benefit-Cost Ratio	0.74 to 0.73	2.13 to 2.21	0.58 to 0.57	0.54

Table 10.4: Technological Rail Innovations without Financial Study Support (Present Value)

Effects in million €	Paid Peak Hour Travel	Shift Lecture Hours	40% Peak Discount + Shift Lecture Hours	Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift
Total Costs	**-2.5**	**-537.1**	**-539.6**	**-539.6**
Total Direct Effects	**-377.4 to -432.0**	**862.2 to 889.8**	**-222.3 to -190.9**	**-278.1 to -254.4**
Total Indirect Effects	**-498.3**	**-154.5**	**-169.4**	**-84.7**
Total External Effects	**-672.3 to -797.3**	**341.2 to 361.8**	**-388.9 to -467.4**	**-102.8 to -131.3**
Net Present Value	**-1550.5 to -1640.1**	**511.8 to 560.0**	**-1320.2 to -1367.3**	**-1005.2 to -1010.1**
Benefit-Cost Ratio	0.67 to 0.66	1.74 to 1.81	0.45 to 0.43	0.40

10.3. Knowledge Uncertainty

Not only does the unpredictability of the baseline alternative play a role in the uncertainty of the CBA results, but the uncertainty in estimating the effects does as well. Knowledge uncertainty is the type of uncertainty that refers to the lack of understanding regarding the actual effects of a measure and how these effects are valued (Romijn and Renes, 2013). This research also encountered considerable uncertainty about the effects. For example, the changing student travel behaviour is based on a sample of the student population, but the effect is probably different when looking at the population on its whole. Furthermore, the comfort benefits have been calculated using the value of travel time for commuters, despite the fact that not only commuters use public transport during peak hours. An increase in business travel elevates the value of travel time, which enhances the overall impact. Conversely, a greater share of recreational travellers and students decreases the value of time, thereby reducing the effect.

10.4. Sensitivity Analysis

To test the sensitivity of various effect estimates and their valuation on the CBA outcomes, a sensitivity analysis is conducted. In subsection 10.4.1, the CBA outcomes are first examined for both a higher and a lower discount rate. Subsequently, in subsection 10.4.2, the sensitivity of the CBA is addressed concerning changes in several parameters, which were used in the effect estimation.

10.4.1. Discount Rate

The discount rate determines how future effects are valued when adjusted to the base year, and can significantly influence the benefit-cost ratio of policy alternatives. According to Werkgroep discontovoet 2020 (2020), conducting a sensitivity analysis on the discount rate is therefore crucial, especially when using the WLO high and low scenarios. They recommend assessing the sensitivity of the CBA outcome by applying a discount rate of 3.3% for the high scenario and a discount rate of 2.5% for the low scenario.

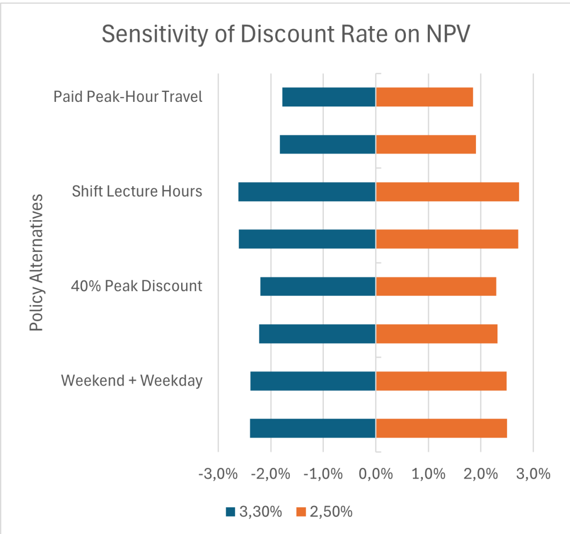


Figure 10.2: Percentage sensitivity of NPV to changes in the discount rate

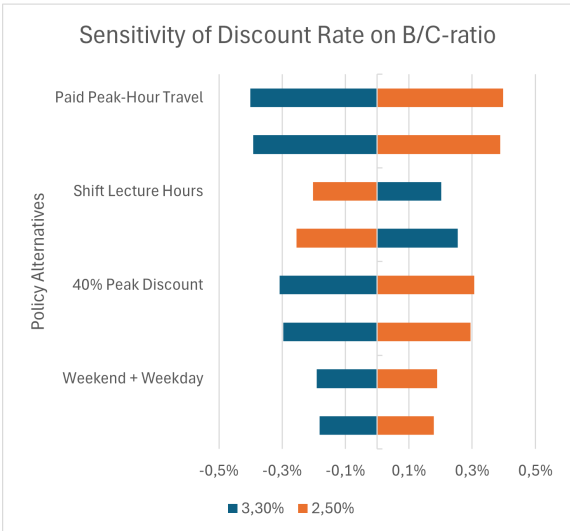


Figure 10.3: Percentage sensitivity of B/C-ratio to changes in the discount rate

The results of the sensitivity analysis, which examined both higher and lower discount rates, are illustrated in the figures above. On the left, Figure 10.2 presents the percentage change in net present value (NPV). On the right, Figure 10.3 shows the percentage change in the benefit-cost ratio (B/C-ratio). A higher discount rate of 3.30% results in a lower NPV across all alternatives, while a lower discount rate of 2.50% consistently leads to a higher NPV. The change in discount rate has a relative equal impact on the NPV across all alternatives. The slight differences between the four alternatives arise from the varying balance of costs and benefits over the time horizon. In the 'Shift Lecture Hours' alternative, which shows the most significant effect, the benefits increasingly fail to outweigh the costs as the valuation of future effects decreases. This trend also occurs in the 'Paid Peak Hour Travel' alternative, but to a lesser degree, making it relatively more appealing as the valuation of future effects declines. Figure 10.3 shows that the B/C ratio is affected even less by an increase in the discount rate. The impact is greatest in the 'Paid Peak Hour Travel' and '40% Discount' scenarios, as these measures have the most significant effects on students' travel behaviour. Figure 10.3 further illustrates that the B/C ratio does not consistently shift in the same direction among the four policy alternatives. A higher discount rate of 3.30% reduces the B/C ratio for 'Paid Peak Hour Travel', '40% Peak Discount' and 'Weekend + Weekday'. In contrast, for the alternative 'Shift Lecture Hours' it actually increases the B/C ratio. This suggests that a high inflation or a diminished valuation of future effects has a positive impact on the welfare impact of the first three mentioned alternatives.

10.4.2. Parameters

The CBA also encounters significant uncertainty resulting from its parameters, which are often estimated based on assumptions and non-scientific sources. Given the limited scope of this research, only a small subset of effect parameters has been subjected to the sensitivity analysis. For each effect, one underlying parameter was selected for the sensitivity analysis. All parameters were increased en decreased by 20% in the analysis. Finally, a more detailed analysis was conducted on the two effects for which the roughest assumptions were made.

In the analysis, the implementation and scheduler labour costs were increased and decreased by 20%. For the cost of employee overtime hours, sensitivity was tested by adjusting the number of average hours worked per year. Educational accessibility was analysed by varying the average kilometer fare for travel by train and BTM. For the comfort benefits, the parameter of the VoTT multiplier for seated and standing passengers was increased and decreased. The analysis considered how the proportion of employees whose utility is higher for overtime working impacts the NPV. Additionally, the sensitivity of the operational savings for railway companies was tested by adjusting the ratio between the decrease in passengers and the reduction in capacity. Although the external effects played a small role in the CBA outcomes, they were also included in the sensitivity analysis. Traffic safety was tested by increasing and decreasing the external safety costs per vehicle kilometer by 20%. Similarly, the costs of greenhouse gas emissions were adjusted by increasing and decreasing the CO_2-equivalent emissions per kilometer by the same percentage. Lastly, air pollution sensitivity was tested by increasing and decreasing the amount of air pollutants per kilometer.

The results of the sensitivity analysis are presented in the Figures 10.4, 10.5, 10.6 and 10.7, with each figure corresponding to a different policy alternative. The figures show the percentage change in NPV for the change of each parameter. It is important to note that the scale of the x-axis in the figures differs between the four policy alternatives.This already indicates that some policy alternatives are more sensitive to the parameter changes compared to the others.

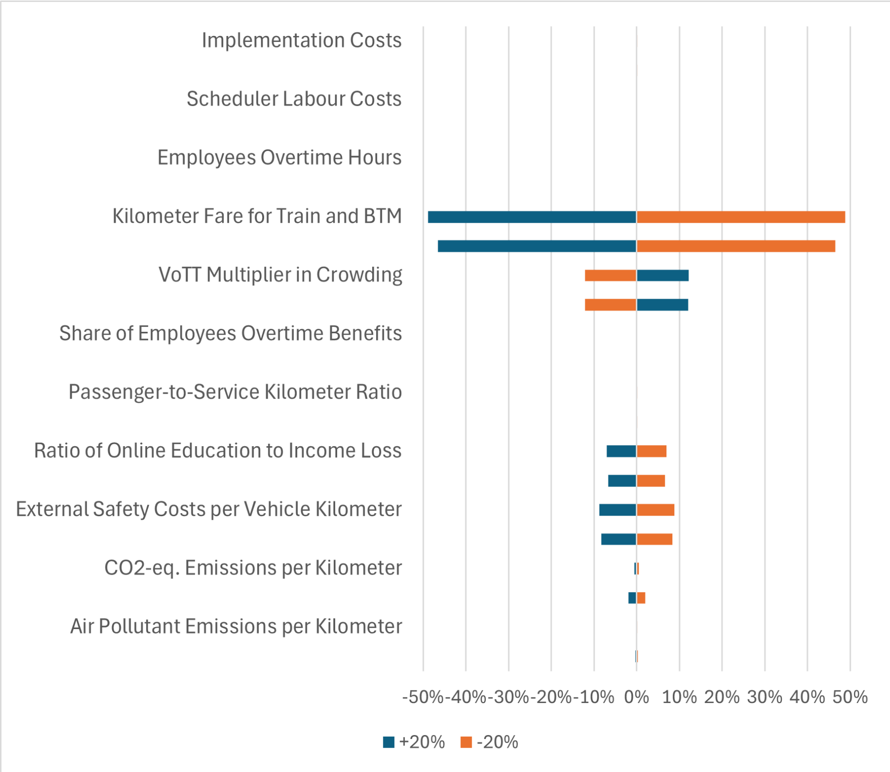


Figure 10.4: Percentage sensitivity of NPV on Paid Peak Hour Travel

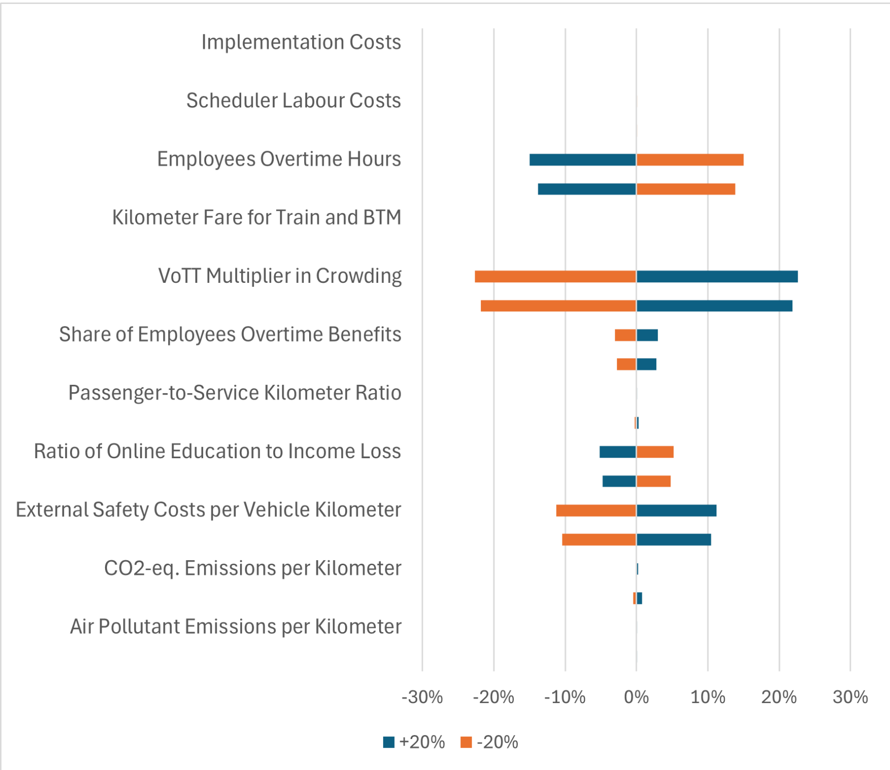


Figure 10.5: Percentage sensitivity of NPV on Shift Lecture Hours

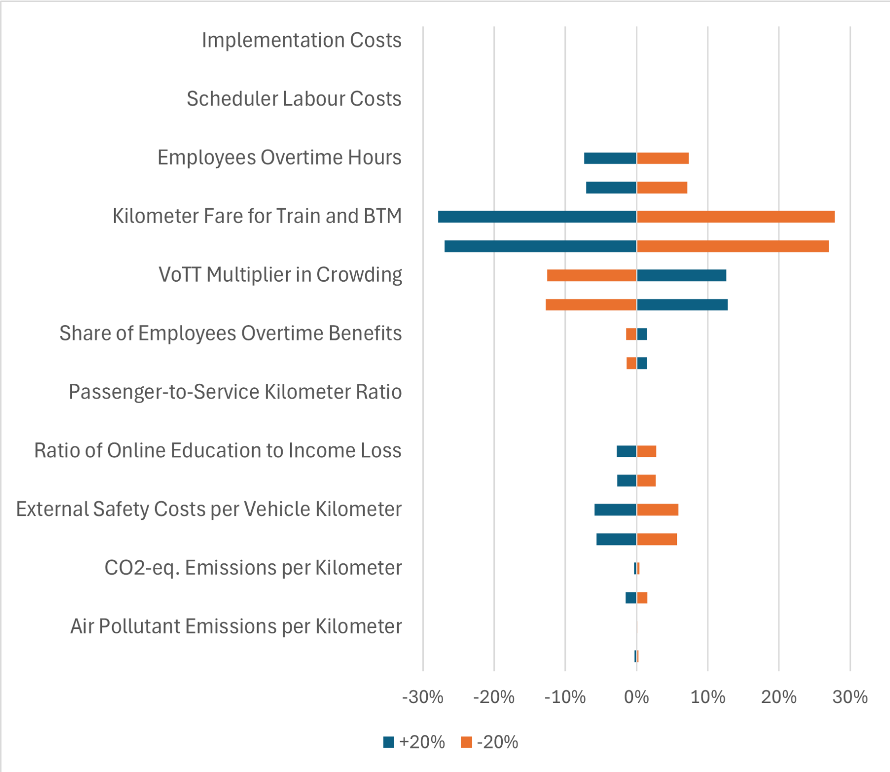


Figure 10.6: Percentage sensitivity of NPV on 40% Peak Discount + Shift Lecture Hours

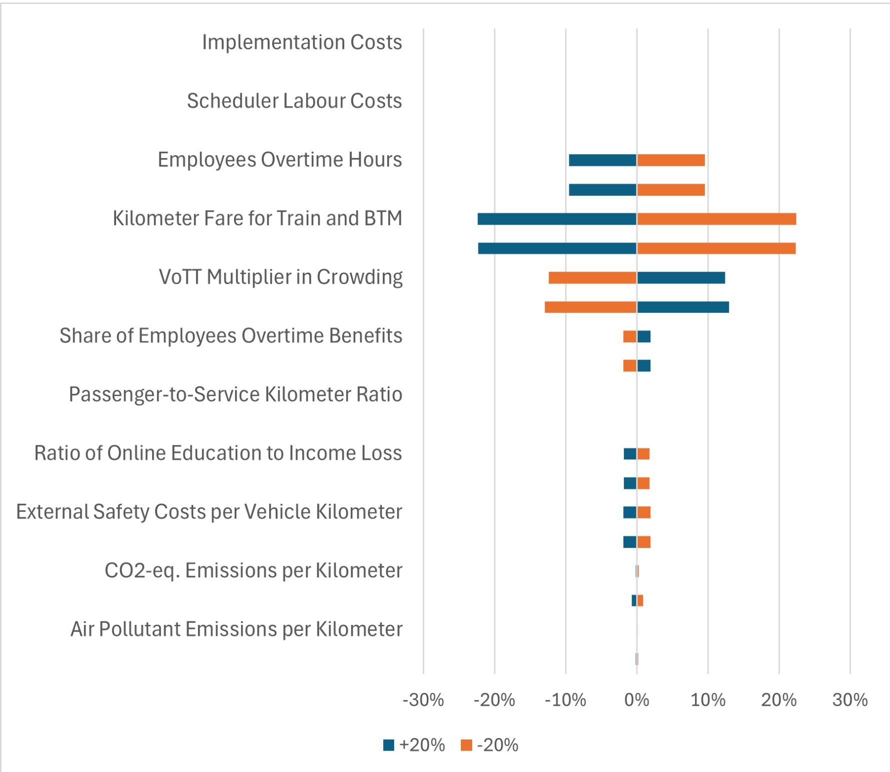


Figure 10.7: Percentage sensitivity of NPV on Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift

In all four figures, there is little to no change observed when increasing implementation costs and scheduler labour costs. These costs are small and initial, making them negligible on the CBA balance. Consequently, the uncertainties in these cost items do not influence the outcomes of the CBA.

The third parameter tested is the employees' overtime hours. In the Tables 10.5, 10.6 and 10.7, it can be seen that a 20% increase respectively leads to a decrease in NPV by approximately 15%, 7%, and 9% in the low scenario. Conversely, a 20% decrease results in an increase in NPV of the same magnitude, as overtime hours represent a cost in the policy alternatives. In the 'Shift Lecture Hours' alternative, Figure 10.5, the impact of the 20% change is noticeably more significant compared to the other two alternatives where lecture times are shifted. This is not because the increase leads to substantially more overtime hours in this alternative, but rather because the NPV of this alternative was initially much closer to zero, and the other effects are much smaller. As a result, the relative impact of all changes in this alternative is much greater.

A change in the kilometer fare for train and BTM has a significant impact on the NPV. This is not surprising, as it represents the largest cost component in the alternatives where fare differentiation is implemented. For this parameter also applies that an increase leads to a lower NPV and a decrease leads to a higher NPV, as it is a negative effect. The 'Paid Peak Hour Travel', '40% Peak Discount + Shift Lecture Hours', and 'Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift' alternatives are sensitive to this parameter, as the effect on the NPV is greater than the change in the parameter itself. The underlying differences are due to the varying differential fares. In 'Paid Peak Hour Travel', students pay the full fare during both peak periods, which amplifies the effect compared to the other two policy alternatives, resulting in a greater impact on the NPV. In the '40% Peak Discount + Shift Lecture Hours' alternative, the sensitivity is smaller because students pay 40% less than in 'Paid Peak Hour Travel'. In the last alternative, sensitivity is the lowest, as students only pay the full fare during the morning peak.

The VoTT multiplier for seated and standing passengers in trains is the fifth parameter and determines the amount of comfort benefits generated by the policy alternatives. In contrast to the previously mentioned parameters, an increase in the VoTT multiplier actually results in a higher NPV, while a decrease leads to a lower NPV. Figures 10.4, 10.5, 10.6 and 10.7 illustrate the sensitivity of the NPV for the VoTT multiplier. Remarkably, the NPV in Figures 10.4, 10.6 and 10.7 changes by approximately 10%, whereas in Figure 10.5, this change exceeds 20%. This indicates that 'Shift Lecture Hours' is the only alternative sensitive to the VoTT multiplier. The reason this alternative is particularly sensitive is that this effect has the most significant impact in this alternative. Additionally, the total range of effects is relatively small, meaning that a change in one effect has a disproportionately large influence on the NPV.

Not only can the costs of employee overtime hours increase, but the benefits for employees can also rise. A larger proportion of teachers generating utility from evening classes means that the costs of overtime hours in the CBA are offset. In Figure 10.4, there is no change because this alternative does not involve any shift in lecture hours. However, there is an observable effect in the other three policy alternatives, though it is limited. The 'Shift Lecture Hours' alternative, Figure 10.5, has again the largest effect. This is because the overall range of effects in this alternative is much lower than in the other policy alternatives, which causes the impact of a change in one effect to weigh more heavily on a percentage basis.

The passenger-to-service ratio, which has been added as a parameter for the operational savings for railway companies, is also included in Figures 10.4, 10.5, 10.6 and 10.7. However, due to the minimal nature of the operational savings, a 20% increase or decrease does not produce a noticeable change in the NPV of the CBA, as shown in the figures.

For the only indirect effect, the sensitivity analysis has considered the ratio of online education to income loss. However, the CBA is not very sensitive to whether online education has a larger or smaller impact on future income. In Figure 10.4 the effect is somewhat larger because, in this alternative, students attend their lectures at their educational institution the least. In Figure 10.5, Figure 10.6 and Figure 10.6 the effect is smaller and remains at or below 5%.

Finally, the analysis included the three external effects: the costs of traffic safety risks, the costs of greenhouse gas emissions, and the costs of air pollution. The sensitivity for the adjusted accident risk and emissions per kilometer is very small. This is consistent with expectations, as the magnitude of the effects in the CBA, as presented in Table 9.1, is also minimal.

Given the greater uncertainty surrounding assumptions about employee overtime costs and the impact of digital education, an additional sensitivity analysis was performed. Previously, based on the collective labour agreement of the Dutch Universities (Universiteiten van Nederland (UNL), 2023), it was assumed that employees receive 50% extra hourly payment for evening teaching hours. However, as this represents a major cost within the CBA, there is a possibility that negotiations will take place over either modifying the collective labour agreement or employees accepting these hour without an additional payment. The assumption that future salary would decrease due to digital education is even more challenging, if not impossible, to substantiate. Digital education may actually be more effective for some educational activities or might have no impact on academic quality. To explore these assumptions further, two extreme cases were tested: one in which employees receive no additional pay for evening teaching, and another where digital education leads to no future income loss.

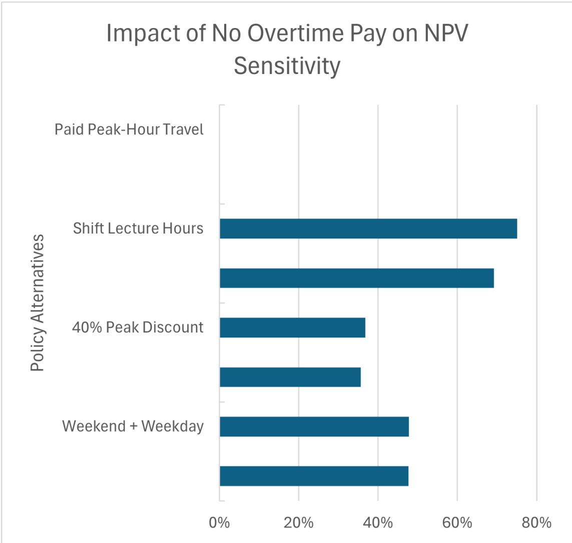


Figure 10.8: Percentage sensitivity of NPV with no extra payment for overtime hours of employees

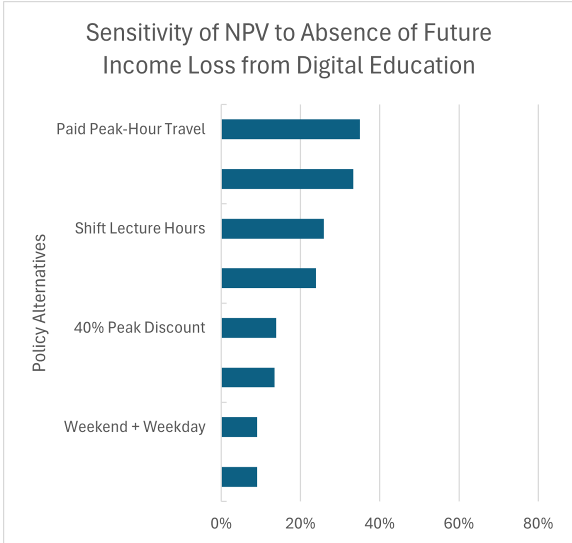


Figure 10.9: Percentage sensitivity of NPV with no future income loss from digital education

Figure 10.8 and Figure 10.9 show the results of these analysis. Getting rid of the extra salary for overtime leads to an increase in NPV for all options involving shifted lecture hours. The magnitude of the impact is related to the sum of all effects. The larger the sum of all effects, the smaller the impact of discarding the extra salary on the NPV. Figure 10.9 shows that the impact of not accounting for future income loss is smaller than that of stopping overtime payment. However, it still results in a 35% higher NPV in the best-case scenario for the Paid Peak Hour alternative. The magnitude of this effect is influenced not only by the total of all effects but also by the number of days students reduce their travel to the educational institution.

In summary, the NPV of the CBA is sensitive for two parameters. The differential fare alternatives are sensitive to the kilometer fare for trains and BTM, as the percentage impact on the NPV is greater than the percentage fare change. 'Shift Lecture Hours' is sensitive to the VoTT multiplier, as the NPV change exceeds the multiplier change. Although 'Shift Lecture Hours' is the most sensitive policy alternative across all parameters, it achieves the highest NPV and is the only alternative with a positive NPV. Which remains true even when no additional salary is provided to educational institution employees for overtime and when there is no future income loss due to digital education.

10.5. Policy Uncertainty

Other policies significantly influence how the measures will unfold. This is the policy uncertainty of a CBA. The current effects are based on the baseline alternative. When substantial policy changes occur during the assessment period that are not accounted for in this alternative, the outcomes of the CBA may vary. Examples of policies that can influence the outcomes of this CBA include the introduction of a distance-based tax for motor vehicles, the potential elimination of housing subsidies, or changes in the collective labour agreement arrangements for higher education. A distance-based tax could incentivize both commuters and students to choose trains more often, particularly for longer journeys, which may diminish the effectiveness of the measures outlined in this CBA. The removal of a housing subsidy might limit the ability of some students to live independently, potentially leading them to either not pursue higher education or continue residing with their parents. Furthermore, if collective labour agreements specify that teachers will not receive additional compensation for evening classes, this could significantly lower educational costs for universities, resulting in higher scores for the policy alternatives in the CBA balance. The general guidelines by Romijn and Renes (2013) do not prescribe an analysis to determine the sensitivity to policy uncertainty. Therefore, this uncertainty is not further tested.

11
Discussion

In this chapter, a critical reflection is conducted on the methods used in this research. First, the chapter discusses remarkable outcomes of the CBA table in section 11.1. Then, the limitations of the CBA are discussed in section 11.2. The shortcomings of the survey are addressed in section 11.3. Finally, the most important findings are discussed in section 11.4.

11.1. The CBA Outcomes

Table 9.1 in chapter 9 presents the outcomes of the CBA. Only one of the four policy alternatives has a positive net present value, which is the 'Shift Lecture Hours' alternative.

What stands out in the results in Table 9.1 is that the costs of employee overtime hours represent a significant expense for the alternatives in which lecture times are shifted to 10:30 and later. That is remarkable, as these costs are not previously mentioned in either the grey or academic literature. It is likely be assumed that teaching staff is flexible and do not require additional pay for evening lectures, as they could be compensated with time off at other moments during the day. I do not agree with this assumption, as people generally like to spend their free time with their significant other or kids which they cannot do each time of the day. Their valuation of free time at a different time of day is therefore lower, resulting in a loss of utility.

Another noticeable aspect is the size of the educational accessibility effect. While it did not surprise me that educational accessibility is one of the most significant impacts of the measures, I did not expect it to involve billions of euros, given that the group of students living at their parents (approximately half of all students) is just over half a million. Not only do students keep travelling during peak hours in the 'Paid Peak Hour Travel' alternative to attend their classes, but they also continue to travel during peak hours in the '40% Peak Discount + Shift Lecture Hours' and 'Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift' alternatives, where classes start after 10:30. As a result, the impact on educational accessibility in these policy alternatives also amounts to billions of euros. The decision to travel during the paid peak hours can be caused by various reasons. For instance, some students have internships with mandatory attendance, while others may meet for group work at their educational institution or prefer studying in the faculty or university library. Additionally, the financial circumstances of students or their parents can significantly influence students' price sensitivity. The more available income they have, the lower the barrier to travelling during peak hours. Moreover, students living with their parents do not allocate funds for renting a room. As a result, these students have a larger budget and may be more willing to pay for travelling during peak hours, as this can be viewed as an alternative use of their funds.

Additionally, the ratio between educational accessibility and comfort benefits is an important aspect to consider. The educational accessibility effect consistently outweighs the comfort benefits for the three policy alternatives with a differential fare. Consequently, this ratio plays a crucial role in determining the net present value. This aligns with my expectations, as measures that disadvantage a small group of travellers in terms of accessibility tend to produce a larger negative impact compared to the positive effects they have on the overall travel quality for the remaining passengers.

NS, the main rail operator, is also aiming to reduce the number of students travelling during peak hours, as discussed in chapter 1. One might expect that they would benefit the most from the four policy measures through lower operational costs; however, the operational savings for railway companies are surprisingly less than anticipated, despite the clear reduction in the number of students travelling during peak hours. In the 'Paid Peak Hour Travel' alternative, where most students avoid peak hours, the savings based on the reduction in congestion during the morning rush amount to approximately €17.5 million over a span of 15 years.

11.2. CBA

The analysis method used in this research is the Cost-Benefit Analysis (CBA). As detailed in chapter 3, the CBA is an appraisal method which means it that serves as a valuable tool in the policy-making process. The choice of CBA is discussed in chapter 3; however, this does not imply that other appraisal methods could not have been applied in this research. For instance, there is the Multi-Criteria Decision Analysis (MCDA), the Environmental Impact Assessment (EIA), and Participatory Value Evaluation (PVE). Each method targets different aspects, bringing its own set of advantages and disadvantages. In the MCDA, for instance, there is greater flexibility in selecting criteria and impacts, along with their corresponding weights (Mouter, 2021). The EIA, on the other hand, specifically examines the environmental effects of a policy (Mouter, 2021). Meanwhile, in the PVE, citizens are asked how much government funding they would allocate to each policy, rather than assuming their willingness to pay for it (Mouter et al., 2019). Although the CBA was regarded as the most suitable appraisal method for this topic, it should be noted that the use of other appraisal methods could have yielded different results.

In the remainder of the section, various components of the CBA will be addressed. First, there will be a reflection on the study scope (subsection 11.2.1), followed by a discussion of the design of the baseline and the policy alternatives (subsection 11.2.2 and subsection 11.2.3). Next, the effect calculations will be discussed (subsection 11.2.4). Finally, there will be a reflection on potential double counting (subsection 11.2.5), the distribution effects (subsection 11.2.6), and the use of the CBA by policymakers (subsection 11.2.7).

11.2.1. Study Scope

The description of the study begins with a problem analysis and boundary setting of the issue in chapter 1. The problem and the boundaries define which conclusions can and cannot be drawn in the following chapter.

When defining the study scope, the emphasis is placed on managing rail demand rather than expanding capacity, as research indicates that there is limited available space for expansion in the Netherlands. As a result, this study does not examine capacity-expanding measures, such as increasing the number of trains or providing trains with greater capacity. Therefore, this study does not allow for a conclusion on whether demand solutions are more effective than capacity solutions, or the other way around.

This research only focused on measures designed to reduce the number of students travelling by train, without considering the other groups of travellers. Measures for commuters, business travellers, and leisure travellers were not evaluated. Consequently, this study cannot offer insights into the effectiveness of measures for these other traveller groups or determine whether restrictions on student travel result in higher or lower societal welfare effects compared to measures for other groups of travellers.

The geographical boundaries of this research are defined by the national borders of the Netherlands. The study does not focus on a specific region where the problem may be most pronounced, nor does it consider an international context, as the Student Travel Product is applicable only within the Netherlands. As a result, the effects observed will be smaller compared to a study centered on a single crowded route with a high proportion of students. This limitation arises from the national scope, which includes quieter routes that have fewer students, likely diminishing the overall effects. Additionally, the implemented measures are less effective at reducing crowding when the percentage of students is relatively low.

The measures within the scope of this study target students from MBO, HBO, and university, all of whom are granted with the Student Travel Product. If the scope was restricted to just one or two of these student groups, the outcomes would likely differ. Consequently, far fewer teachers would need to work overtime beyond the agreed-upon hours in the collective labor agreement, resulting in a decrease in costs for this cost item. Additionally, fewer students would experience accessibility issues, and the decline in the number of students travelling during peak hours would be less pronounced, thereby minimizing these effects. Furthermore, significant differences may exist among students from the three educational levels. If students from one level typically travel considerably more kilometers than those from another, focusing on this group of students could lead to a shift in the cost-benefit ratio.

Finally, the scope of the analysis is limited to a time horizon of 15 years, up to 2040. Any effects arising beyond this point are excluded from consideration. As a result, there is a shorter period to recapture the implementation costs. Policy measures with substantial long-term benefits are possibly undervalued, especially given a high discount rate.

11.2.2. Design of Baseline Alternative

The policy alternatives in this study are compared to the baseline alternative. The baseline alternative outlines a future that does not incorporate new measures to address the identified problem but does account for the measures already in the pipeline. However, the design of the baseline alternative is based solely on train passenger kilometers and the distances travelled by students using trains, public transport, cars, and bicycles. This provides only a limited view of the future and may be considered insufficient. In the researcher's opinion, these were the minimal outlines needed to describe the future relevant to the defined problem.

What has not been considered in the baseline alternative used in this study is the infrastructural growth of the railway network. To accommodate the passenger growth outlined in chapter 4,it will likely be necessary to construct new infrastructure and upgrade the existing one. The lower passenger demand in the policy alternatives means that the infrastructural network requires less expansion. This suggests that there is potential to reduce infrastructure costs within the policy alternatives. However, this effect has not been considered in this study, potentially overlooking an impact that could be several times greater than the operational savings for railway companies.

Additionally, assumptions were made in the design of the baseline alternative. For instance, the forecast for future passenger kilometers is based on the projections from Hamersma and Moorman (2023) and Rijkswaterstaat WVL (2024), with the assumption that it increases linearly between the predicted years. In reality, this forecast will differ from the actual number of kilometers and may fluctuate over time, sometimes increasing or decreasing at rates that are either less than or greater than linear. This may also apply to the distance travelled by students using trains or BTM. The baseline alternative is based on data collected between July 2022 and June 2023 (Jonkers et al., 2023), but this travel behaviour immediately following the pandemic may not reflect the current levels. It is also assumed that the number of kilometers students travel by public transport will grow in proportion to the student population. The only adjustment made is a slight decrease caused by a higher proportion of students living away from home. However, future students may attend the educational institution less frequently, as they have become more used to studying from home due to the COVID-19 pandemic.

The results of the scenario analysis, as presented in chapter 10, show that the outcome of the CBA is robust within the tested ranges. The 'Shift Lecture Hours' policy alternative continues to demonstrate a positive NPV, and remains the alternative with the highest expected welfare benefits. It can be concluded that minor uncertainties related to the design of the baseline alternative have not influenced the conclusions drawn from the analysis.

11.2.3. Design of Policy Alternatives

In chapter 5 of this report, it is described how the policy alternatives were formulated. This process started with a systematic review of both academic and grey literature. Despite the thorough identification of policy measures, the selection and design of the policy alternatives were executed with less precision. Given the limited time for this research, the identified articles were broadly categorized by the effectiveness of the measures, without taking into account additional limitations or comments noted in the articles. This may have led to certain important aspects being overlooked when evaluating a measure on a qualitative scale of low, moderate, and high. The design process for the policy alternatives was also simplified. One alternative involved a full fare for students during peak hours, while another offered classes starting at 10:30. A third alternative provided a 40% discount during peak hours along with classes from 10:30 onwards. The final option featured a single type of subscription, allowing free travel in weekends and on weekdays from 09:00, with classes starting at 10:30 or later. However, the choice of this particular design for the alternatives was not grounded in scientifically proven principles or evaluated by stakeholders.

11.2.4. Effect Calculations

The outcome of a CBA is influenced by the effects that are considered. While several direct, indirect, and external effects have been included, it is impossible to capture all welfare effects of a policy alternative in the analysis (Mouter, 2023). In CBAs with a limited scope, like this one, there is not enough time to assess all potential effects. Consequently, chapter 6 intentionally excludes certain impacts, such as those related to the decision to study and the choice of study location, as well as effects on the housing market.

Some effects are included in the CBA only in a qualitative manner, rather than quantitatively. Since these qualitative effects cannot be integrated into the CBA balance, comparing the policy alternatives becomes more challenging. This is, by the way, entirely impossible for effects that are absent from the CBA, such as the policy's impact on stakeholder support, political implications, changes in public perception, and effects on other ethical values (Mouter, 2021).

For the effects that are quantified, the calculations themselves are open to debate and carry a degree of uncertainty (Mouter, 2021), as previously mentioned in chapter 10. This CBA has not been prepared in collaboration with the relevant stakeholders regarding the formulated problem, as described in chapter 1, except for the survey. This leads to a substantial reduction in the available information and data to support the calculations. As a result, many effect calculations rely on general index numbers and assumptions that are not grounded in literature. Moreover, calculating the effects proves challenging due to the complex relationships among them, as detailed in chapter 6.

One way handle the lack of knowledge about various relationships is by making assumptions. In this CBA, many of the estimated effects are based on one or more assumptions. Where possible, these assumptions are supported by sources to ensure they are well-founded and to help the reader understand the reasoning behind them. The main assumptions, accounting for the uncertainty and potential impact, are that teaching staff at MBOs, HBOs, and universities is required to conduct an average of two evening classes per week, for a 50% extra salary for those hours. It is further presumed that railway companies will only cut back 20% of the capacity compared to the decrease in travelled kilometers, and that a year of online education will reduce future earnings by 8%.

The CBA effects have ultimately been calculated on averages. However, this approach does not reflect the heterogeneity within the student population. Actual behaviour will therefore likely differ from the calculated ones. For instance, it is assumed that the average change in travel behaviour is the same for students living far from their educational institution as it is for those living nearby. This assumption neglects the possibility that students living farther away might choose more often not to travel during peak hours or to use a different mode of transport. If this were the case, there would be relatively fewer peak hour kilometers compared to a situation where students living closer to campus more frequently decide to avoid peak hour train travel.

11.2.5. Double Counting

In addition to reflecting on the effect estimations, it is also relevant to consider possible double counting of effects. This refers to instances where certain effects are unintentionally included for more than once within the CBA (Mouter et al., n.d.). In this CBA, efforts have been made to avoid any instances of double counting. For instance, the value of the comfort benefits was adjusted following reductions in operational costs. As a result, there are no benefits that are counted both as comfort benefits and as operational savings for railway companies. In other cases, double counting is less clear, such as with indirect effects. It is difficult to definitively prove that the increase in time spent on side jobs, sports, and social activities is directly related to the policy measures.

11.2.6. Distribution Effects

The CBA presents the societal welfare effect of the policy measure through the CBA balance. The societal welfare effect, however, provides no insights into how costs and benefits are distributed among various social groups (Romijn & Renes, 2013). An uneven distribution of positive and negative effects among stakeholders can be viewed as unfair from a societal perspective. Therefore, the distribution of these effects can be relevant for policymakers when addressing various issues. A quick analytical glance at the CBA results from Table 9.1 suggests that the costs for the proposed policy measures primarily fall on students, teaching staff and educational institutions. In welfare theory, they are therefore often referred to as the 'losers'. In contrast, other train passengers, the government, and railway companies appear to be the stakeholders benefiting more from the measures. This makes them, in fact, the 'winners' of the policy alternative.

This uneven distribution of costs and benefits may result in limited support for the policy among students and educational institutions. Forced implementation could not only change the expected outcomes of the measures but also provoke resistance, as seen with past student protests against the loan system (NOS, 2022a) and the extended study surcharge (Jonk, 2024). Students do not lose their current travel rights with the 'Shift Lecture Hours' alternative, but it does require them to reorganize their day, which also applies to teachers. The positive balance allows for compensating the losers with the gains from the winners. By reducing the obstacles faced by the losers, support for the policy can be strengthened, and resistance lowered. In section 12.2 of chapter 12, recommendations will be provided on how policymakers can effectively address the resistance among students, educators, and educational institutions.

11.2.7. CBA and politicians

The results of a CBA can, as previously mentioned, be utilized in the policy-making process. While it is a positive development that decisions are based on research, it is essential that the interpretation of the results is both accurate and nuanced.

According to Mouter (2023), politicians often misuse the results of a CBA, whether intentionally or unintentionally. The unintentional misuse of the CBA may arise from policymakers and politicians finding certain aspects difficult to understand, such as discounting and the role of the baseline alternative. Additionally, assumptions related to the discount rate, baseline alternative, and index numbers are often embedded in long reports, while policymakers and politicians typically focus only on the summary and the research findings (Mouter, 2023). Policymakers and politicians also intentionally misuse the CBA. For example, they point out the limitations of a CBA when the results are not in their favour. Conversely, when the results are favourable, they assert that the CBA has almost no limitations (Mouter, 2023).

Additionally, Mouter (2023) points out that in the decision-making process, sometimes too much and sometimes too little value is placed on the CBA. When decisions in the policy-making process are based solely on the CBA, its role is overvalued. Instead, the CBA should be regarded as a tool to inform policy choices, with its results serving as one aspect of the justification for decisions rather than the primary basis. On the other hand, policymakers and politicians sometimes view the CBA as a complex analysis filled with assumptions and uncertainties, which can lead to a loss of confidence in its findings. As a result, the findings are discussed only to a limited extent, even though the analysis can offer valuable insights into the scale of various societal effects.

Both intentional and unintentional misinterpretations and uses of the CBA lead to suboptimal discussions regarding societal issues, which in turn result in suboptimal decision-making as stated by Mouter (2023).

11.3. Survey

The choice and design of the survey have also introduced certain limitations of this study. Section 11.3.1 discusses which stakeholders were surveyed and which were not. The survey design is then reviewed in subsection 11.3.2. Lastly, subsection 11.3.3 examines the potential biases in the survey.

11.3.1. Target Group

In chapter 3, the target group of the survey was defined. Due to time constraints, only one survey was conducted, targeting students living outside the city where they study. While this group likely includes most students travelling during peak hours, the survey does not account for potential changes in living situations or travel behaviour of students residing in their university city, nor does it consider that of faculty staff.

11.3.2. Survey Design

As discussed in chapter 3, the survey does not present the respondent with a choice set like a stated preference experiment would. Instead, respondents are directly asked about their anticipated changes in travel behaviour using the stated opinion approach. This makes it more difficult to translate the survey results into statistically significant insights.

In designing the survey format, the decision was made to first ask respondents about their socio-demographic characteristics and current travel behaviour. After that, all four policy alternatives are presented, followed by questions on expected travel behaviour under each policy measure. By using this order, students were prevented from not realizing, after answering questions for one policy alternative, that they might have preferred to indicate different expected travel behaviour compared to other policy alternatives. However, this approach carries the risk that respondents may have answered strategically, comparing the policy alternatives when indicating their expected travel behaviour. Additionally, in an effort to shorten the survey, the descriptions of the four policy alternatives were compressed. While the goal was to still clearly communicate the essence of each alternative, this decision may have increased the risk of misinterpretation by respondents.

Furthermore, it should be noted that after administering the survey, it became evident that the survey did not clarify whether the policy measures would also apply to other public transport modes accessible with the Student Travel Product, aside from the train. In further analysis it was assumed that the survey also limits students' travel rights for bus, tram, and metro (BTM). However, because this was not clearly communicated in the survey, respondents may have believed that BTM would not implement peak pricing, which could have undermined the reliability of the survey results.

Finally, the survey results in this survey design represent a moment-in-time capture. Respondents were asked how they would react to the four policy measures, but it was not explicitly specified when these would be implemented. iven that students are typically enrolled for only a few years, the survey results likely better reflect short-term behaviour than long-term behaviour. As a result, the survey findings, and therefore the analysis, lack the longer-term effects of the policy measures. Long-term effects are often stronger than short-term ones, as individuals have more time to adapt. For example, more students might purchase a car in the long term, leading to a significant shift in their chosen mode of transport. Consequently, the effects of the policy measures, especially beyond 2030, may be underestimated in this analysis.

11.3.3. Biases

Survey results are biased when the measured value systematically differs from the population value (Walters, 2021). The results of this survey also contain a bias. Firstly, the survey exhibits a sampling bias; the respondents who completed the survey are not representative of the entire population of students living outside their study city (Walters, 2021). Table 11.1 shows the share of students per educational type. The proportion of students studying at the university in the survey is 80%, whereas in the student population, this proportion is 26.7%. Moreover, only conducting active recruitment of students at Delft Station in the late afternoon has also affected the distribution of different types of respondents. This increased the likelihood that a relatively high number of respondents are regularly train travellers, and, furthermore, travel home at the end of the afternoon. The fact that the active recruitment took place during the final exam week of the academic year also influenced the extent to which different students participated in the survey.

Table 11.1: Educational Type Distribution in Population and Survey

Educational Type		Population	Survey
MBO	Number	479,500[a]	0
	%	37.4%	0.0%
HBO	Number	459,700[b]	17
	%	35.9%	19.3%
University	Number	341,800[c]	71
	%	26.7%	80.7%

[a] Ministerie van Onderwijs (2024b).
[b] Ministerie van Onderwijs (2024a).
[c] Ministerie van Onderwijs (2024c).

Additionally, the survey may contains a non-response bias (Berg, 2005), due to its distribution the survey via social media, there is little visibility on respondents who do not fill out the survey. There is a chance that certain type of respondents didn't fill out the survey more often than others. For example, students not using public transport or students who cannot imagine a shift of lecture hours.

In addition to the survey being completed by only a small portion of the population and the respondent types not being representative of the overall population, there is also the potential for response bias. This means that the answers may not accurately reflect the true beliefs or behaviours of the respondents. Possible causes of this bias include respondents perceiving certain answers as more socially acceptable than others, unclear or confusing question wording, or other factors. There may be respondents who are fundamentally against price increases in public transport. In the survey, they might indicate that they would stop going to their educational institution or always opt to drive by car if fares were raised. This behaviour could be a strategic move to influence the study's results, leading to the potential overestimation of behavioural effects.

11.4. Main Discussion Points

As both the survey and the CBA have their limitations, while offering valuable insights, many discussion points are addressed in this chapter. The main points for policymakers to consider is that the analysis does not address the expansion of rail infrastructure or the potential savings that could result from it in the policy alternatives. Furthermore, the analysis examines only one approach to staggered lecture hours, and the effects of the measures are derived from a rough survey conducted with a non-representative group of students.

Based on the difficult-to-justify extra overtime salary and the reduction of future income due to digital education, the analysis does present a robust alternative. However, with a unbalanced distribution of costs and benefits, where the costs primarily fall on stakeholders in education, there is a lack of support among students, teachers, and educational institutions for a direct policy implementation.

12 Conclusion and Recommendations

In this final chapter of the study, the findings will be synthesized to formulate an answer to the main research question. Before drawing conclusions, this section will revisit the problem addressed by the study and examine the specific knowledge gap it aims to fill. Subsequently, the main steps of the research will be outlined, leading to a comprehensive answer to the main question. In the end of the chapter some recommendations are discussed for further or improved research on this topic.

Many Dutch trains are extremely crowded during peak hours. Unfortunately, the options for expanding capacity are limited. With the predicted growth in passenger numbers in mind, society is searching for solutions to manage demand both now and in the future. Alongside commuters, business travellers, and leisure travellers, students make up as much as 25% of the passengers on certain routes. The majority of the students hold a weekday subscription, which allows them to travel for free, while other passengers pay extra for travel during peak hours. As a result, students lack the financial incentive that other travellers have to avoid the busiest time of day.

The proposal of adjusting the Student Travel Product requiring students to pay for peak hour travel has been proposed in the Netherlands several times before. Previous studies showed that students tend to travel less when prices rise, which could reduce congestion in public transport. Transport companies and the ministry also have explored whether educational institutions could start later in the day, allowing students to avoid travelling during peak hours. However, both measures have faced significant resistance from students, educational institutions and their staff.

The aim of this research is to assess whether the societal benefits of measures designed to reduce the number of students travelling during peak hours outweigh their societal costs. The study was designed around the following main research question:

”To what extent are policies, designed to reduce student travel during peak hours on Dutch trains, socially beneficial?”

The research was structured into several intermediate steps, each corresponding to the sub-questions outlined in chapter 3. A systematic literature review was conducted to design four policy alternatives. The effects of these alternatives were mapped out using a conceptual model. Following this, a survey was conducted to determine missing effects related to the elasticity of student travel behaviour. The identified effects were then calculated and estimated based on the survey results and index numbers from the literature. The effects were presented in a table, and the impact of each effect was determined in the sensitivity analysis.

The research revealed that fare differentiation and schedule adjustments are widely discussed measures that could significantly reduce peak congestion. In examining the effects of these measures on students, several complex relationships emerged, linking the transport schedules of public transportation companies, compensation from the ministry, and students' travel behaviour. The results of the survey revealed how students' travel behaviour changes in response to the different policy measures.

Based on the CBA table and its context, it can be concluded that the 'Shift Lecture Hours' alternative is the only policy alternative that will provide a better welfare outcome than the baseline alternative. This alternative not only has a positive NPV value according to the analysis, but its cost-benefit ratio can also reach 1.2. This indicates that the benefits are 1.2 times greater than the costs associated with this policy alternative. Furthermore, this alternative is also expected to have a positive effect on the impacts that were only qualitatively considered in the analysis. When considering the future scenarios, as discussed in chapter 10, the 'Shift Lecture Hours' alternative also remains the only policy alternative with a positive net welfare effect. But, as indicated in chapter 10, this alternative is sensitive to various knowledge uncertainties. The number of overtime hours worked and paid to educational institution staff, as well as the amount of knowledge lost due to online education, have a disproportionately large impact on the NPV value.

However, if the objective of the policy implementation is solely to reduce peak congestion on trains, the analysis indicates that more attention should be given to the alternatives 'Paid Peak Hour Travel' and '40% Peak Discount + Shift Lecture Hours.' These two options provide greater comfort benefits for train travellers. Additionally, these alternatives could result in increased savings on the Student Travel Product for the ministry.

12.1. Recommendations for Further Research

Building on the findings of this research, and particularly its limitations as outlined in chapter 11, several recommendations are proposed for future studies that could further enhance and complement this work.

A first recommendation for future research in this area is conducting a large-scale stated choice experiment involving tens of thousands of students. Designing a stated choice experiment requires considerable time and attention to ensure that the right alternatives are presented to respondents through a well-constructed experimental design. Moreover, the survey would need to be distributed through educational institutions or the ministry to achieve the necessary participation levels. Nevertheless, the experiment would be highly valuable, as it would provide a more accurate representation of student travel behaviour and offer insights into the factors students consider when making decisions. When distributing the experiment through a survey, more attention should be given to achieving a representative distribution between MBO, HBO, and university students compared to this study.

Secondly, future research should focus more on accurately assessing the effects, particularly concerning the 'Costs of Employee Overtime Hours'. This effect is considerably bigger than expected, as previously discussed in section 11.1 in chapter 11. To achieve more accurate effect calculations, future research should emphasize collaboration with relevant stakeholders. For this effect, this includes educational staff from institutions, the institutions themselves, and organizations such as the trade union for higher education and the 'Universiteiten van Nederland'. But stakeholders can also assist in accurately quantifying other effects. For example, DUO has a better understanding of the exact costs associated with implementing the 'new' Student Travel Products, while railway companies gain insights into how much they can save by reduced peak congestion.

An alternative and possible effective method for calculating effects is through the use of models or simulations. This study revealed that there are not only complex relationships among various effects but also feedback loops (chapter 6). As a result, changes in one effect can trigger alterations in another, which in turn influences the first effect again. This complexity makes it challenging to establish a clear understanding of the effects, as no distinct equilibrium situation exists. Models and simulations are better equipped to manage the dynamic behaviour in complex systems compared to the CBA.

Additionally, this research recommends further exploration into the distribution of benefits and costs among the various stakeholders involved. As discussed in subsection 11.2.6 of chapter 11, the current CBA does not account for the effects distributed across different demographic groups and stakeholders. However, the Student Travel Product is a politically sensitive issue due to the accumulation of inconsistent government policies regarding student support. Considering fo example the recent budget cuts in education, the increase of interest on student loans, and the long-study penalty. The generation of recent graduates has even been referred to as the 'pechgeneratie', highlighting their lack of access to basic grants during their studies. A qualitative analysis, such as a CBA, does not fully capture the emotional weight of this societal issue. Therefore, an additional Participatory Value Evaluation (PVE) study or a similar qualitative evaluation would be beneficial, as it ensures a greater involvement of stakeholders. This increased engagement can lead to heightened attention in addressing obstacles and reaching compromises.

Finally, it is recommended to explore alternative policy measures that could potentially have lower costs or generate fewer negative impacts compared to the current policy options. The high expenses associated with overtime hours for employees at educational institutions could be mitigated by offering more classes over a shorter timeframe. This approach however may require additional facilities that the current institution lacks. Furthermore, investing in digital education could help reduce negative consequences associated with physical attendance. Alternatively, customized transportation options could be tested for students, aimed at improving their accessibility and preventing them from using cars.

12.2. Policy Recommendations

The study was conducted not only for scientific purposes but it can also contribute to make the rail sector future-proof, given its societal relevance. Recommendations can also be made for the decision-making process about policies to reduce the number of students travelling by train during peak hours.

The outcomes of the CBA in this thesis show that both differential fares, staggered hours and a combination of both measures are effective in reducing student travel in trains during peak hours. The measures effectively reduce crowding. However, when students are charged a differential fare for travelling during peak hours, the negative societal impacts at a national level outweigh the positive outcomes of the measure. So, the research suggests that implementing a nationwide differential fare for students, in any form, should be discouraged.

Only shifting the lecture hours to 10:30 or later results instead in a net gain in welfare. This approach can be recommended to policymakers. However, there is limited support among students, teachers, and educational institutions for this. To mitigate resistance among these stakeholders, it is essential to engage them in the policy process from the very beginning. Communicate not only the societal benefits of the measure to them but also the individual advantages. The 'Shift Lecture Hours' initiative offers students and teachers a more comfortable travel experience outside peak hours. This may not be sufficient to enhance support for the measure, making it essential to investigate the underlying reasons for the resistance to the policy. For instance, by conducting a Participatory Value Evaluation (PVE). The outcome of the PVE reveals the obstacles that students, teachers, and educational institutions face, and possibly how these obstacles can be mitigated.

The savings by the government on the Student Travel Product could be used to support educational institutions with the extra costs associated with paying employees for overtime or rescheduling educational activities. The money could also be directed towards improving the quality of digital education, thereby reducing the impact of online learning on future salaries. Beyond reallocating resources among stakeholders, we can address these challenges in other ways. For example, establishing a pool of teachers could better accommodate the individual preferences of teaching staff when scheduling evening classes. If teachers can choose which days they teach evening classes, they may find it less inconvenient. Furthermore, optimising the class schedule could reduce the number of students attending evening sessions. For example, consider scheduling lectures with fewer breaks in between or increasing the number of lecture-free days. Conversations should also be held with study, sports, and student associations. Will it still be feasible for them to organize activities during the evening hours? Many of these activities start later in the evening, but universities and associations could potentially agree to keep one or more evenings a week free from scheduled classes.

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A

Research Flow Diagram

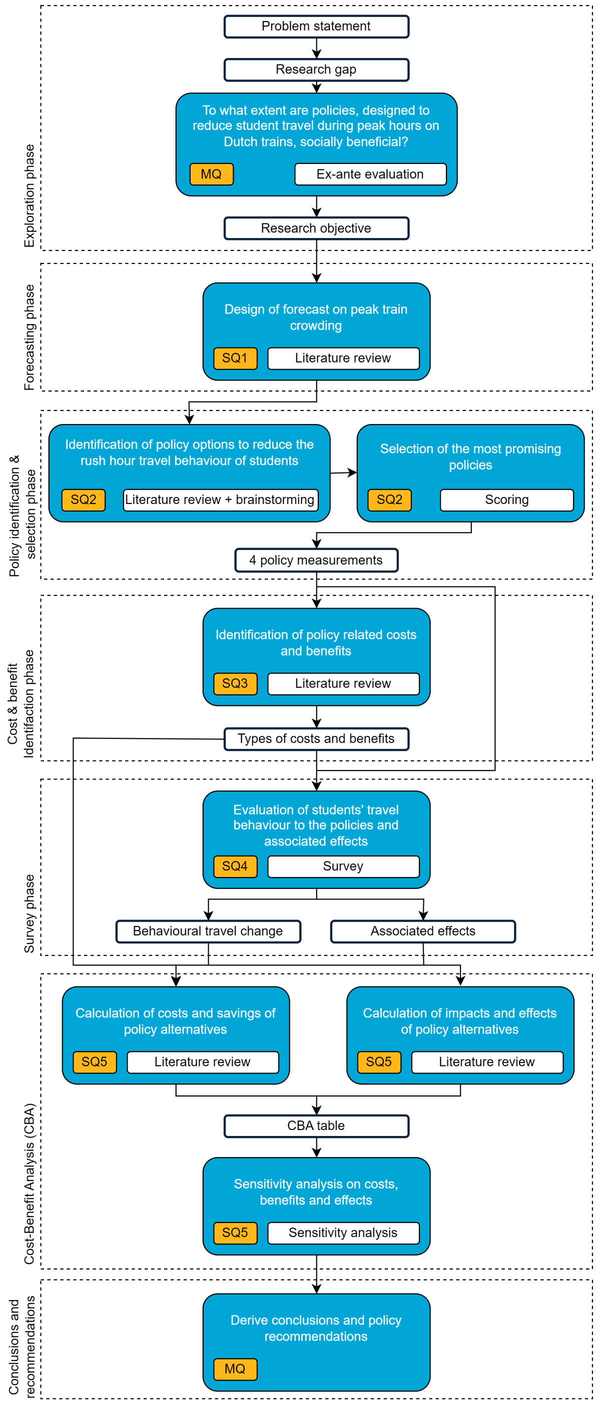

Figure A.1: Research Flow Diagram (RFD)

B

Survey Questions

This appendix contains the survey questions as presented to the respondents in the Qualtrics survey.

Policies Evaluation Survey

Introduction

Welcome and thank you for participating in this survey on student travel behaviour, conducted by Tibbe Bos from TU Delft for his Master Thesis in Complex System Engineering and Management.

This study aims to evaluate policies aimed at reducing student travel during peak hours on Dutch trains. Completing the survey will take approximately 9 minutes. The target audience is students living outside their study city, and the data will inform a Cost-Benefit Analysis (CBA) of the policies.

Your data will be stored securely at TU Delft and will only be accessible to the research team. At the end of the project, the data will be made public, but your responses will remain anonymous and confidential. Participation is voluntary, and you can withdraw at any time. By continuing, you consent to participate and agree to the described data processing.

For questions, please contact: Tibbe Bos – `T.S.Bos@student.tudelft.nl`

Socio-Demographic Questions

Before asking about your travel behaviour in different policy scenarios, we would like to gather some contextual information.

- **How old are you?**
  - Younger than 18
  - 18-20
  - 21-23
  - 24-26
  - Older than 26
- **Where do you live?**
  - **Alblasserdam ...**
  - **... Zwolle**
  - **Other**
- **What type of education are you following?**
  - Bachelor’s degree (University)
  - Bachelor’s degree (HBO)

  - Master's degree (University)
  - Master's degree (HBO)
  - Associate degree
  - MBO level 1-4
- **If MBO level 1-4, what is your educational institution?**
  - **Aeres MBO ...**
  - **... Zadkine**
  - **Other**
- **If HBO, what is your educational institution?**
  - **Amsterdam University of the Arts (AHK) ...**
  - **... Zuyd University of Applied Sciences (Zuyd Hogeschool)**
  - **Other**
- **If University, what is your educational institution?**
  - **Delft University of Technology ...**
  - **... Wageningen University and Research**
  - **Other**
- **Do you own a Student Travel Product (Student-OV)?**
  - Yes, a weekday subscription
  - Yes, a weekend subscription
  - No

Current Travel Behavior

Now we would like to know about your current travel behaviour.

- **On average, how many times a week do you travel to your educational institution?**
  - 5 times a week
  - 4 times a week
  - 3 times a week
  - 2 times a week
  - 1 time a week
  - Never
- **Which mode of transportation do you use for the majority of the distance travelled (one per trip)?**
  - Train
  - Bus, Tram, Metro (BTM)
  - Car
  - Bicycle
- **On average, how many times a week do you travel by train during rush hours?**
  - **The morning peak (06:30 - 09:00)**
    - 5 times a week
    - 4 times a week
    - 3 times a week
    - 2 times a week

    * 1 time a week
    * Never
  - **The evening peak (16:00 - 18:30)**
    * 5 times a week
    * 4 times a week
    * 3 times a week
    * 2 times a week
    * 1 time a week
    * Never
- **On average, how many times a week do you travel by bus, tram, or metro (BTM) during rush hours?**
  - **The morning peak (06:30 - 09:00)**
    * 5 times a week
    * 4 times a week
    * 3 times a week
    * 2 times a week
    * 1 time a week
    * Never
  - **The evening peak (16:00 - 18:30)**
    * 5 times a week
    * 4 times a week
    * 3 times a week
    * 2 times a week
    * 1 time a week
    * Never
- **On average, how many times a week do you travel by car during rush hours?**
  - **The morning peak (06:30 - 09:00)**
    * 5 times a week
    * 4 times a week
    * 3 times a week
    * 2 times a week
    * 1 time a week
    * Never
  - **The evening peak (16:00 - 18:30)**
    * 5 times a week
    * 4 times a week
    * 3 times a week
    * 2 times a week
    * 1 time a week
    * Never
- **On average, how many times a week do you travel by bicycle during rush hours?**

- **The morning peak (06:30 - 09:00)**
  * 5 times a week
  * 4 times a week
  * 3 times a week
  * 2 times a week
  * 1 time a week
  * Never
- **The evening peak (16:00 - 18:30)**
  * 5 times a week
  * 4 times a week
  * 3 times a week
  * 2 times a week
  * 1 time a week
  * Never

Impact of Policies

We are presenting four policies to reduce student numbers during peak hours. The Ministry of Education, Culture and Science aims to free up resources to invest in educational quality and stabilize student public transport costs amidst expected student growth. This also helps transport providers manage peak time issues. We ask you how these measures would impact your travel behaviour and activities.

- **Policy 1: Paid Peak Hour Travel**
  - Under this policy, both weekday and weekend subscription holders must pay the full fare when traveling by train between 06:30-09:00 and 16:00-18:30.
- **Policy 2: Shift Lecture Hours**
  - Under this policy, all lectures and scheduled educational activities start no earlier than 10:30. Additionally, lectures will be extended by the same duration they are delayed. The conditions of the student travel subscription do not change.
- **Policy 3: 40% Peak Discount + Shift Lecture Hours**
  - 40% Under this policy, weekday subscription holders will receive a 40% discount when traveling by train between 06:30-09:00 and 16:00-18:30. There is no change for students with a weekend subscription. Lectures begin at 10:30 and end later, as in the previous policy.
- **Policy 4: Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift**
  - Under this policy, all students receive a card for free weekend travel and weekday travel after 09:00. Additionally, lecture times will shift to start at 10:30, as described in policy 2.

1. Paid Peak Hour Travel

Full fare required between 06:30-09:00 and 16:00-18:30 for both weekday and weekend subscriptions.

- **Considering this policy, on average, how many times a week would you travel to your educational institution?**
  - 5 times a week
  - 4 times a week
  - 3 times a week
  - 2 times a week
  - 1 time a week
  - Never
- **Which mode of transportation will you use for the majority of the distance travelled (one per trip)?**
  - Train
  - Bus, Tram, Metro (BTM)
  - Car
  - Bicycle
  - Alternates among Train, BTM, Car, and Bicycle
- **Display This Question:**

  If Q144 = Train **or**
  Q144 = Alternates between Train and BTM **or**
  Q144 = Alternates between Train and Car **or**
  Q144 = Alternates between Train and Bicycle **or**
  Q144 = Alternates among Train, BTM, and Car **or**
  Q144 = Alternates among Train, BTM, and Bicycle **or**
  Q144 = Alternates among Train, Car, and Bicycle **or**
  Q144 = Alternates among Train, BTM, Car, and Bicycle
- **On average, how many times a week would you travel by train during rush hours considering this policy?**
  - The morning peak (06:30 - 09:00)
    - 5 times a week
    - 4 times a week
    - 3 times a week
    - 2 times a week
    - 1 time a week
    - Never
  - The evening peak (16:00 - 18:30)
    - 5 times a week
    - 4 times a week
    - 3 times a week
    - 2 times a week
    - 1 time a week
    - Never

- **Display This Question:**

  If Q144 = Bus, Tram, Metro (BTM) **or**
  Q144 = Alternates between Train and BTM **or**
  Q144 = Alternates between BTM and Car **or**
  Q144 = Alternates between BTM and Bicycle **or**
  Q144 = Alternates among Train, BTM, and Car **or**
  Q144 = Alternates among Train, BTM, and Bicycle **or**
  Q144 = Alternates among BTM, Car, and Bicycle **or**
  Q144 = Alternates among Train, BTM, Car, and Bicycle
- **On average, how many times a week would you travel by bus, tram, or metro (BTM) during rush hours?**
  - The morning peak (06:30 - 09:00)
    * 5 times a week
    * 4 times a week
    * 3 times a week
    * 2 times a week
    * 1 time a week
    * Never
  - The evening peak (16:00 - 18:30)
    * 5 times a week
    * 4 times a week
    * 3 times a week
    * 2 times a week
    * 1 time a week
    * Never
- **Display This Question:**

  If Q144 = Car **or**
  Q144 = Alternates between Train and Car **or**
  Q144 = Alternates between BTM and Car **or**
  Q144 = Alternates between Car and Bicycle **or**
  Q144 = Alternates among Train, BTM, and Car **or**
  Q144 = Alternates among Train, Car, and Bicycle **or**
  Q144 = Alternates among BTM, Car, and Bicycle **or**
  Q144 = Alternates among Train, BTM, Car, and Bicycle
- **On average, how many times a week would you travel by car during rush hours?**
  - The morning peak (06:30 - 09:00)
    * 5 times a week
    * 4 times a week
    * 3 times a week
    * 2 times a week
    * 1 time a week
    * Never
  - The evening peak (16:00 - 18:30)
    * 5 times a week
    * 4 times a week

    * 3 times a week
    * 2 times a week
    * 1 time a week
    * Never

- **Display This Question:**

  If Q144 = Bicycle **or**
  Q144 = Alternates between Train and Bicycle **or**
  Q144 = Alternates between BTM and Bicycle **or**
  Q144 = Alternates between Car and Bicycle **or**
  Q144 = Alternates among Train, BTM, and Bicycle **or**
  Q144 = Alternates among Train, Car, and Bicycle **or**
  Q144 = Alternates among BTM, Car, and Bicycle **or**
  Q144 = Alternates among Train, BTM, Car, and Bicycle

- **On average, how many times a week would you travel by bicycle during rush hours?**
  - The morning peak (06:30 - 09:00)
    * 5 times a week
    * 4 times a week
    * 3 times a week
    * 2 times a week
    * 1 time a week
    * Never
  - The evening peak (16:00 - 18:30)
    * 5 times a week
    * 4 times a week
    * 3 times a week
    * 2 times a week
    * 1 time a week
    * Never
- **Changes in Other Activities** Due to the implementation of this policy, the time you spend on other activities may change.
- **How many hours per week will your time spent on the following activities change?**
  - Weekly hours spent on:
    * Side job
    * Sports
    * Social activities

  Scale: -20, -16, -12, -8, -4, 0, 4, 8, 12, 16, 20
- **Acceptability of the New Policy** How acceptable is the new policy to you?
  - Very unacceptable
  - Unacceptable
  - Neutral
  - Acceptable
  - Very acceptable

2. Shift Lecture Hours

Classes begin at 10:30; lectures extended accordingly. No change to student travel terms.

- **Considering this policy, on average, how many times a week would you travel to your educational institution?**
  - 5 times a week
  - 4 times a week
  - 3 times a week
  - 2 times a week
  - 1 time a week
  - Never
- **Which mode of transportation will you use for the majority of the distance travelled (one per trip)?**
  - Train
  - Bus, Tram, Metro (BTM)
  - Car
  - Bicycle
  - Alternates among Train, BTM, Car, and Bicycle
- **Display This Question:**

  If Q159 = Train **or**
  Q159 = Alternates between Train and BTM **or**
  Q159 = Alternates between Train and Car **or**
  Q159 = Alternates between Train and Bicycle **or**
  Q159 = Alternates among Train, BTM, and Car **or**
  Q159 = Alternates among Train, BTM, and Bicycle **or**
  Q159 = Alternates among Train, Car, and Bicycle **or**
  Q159 = Alternates among Train, BTM, Car, and Bicycle
- **On average, how many times a week would you travel by train during rush hours considering this policy?**
- **The morning peak from 06:30 till 09:00**
  - 5 times a week
  - 4 times a week
  - 3 times a week
  - 2 times a week
  - 1 time a week
  - Never
- **The evening peak from 16:00 till 18:30**
  - 5 times a week
  - 4 times a week
  - 3 times a week
  - 2 times a week
  - 1 time a week
  - Never

- **Display This Question:**

  If Q159 = Bus, Tram, Metro (BTM) **or**
  Q159 = Alternates between Train and BTM **or**
  Q159 = Alternates between BTM and Car **or**
  Q159 = Alternates between BTM and Bicycle **or**
  Q159 = Alternates among Train, BTM, and Car **or**
  Q159 = Alternates among Train, BTM, and Bicycle **or**
  Q159 = Alternates among BTM, Car, and Bicycle **or**
  Q159 = Alternates among Train, BTM, Car, and Bicycle
- **On average, how many times a week would you travel by bus, tram, or metro (BTM) during rush hours?**
- **The morning peak from 06:30 till 09:00**
  - 5 times a week
  - 4 times a week
  - 3 times a week
  - 2 times a week
  - 1 time a week
  - Never
- **The evening peak from 16:00 till 18:30**
  - 5 times a week
  - 4 times a week
  - 3 times a week
  - 2 times a week
  - 1 time a week
  - Never
- **Display This Question:**

  If Q159 = Car **or**
  Q159 = Alternates between Train and Car **or**
  Q159 = Alternates between BTM and Car **or**
  Q159 = Alternates between Car and Bicycle **or**
  Q159 = Alternates among Train, BTM, and Car **or**
  Q159 = Alternates among Train, Car, and Bicycle **or**
  Q159 = Alternates among BTM, Car, and Bicycle **or**
  Q159 = Alternates among Train, BTM, Car, and Bicycle
- **On average, how many times a week would you travel by car during rush hours?**
- **The morning peak from 06:30 till 09:00**
  - 5 times a week
  - 4 times a week
  - 3 times a week
  - 2 times a week
  - 1 time a week
  - Never
- **The evening peak from 16:00 till 18:30**
  - 5 times a week
  - 4 times a week

  - 3 times a week
  - 2 times a week
  - 1 time a week
  - Never
- **Display This Question:**

  If Q159 = Bicycle **or**
  Q159 = Alternates between Train and Bicycle **or**
  Q159 = Alternates between BTM and Bicycle **or**
  Q159 = Alternates between Car and Bicycle **or**
  Q159 = Alternates among Train, BTM, and Bicycle **or**
  Q159 = Alternates among Train, Car, and Bicycle **or**
  Q159 = Alternates among BTM, Car, and Bicycle **or**
  Q159 = Alternates among Train, BTM, Car, and Bicycle
- **On average, how many times a week would you travel by bicycle during rush hours?**
- **The morning peak from 06:30 till 09:00**
  - 5 times a week
  - 4 times a week
  - 3 times a week
  - 2 times a week
  - 1 time a week
  - Never
- **The evening peak from 16:00 till 18:30**
  - 5 times a week
  - 4 times a week
  - 3 times a week
  - 2 times a week
  - 1 time a week
  - Never
- **Changes in Other Activities** Due to the implementation of this policy, the time you spend on other activities may change.
- **How many hours per week will your time spent on the following activities change?**
  - Weekly hours spent on:
    - Side job
    - Sports
    - Social activities

  Scale: -20, -16, -12, -8, -4, 0, 4, 8, 12, 16, 20
- **Acceptability of the New Policy** How acceptable is the new policy to you?
  - Very unacceptable
  - Unacceptable
  - Neutral
  - Acceptable
  - Very acceptable

3. 40% Peak Discount + Shift Lecture Hours

Weekday subscription: 40% peak hour discount. Lecture schedule shifts to 10:30 start, extended by the same duration.

- **Considering this policy, on average, how many times a week would you travel to your educational institution?**
  - 5 times a week
  - 4 times a week
  - 3 times a week
  - 2 times a week
  - 1 time a week
  - Never
- **Which mode of transportation will you use for the majority of the distance travelled (one per trip)?**
  - Train
  - Bus, Tram, Metro (BTM)
  - Car
  - Bicycle
  - Alternates among Train, BTM, Car, and Bicycle
- **Display This Question:**

  If Q176 = Train **or**
  Q176 = Alternates between Train and BTM **or**
  Q176 = Alternates between Train and Car **or**
  Q176 = Alternates between Train and Bicycle **or**
  Q176 = Alternates among Train, BTM, and Car **or**
  Q176 = Alternates among Train, BTM, and Bicycle **or**
  Q176 = Alternates among Train, Car, and Bicycle **or**
  Q176 = Alternates among Train, BTM, Car, and Bicycle
- **On average, how many times a week would you travel by train during rush hours considering this policy?**
- **The morning peak from 06:30 till 09:00**
  - 5 times a week
  - 4 times a week
  - 3 times a week
  - 2 times a week
  - 1 time a week
  - Never
- **The evening peak from 16:00 till 18:30**
  - 5 times a week
  - 4 times a week
  - 3 times a week
  - 2 times a week
  - 1 time a week
  - Never

- **Display This Question:**

  If Q176 = Bus, Tram, Metro (BTM) **or**
  Q176 = Alternates between Train and BTM **or**
  Q176 = Alternates between BTM and Car **or**
  Q176 = Alternates between BTM and Bicycle **or**
  Q176 = Alternates among Train, BTM, and Car **or**
  Q176 = Alternates among Train, BTM, and Bicycle **or**
  Q176 = Alternates among BTM, Car, and Bicycle **or**
  Q176 = Alternates among Train, BTM, Car, and Bicycle
- **On average, how many times a week would you travel by bus, tram, or metro (BTM) during rush hours?**
- **The morning peak from 06:30 till 09:00**
  - 5 times a week
  - 4 times a week
  - 3 times a week
  - 2 times a week
  - 1 time a week
  - Never
- **The evening peak from 16:00 till 18:30**
  - 5 times a week
  - 4 times a week
  - 3 times a week
  - 2 times a week
  - 1 time a week
  - Never
- **Display This Question:**

  If Q176 = Car **or**
  Q176 = Alternates between Train and Car **or**
  Q176 = Alternates between BTM and Car **or**
  Q176 = Alternates between Car and Bicycle **or**
  Q176 = Alternates among Train, BTM, and Car **or**
  Q176 = Alternates among Train, Car, and Bicycle **or**
  Q176 = Alternates among BTM, Car, and Bicycle **or**
  Q176 = Alternates among Train, BTM, Car, and Bicycle
- **On average, how many times a week would you travel by car during rush hours?**
- **The morning peak from 06:30 till 09:00**
  - 5 times a week
  - 4 times a week
  - 3 times a week
  - 2 times a week
  - 1 time a week
  - Never
- **The evening peak from 16:00 till 18:30**
  - 5 times a week
  - 4 times a week

- 3 times a week
- 2 times a week
- 1 time a week
- Never

- **Display This Question:**

  If Q176 = Bicycle **or**
  Q176 = Alternates between Train and Bicycle **or**
  Q176 = Alternates between BTM and Bicycle **or**
  Q176 = Alternates between Car and Bicycle **or**
  Q176 = Alternates among Train, BTM, and Bicycle **or**
  Q176 = Alternates among Train, Car, and Bicycle **or**
  Q176 = Alternates among BTM, Car, and Bicycle **or**
  Q176 = Alternates among Train, BTM, Car, and Bicycle

- **On average, how many times a week would you travel by bicycle during rush hours?**
- **The morning peak from 06:30 till 09:00**
  - 5 times a week
  - 4 times a week
  - 3 times a week
  - 2 times a week
  - 1 time a week
  - Never
- **The evening peak from 16:00 till 18:30**
  - 5 times a week
  - 4 times a week
  - 3 times a week
  - 2 times a week
  - 1 time a week
  - Never
- **Changes in Other Activities**

  Due to the implementation of this policy, the time you spend on other activities may change.
- **How many hours per week will your time spent on the following activities change?**
  - Weekly hours spent on:
    * Side job
    * Sports
    * Social activities

  Scale: -20, -16, -12, -8, -4, 0, 4, 8, 12, 16, 20
- **Acceptability of the New Policy**

  How acceptable is the new policy to you?
  - Very unacceptable
  - Unacceptable
  - Neutral
  - Acceptable
  - Very acceptable

4. Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift

Free weekend and weekday travel after 09:00. Lecture schedule shifts to 10:30 start and are extended by the same duration they are delayed.

- **Considering this policy, on average, how many times a week would you travel to your educational institution?**
  - 5 times a week
  - 4 times a week
  - 3 times a week
  - 2 times a week
  - 1 time a week
  - Never
- **Which mode of transportation will you use for the majority of the distance travelled (one per trip)?**
  - Train
  - Bus, Tram, Metro (BTM)
  - Car
  - Bicycle
  - Alternates among Train, BTM, Car, and Bicycle
- **Display This Question:**

  If Q193 = Train **or**
  Q193 = Alternates between Train and BTM **or**
  Q193 = Alternates between Train and Car **or**
  Q193 = Alternates between Train and Bicycle **or**
  Q193 = Alternates among Train, BTM, and Car **or**
  Q193 = Alternates among Train, BTM, and Bicycle **or**
  Q193 = Alternates among Train, Car, and Bicycle **or**
  Q193 = Alternates among Train, BTM, Car, and Bicycle
- **On average, how many times a week would you travel by train during rush hours considering this policy?**
- **The morning peak from 06:30 till 09:00**
  - 5 times a week
  - 4 times a week
  - 3 times a week
  - 2 times a week
  - 1 time a week
  - Never
- **The evening peak from 16:00 till 18:30**
  - 5 times a week
  - 4 times a week
  - 3 times a week
  - 2 times a week
  - 1 time a week
  - Never

- **Display This Question:**

  If Q193 = Bus, Tram, Metro (BTM) **or**
  Q193 = Alternates between Train and BTM **or**
  Q193 = Alternates between BTM and Car **or**
  Q193 = Alternates between BTM and Bicycle **or**
  Q193 = Alternates among Train, BTM, and Car **or**
  Q193 = Alternates among Train, BTM, and Bicycle **or**
  Q193 = Alternates among BTM, Car, and Bicycle **or**
  Q193 = Alternates among Train, BTM, Car, and Bicycle
- **On average, how many times a week would you travel by bus, tram, or metro (BTM) during rush hours?**
- **The morning peak from 06:30 till 09:00**
  - 5 times a week
  - 4 times a week
  - 3 times a week
  - 2 times a week
  - 1 time a week
  - Never
- **The evening peak from 16:00 till 18:30**
  - 5 times a week
  - 4 times a week
  - 3 times a week
  - 2 times a week
  - 1 time a week
  - Never
- **Display This Question:**

  If Q193 = Car **or**
  Q193 = Alternates between Train and Car **or**
  Q193 = Alternates between BTM and Car **or**
  Q193 = Alternates between Car and Bicycle **or**
  Q193 = Alternates among Train, BTM, and Car **or**
  Q193 = Alternates among Train, Car, and Bicycle **or**
  Q193 = Alternates among BTM, Car, and Bicycle **or**
  Q193 = Alternates among Train, BTM, Car, and Bicycle
- **On average, how many times a week would you travel by car during rush hours?**
- **The morning peak from 06:30 till 09:00**
  - 5 times a week
  - 4 times a week
  - 3 times a week
  - 2 times a week
  - 1 time a week
  - Never
- **The evening peak from 16:00 till 18:30**
  - 5 times a week
  - 4 times a week

- 3 times a week
- 2 times a week
- 1 time a week
- Never

- **Display This Question:**

  If Q193 = Bicycle **or**
  Q193 = Alternates between Train and Bicycle **or**
  Q193 = Alternates between BTM and Bicycle **or**
  Q193 = Alternates between Car and Bicycle **or**
  Q193 = Alternates among Train, BTM, and Bicycle **or**
  Q193 = Alternates among Train, Car, and Bicycle **or**
  Q193 = Alternates among BTM, Car, and Bicycle **or**
  Q193 = Alternates among Train, BTM, Car, and Bicycle

- **On average, how many times a week would you travel by bicycle during rush hours?**
- **The morning peak from 06:30 till 09:00**
  - 5 times a week
  - 4 times a week
  - 3 times a week
  - 2 times a week
  - 1 time a week
  - Never
- **The evening peak from 16:00 till 18:30**
  - 5 times a week
  - 4 times a week
  - 3 times a week
  - 2 times a week
  - 1 time a week
  - Never
- **Changes in Other Activities** Due to the implementation of this policy, the time you spend on other activities may change.
- **How many hours per week will your time spent on the following activities change?**
  - Weekly hours spent on:
    - Side job
    - Sports
    - Social activities

  Scale: -20, -16, -12, -8, -4, 0, 4, 8, 12, 16, 20
- **Acceptability of the New Policy** How acceptable is the new policy to you?
  - Very unacceptable
  - Unacceptable
  - Neutral
  - Acceptable
  - Very acceptable

C

HREC - Letter of Approval

See next page.

Date 28-Jun-2024
Correspondence hrec@tudelft.nl

Human Research Ethics
Committee TU Delft
(http://hrec.tudelft.nl)

Visiting address
Jaffalaan 5 (building 31)
2628 BX Delft

Postal address
P.O. Box 5015 2600 GA Delft
The Netherlands

Ethics Approval Application: CBA: reducing student peak travel on Dutch trains
Applicant: Bos, Tibbe

Dear Tibbe Bos,

It is a pleasure to inform you that your application mentioned above has been approved.

Thanks very much for your submission to the HREC which has been approved.

In addition to any specific conditions or notes, the HREC provides the following standard advice to all applicants:
• In light of recent tax changes, we advise that you confirm any proposed remuneration of research subjects with your faculty contract manager before going ahead.
• Please make sure when you carry out your research that you confirm contemporary covid protocols with your faculty HSE advisor, and that ongoing covid risks and precautions are flagged in the informed consent - with particular attention to this where there are physically vulnerable (eg: elderly or with underlying conditions) participants involved.
• Our default advice is not to publish transcripts or transcript summaries, but to retain these privately for specific purposes/checking; and if they are to be made public then only if fully anonymised and the transcript/summary itself approved by participants for specific purpose.
• Where there are collaborating (including funding) partners, appropriate formal agreements including clarity on responsibilities, including data ownership, responsibilities and access, should be in place and that relevant aspects of such agreements (such as access to raw or other data) are clear in the Informed Consent.

Good luck with your research!

Sincerely,

Dr. Ir. U. Pesch
Chair HREC
Faculty of Technology, Policy and Management

D Student Travel Behavioural Change

D.0.1. Paid Peak Hour Travel

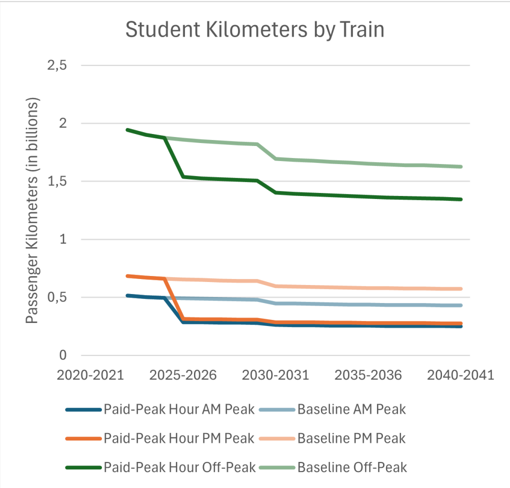

Figure D.1: Student Travel Behaviour by Train in Paid Peak Hour Travel alternative

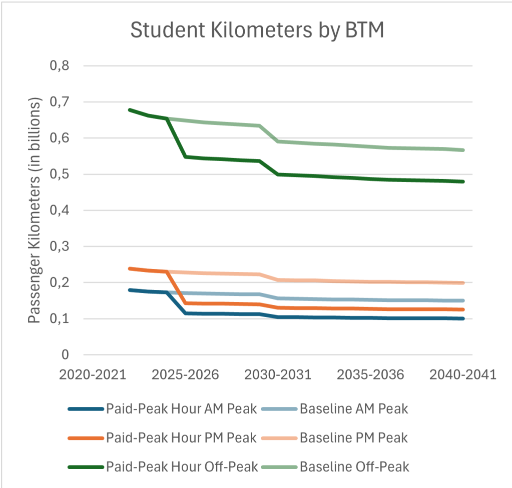

Figure D.2: Student Travel Behaviour by BTM in Paid Peak Hour Travel alternative

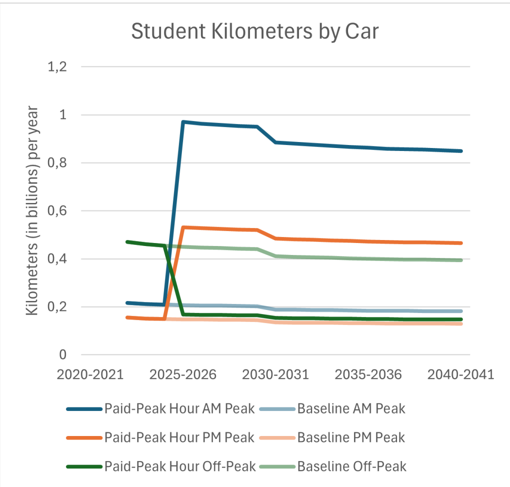

Figure D.3: Student Travel Behaviour by Car in Paid Peak Hour Travel alternative

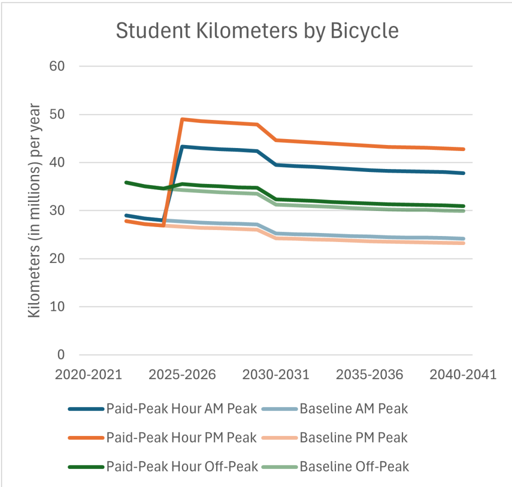

Figure D.4: Student Travel Behaviour by Bicycle in Paid Peak Hour Travel alternative

D.0.2. Shift Lecture Hours

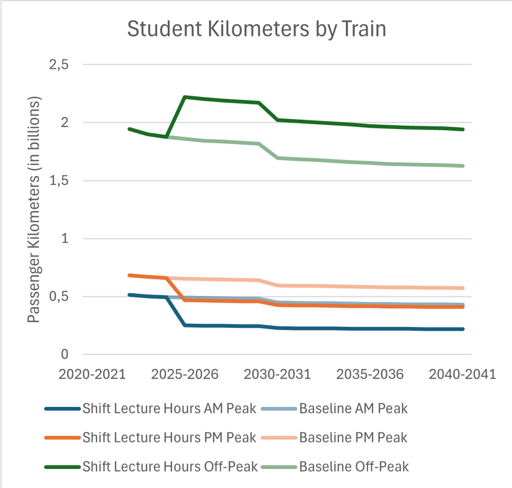

Figure D.5: Student Travel Behaviour by Train in Shift Lecture Hours alternative

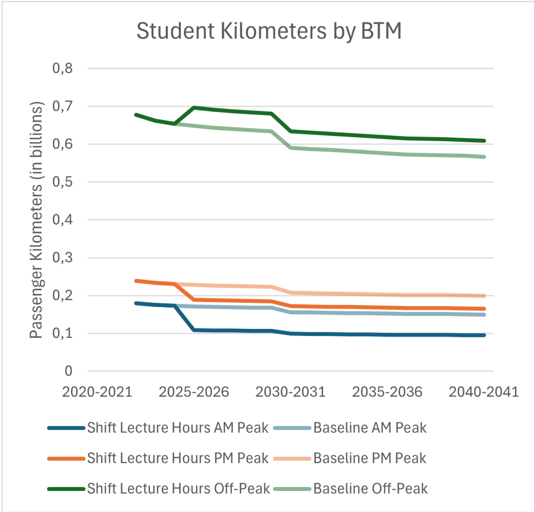

Figure D.6: Student Travel Behaviour by BTM in Shift Lecture Hours alternative

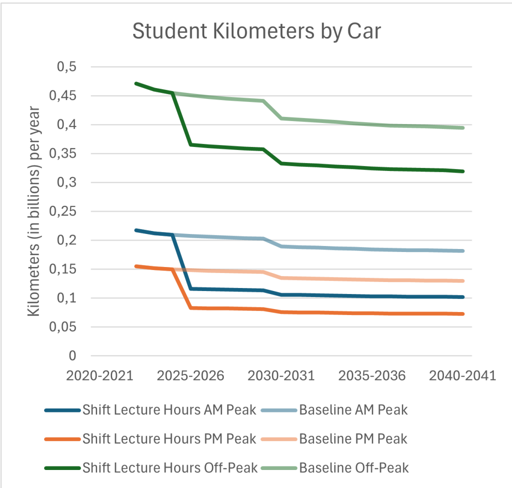

Figure D.7: Student Travel Behaviour by Car in Shift Lecture Hours alternative

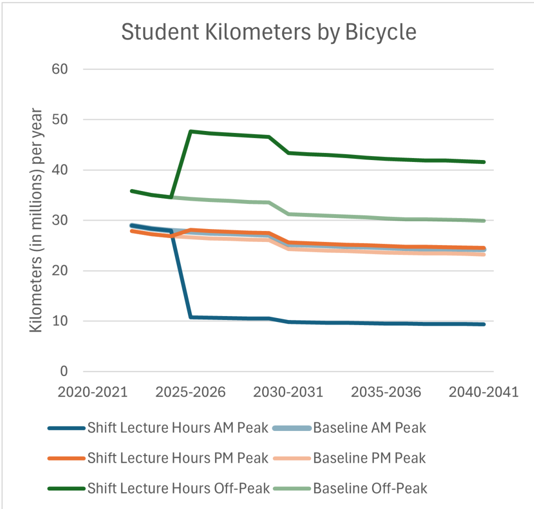

Figure D.8: Student Travel Behaviour by Bicycle in Shift Lecture Hours alternative

D.0.3. 40% Peak Discount + Shift Lecture Hours

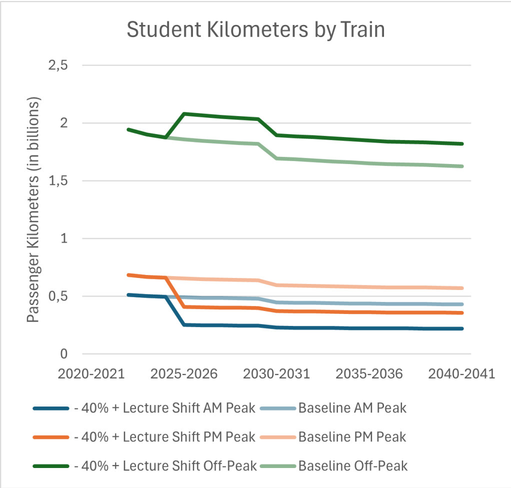

Figure D.9: Student Travel Behaviour by Train in 40% Peak Discount + Shift Lecture Hours alternative

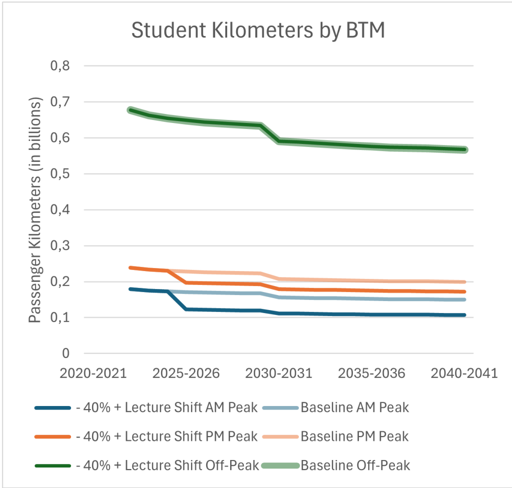

Figure D.10: Student Travel Behaviour by BTM in 40% Peak Discount + Shift Lecture Hours alternative

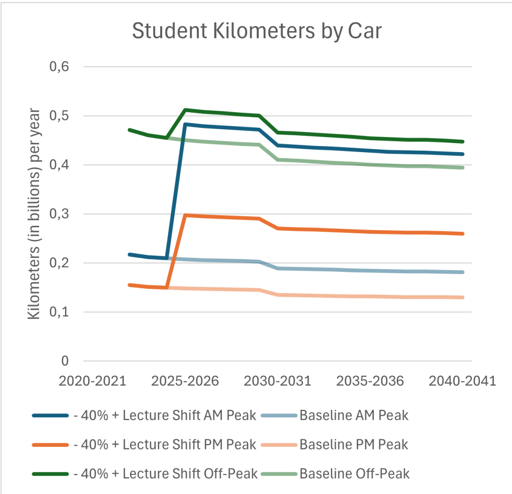

Figure D.11: Student Travel Behaviour by Car in 40% Peak Discount + Shift Lecture Hours alternative

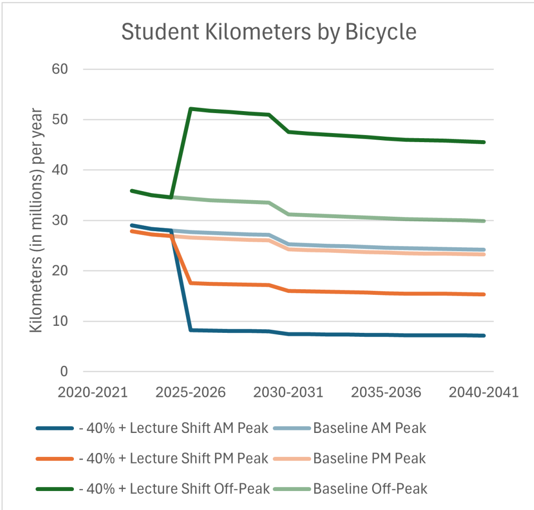

Figure D.12: Student Travel Behaviour by Bicycle in 40% Peak Discount + Shift Lecture Hours alternative

D.0.4. Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift

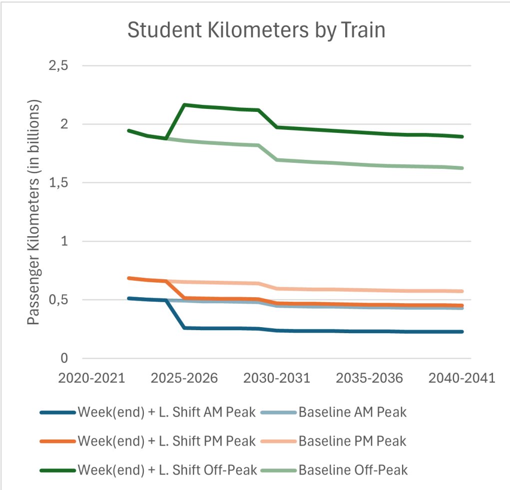

Figure D.13: Student Travel Behaviour by Train in Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift alternative

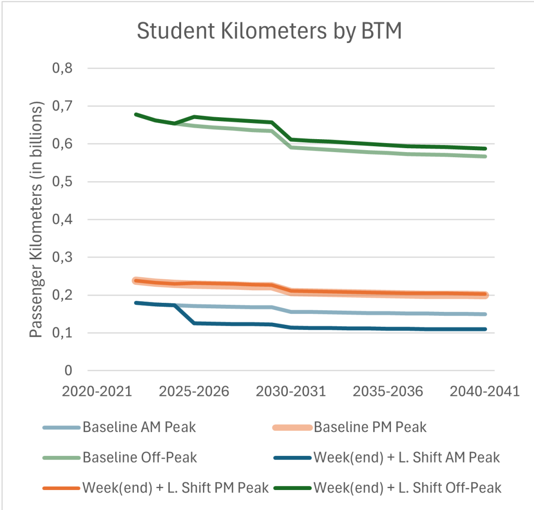

Figure D.14: Student Travel Behaviour by BTM in Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift alternative

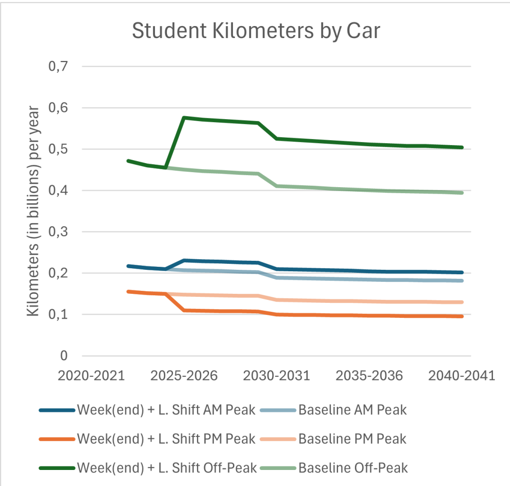

Figure D.15: Student Travel Behaviour by Car in Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift alternative

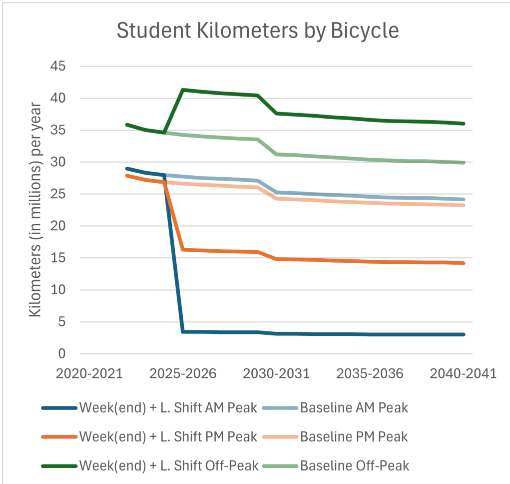

Figure D.16: Student Travel Behaviour by Bicycle in Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift alternative

E

Variables and Index Numbers

E.1. Costs

E.1.1. Costs of Student Travel Product Implementation

Table E.1: Variables and Index Number for Student Travel Product Implementation

Variable	Quantity	Unit	Source
Costs for transitioning from OV-chip card to OV-pay	2,500,000	€	Dijkgraaf (2023a)

E.1.2. Costs of Scheduler Labour

Table E.2: Variables and Index Number for Scheduler Labour

Variable	Quantity	Unit	Source
Average annual FTE salary	27,585	€	talent.com (2024)
Average size of educational institution	25,000	number of students	*assumption*
Required FTE for schedule shift	0.5	FTE	*assumption*

E.1.3. Costs of Employee Overtime Hours

Table E.3: Variables and Index Number for Employee Overtime Hours

Variable	Quantity	Unit	Source
Average weekly overtime hours	2.0	hr	*assumption*
Average number of education weeks per year	30.0	number of weeks	Adriaenssen et al. (2021)
Number of FTEs in MBO teaching	27,200	FTE	MBO raad (2023)
Number of FTEs in HBO teaching	26,600	FTE	Vereniging Hogescholen (2023)
Number of FTEs in WO teaching	17,535	FTE	Puylaert (2023)
Additional salary for overtime hours	50	%	Universiteiten van Nederland (UNL) (2023)
Minimum salary for lectures in MBO	19.79	€	Onderwijsloket (2024)
Minimum salary for lectures in HBO	20.54	€	Hoger Onderwijs Persbureau (2019)
Minimum salary for lectures in WO	20.98	€	Hoger Onderwijs Persbureau (2019)

E.2. Direct Effects

E.2.1. Educational Accessibility

Table E.4: Variables and Index Number for Educational Accessibility

Variable	Quantity	Unit	Source
Average kilometer fare for train	0.14	€	Autoriteit Consument & Markt (ACM) (2021)
Average kilometer fare for bus and metro	0.23	€	2021
Average kilometer fare for tram	0.35	€	2021
Price increase public transport between 2009 and 2019	30.0	%	Centraal Bureau voor de Statistiek (2019b)
Share of travelled kilometers by bus	3.63	%	Autoriteit Consument & Markt (ACM) (2021)
Share of travelled kilometers by tram	0.81	%	Autoriteit Consument & Markt (ACM) (2021)
Share of travelled kilometers by metro	1.2	%	Autoriteit Consument & Markt (ACM) (2021)

E.2.2. Comfort Benefits

Table E.5: Variables and Index Number for Comfort Benefits

Variable	Quantity	Unit	Source
Average speed of a train including stops	69.3	km/h	Planbureau voor de Leefomgeving (PBL) (2018)
Value of Travel Time low	11.79	€/hr	Kouwenhoven et al. (2023)
Value of Travel Time high	12.31	€/hr	Kouwenhoven et al. (2023)
Seating chance HRN peak hours	94.7	%	Nederlandse Spoorwegen (2024c)
Multiplier VoTT for seated passenger crowded train	1.18	-	Kouwenhoven et al. (2023)
Multiplier VoTT for standing passenger crowded train	1.93	-	2023
Share of passengers standing in a crowded train	25.0	%	*assumption*

E.2.3. Governmental Savings on Student Mobility

Table E.6: Variables and Index Number for Governmental Savings on Student Mobility

Variable	Quantity	Unit	Source
Reimbursement from Ministry of OCW to transport providers in '23-'24	1,000,000,000	€	Hoger Onderwijs Persbureau (2023)
Travelled kilometers with Student Travel Product	4,240,000,000	km	Jonkers et al. (2023)

E.2.4. Benefits of Overtime Hours for Employees

Table E.7: Variables and Index Number for Benefits of Overtime Hours for Employees

Variable	Quantity	Unit	Source
Share of employees that are negative about shifting lecture hours	66.7	%	NOS Nieuws (2017)

E.2.5. Operational Savings for Railway Companies

Table E.8: Variables and Index Number for Operational Savings for Railway Companies

Variable	Quantity	Unit	Source
Average peak occupancy rate of trains	40.0	%	Nederlandse Spoorwegen (2024c)
Average seats in a train	500.0	number of seats	Nederlandse Spoorwegen (2016)
Ratio decrease in passengers vs. decrease in capacity	0.2	%	*assumption*
Average distance travelled per train per day	680	km	Hilhorst (2012)
Average lifetime of a train	40	years	Nederlandse Spoorwegen (2022)
Acquisition costs of a sprinter train	5,000,000	€	nu.nl (2023)
Acquisition costs of an intercity train	10,101,010.0	€	Verlaan (2017)
Average maintenance costs of a train	0.40 - 1.00	€/km	Poppeliers et al. (2022)
Average personnel costs of a train	100.08 - 108.88	€/DRU	Poppeliers et al. (2022)

E.3. Indirect Effects

E.3.1. Impact of Digital Education

Table E.9: Variables and Index Number for Impact of Digital Education

Variable	Quantity	Unit	Source
Share of unearned study credits HBO during COVID	22.5	%	Warps and Van den Broek (2020)
Share of unearned study credits WO during COVID	19.2	%	Warps and Van den Broek (2020)
Share of unearned study credits not related to practicals/laboratory work	33.3	%	Warps and Van den Broek (2020)
Share of students with functional limitations	33.3	%	Warps and Van den Broek (2020)
Improvement in digital education since COVID	50.0	%	*assumption*
Percentage extra future salary per year of education	8.0	%	Ter Weel et al. (2020); Van Heest (2020)
Average study duration	5.0	years	*assumption*
Modal income 2024	40,0000	€/years	Klees (2024)
Average yearly salary increase	1.95	%	Klees (2024)

E.4. External Effects

E.4.1. Costs of Traffic Safety Risks

Table E.10: Variables and Index Number for Traffic Safety Risks

Variable	Quantity	Unit	Source
Average external train accident costs	1.42	€ per 1,000 passenger kilometers	Schroten et al. (2022)
Average external car accident costs	69.0	€ per 1,000 passenger kilometers	Schroten et al. (2022)
Average external bus accident costs	50.0	€ per 1,000 passenger kilometers	Schroten et al. (2022)
Average external bicycle accident costs	176.0	€ per 1,000 passenger kilometers	Schroten et al. (2022)

E.4.2. Costs of Greenhouse Gas Emissions

Table E.11: Variables and Index Number for Greenhouse Gas Emissions

Variable	Quantity	Unit	Source
Average CO_2-equivalent emissions train	0.0219	Kg CO_2-equivalent per kilometer	Leestemaker et al. (2023)
Average CO_2-equivalent emissions car	0.1506	Kg CO_2-equivalent per kilometer	Leestemaker et al. (2023)
Average CO_2-equivalent emissions bus	0.1151	Kg CO_2-equivalent per kilometer	Leestemaker et al. (2023)
Average CO_2-equivalent emissions metro	0.0418	Kg CO_2-equivalent per kilometer	Leestemaker et al. (2023)
Average CO_2-equivalent emissions tram	0.0640	Kg CO_2-equivalent per kilometer	Leestemaker et al. (2023)
Low efficient CO_2 price for 2030	26.0	€ per ton CO_2-equivalent	De Bruyn et al. (2023)
High efficient CO_2 price for 2030	104.0	€ per ton CO_2-equivalent	De Bruyn et al. (2023)

E.4.3. Costs of Air Pollution

Table E.12: Variables and Index Number for Air Pollution

Variable	Quantity	Unit	Source
Average NO_x emissions train	0.069	g. NO_x per kilometer	Leestemaker et al. (2023)
Average NO_x emissions car	0.229	g. NO_x per kilometer	Leestemaker et al. (2023)
Average NO_x emissions bus	0.251	g. NO_x per kilometer	Leestemaker et al. (2023)
Average NO_x emissions metro	0.025	g. NO_x per kilometer	Leestemaker et al. (2023)
Average NO_x emissions tram	0.038	g. NO_x per kilometer	Leestemaker et al. (2023)
Average $PM_{2.5}$ emissions train	0.002	g. $PM_{2.5}$ per kilometer	Leestemaker et al. (2023)
Average $PM_{2.5}$ emissions car	0.002	g. $PM_{2.5}$ per kilometer	Leestemaker et al. (2023)
Average $PM_{2.5}$ emissions bus	0.004	g. $PM_{2.5}$ per kilometer	Leestemaker et al. (2023)
Average $PM_{2.5}$ emissions metro	0.000	g. $PM_{2.5}$ per kilometer	Leestemaker et al. (2023)
Average $PM_{2.5}$ emissions tram	0.000	g. $PM_{2.5}$ per kilometer	Leestemaker et al. (2023)
Average PM_{10} emissions train	0.015	g. PM_{10} per kilometer	Leestemaker et al. (2023)
Average PM_{10} emissions car	0.027	g. PM_{10} per kilometer	Leestemaker et al. (2023)
Average PM_{10} emissions bus	0.020	g. PM_{10} per kilometer	Leestemaker et al. (2023)
Average PM_{10} emissions metro	0.024	g. PM_{10} per kilometer	Leestemaker et al. (2023)
Average PM_{10} emissions tram	0.006	g. PM_{10} per kilometer	Leestemaker et al. (2023)
Low NO_x price	18.3	€ per kg NO_x	De Bruyn et al. (2023)
High NO_x price	44.1	€ per kg NO_x	De Bruyn et al. (2023)
Low $PM_{2.5}$ price	73.3	€ per kg $PM_{2.5}$	De Bruyn et al. (2023)
High $PM_{2.5}$ price	169.0	€ per kg $PM_{2.5}$	De Bruyn et al. (2023)
High PM_{10} price	41.4	€ per kg PM_{10}	De Bruyn et al. (2023)
High PM_{10} price	97.9	€ per kg PM_{10}	De Bruyn et al. (2023)

F

Full CBA Tables of Scenario Analysis

Table F.1: Full CBA Technological Rail Innovations with Financial Study Support (Present Value)

Effects in million €	**Paid Peak Hour Travel**	**Shift Lecture Hours**	**40% Peak Discount + Shift Lecture Hours**	**Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift**
Costs				
Costs of Student Travel Product Implementation	-2.5	0.0	-2.5	-2.5
Costs of Employee Overtime Hours	0.0	-655.7	-655.7	-655.7
Costs of Scheduler Labour	0.0	-0.8	-0.8	-0.8
Total Costs	**-2.5**	**-656.5**	**-659.0**	**-659.0**
Direct Effects				
Educational Accessibility	-4243.3	0.0	-2072.0	-1282.3
Comfort Benefits	943.0 to 987.0	760.4 to 795.4	849.7 to 889.1	669.1 to 699.7
Travel Time Reliability	0.0	0.0	0.0	0.0
Governmental Savings on Student Mobility	2868.3	223.8	876.1	208.4
Benefits of Overtime Education for Employees	0.0	109.3	109.3	109.3
Operational Savings for Railway Companies	11.1 to 19.7	1.1 to 3.0	2.1 to 5.7	1.2 to 3.1
Total Direct Effects	**-420.0 to -368.2**	**1094.6 to 1131.4**	**-234.8 to -191.8**	**-294.3 to -261.8**
Indirect Effects				
Side Job Income	++	+	+	+
Sports	++	+	+	++
Social Activities	+	+	0	+
Impact of Digital Education	-609.0	-188.8	-207.1	-103.5
Mental Health & Wellbeing	-	+	0	0
Total Indirect Effects	**-609.0**	**-188.8**	**-207.1**	**-103.5**
External Effects				
Costs of Traffic Safety Risks	-763.4 to -758.4	409.5 to 412.1	-437.5 to -434.5	-110.7 to -108.4
Costs of Greenhouse Gas Emissions	-48.5 to -193.2	7.1 to 28.9	-29.6 to -117.5	-10.6 to -41.9
Costs of Air Pollution	-9.8 to -22.9	0.4 to 1.1	-8.2 to -19.2	-4.4 to -10.2
Total External Effects	**-821.7 to -974.5**	**417.0 to 442.0**	**-475.3 to -571.2**	**-125.6 to -160.5**
Total Effects	**-1851.6 to -1951.7**	**1322.8 to 1384.8**	**-917.1 to -970.1**	**-523.4 to -525.8**
Net Present Value	**-1854.1 to -1954.1**	**666.3 to 728.3**	**-1576.1 to -1629.1**	**-1182.4 to -1184.8**
Benefit-Cost Ratio	0.67 to 0.66	1.79 to 1.86	0.46 to 0.45	0.42

Table F.2: Full CBA Infrastructural Rail Constraints with Financial Study Support (Present Value)

Effects in million €	**Paid Peak Hour Travel**	**Shift Lecture Hours**	**40% Peak Discount + Shift Lecture Hours**	**Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift**
Costs				
Costs of Student Travel				
Product Implementation	-2.5	0.0	-2.5	-2.5
Costs of Employee Overtime Hours	0.0	-655.7	-655.7	-655.7
Costs of Scheduler Labour	0.0	-0.8	-0.8	-0.8
Total Costs	**-2.5**	**-656.5**	**-659.0**	**-659.0**
Direct Effects				
Educational Accessibility	-4243.3	0.0	-2072.0	-1282.3
Comfort Benefits	1369.3 to 1432.2	1103.3 to 1154.1	1233.0 to 1290.1	970.9 to 1015.3
Travel Time Reliability	0.0	0.0	0.0	0.0
Governmental Savings on Student Mobility	2868.3	223.8	876.1	208.4
Benefits of Overtime Education for Employees	0.0	109.3	109.3	109.3
Operational Savings for Railway Companies	121.6 to 240.8	108.4 to 221.8	111.9 to 226.8	108.8 to 222.3
Total Direct Effects	**115.0 to 298.1**	**1544.9 to 1709.0**	**258.3 to 430.4**	**115.1 to 272.9**
Indirect Effects				
Side Job Income	++	+	+	+
Sports	++	+	+	++
Social Activities	+	+	0	+
Impact of Digital Education	-609.0	-188.8	-207.1	-103.5
Mental Health & Wellbeing	-	+	0	0
Total Indirect Effects	**-609.0**	**-188.8**	**-207.1**	**-103.5**
External Effects				
Costs of Traffic Safety Risks	-763.4 to -758.4	409.5 to 412.1	-437.5 to -434.5	-110.7 to -108.4
Costs of Greenhouse Gas Emissions	-44.8 to -178.2	5.8 to 23.8	-29.4 to -116.8	-11.6 to -46.1
Costs of Air Pollution	-10.1 to -23.6	0.6 to 1.4	-8.2 to -19.2	-4.3 to -10.0
Total External Effects	**-818.2 to -960.2**	**415.8 to 437.4**	**-475.1 to -570.5**	**-126.6 to -164.5**
Total Effects	**-1312.2 to -1271.2**	**1771.9 to 1957.6**	**-423.9 to -347.2**	**-115.0 to 4.9**
Net Present Value	**-1314.7 to -1273.7**	**1115.4 to 1301.1**	**-1082.9 to -1006.2**	**-774.0 to -654.1**
Benefit-Cost Ratio	0.77 to 0.78	2.32 to 2.54	0.63 to 0.66	0.62 to 0.68

Table F.3: Full CBA Infrastructural Rail Constraints without Financial Study Support (Present Value)

Effects in million €	**Paid Peak Hour Travel**	**Shift Lecture Hours**	**40% Peak Discount + Shift Lecture Hours**	**Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift**
Costs				
Costs of Student Travel				
Product Implementation	-2.5	0.0	-2.5	-2.5
Costs of Employee Overtime Hours	0.0	-536.5	-536.5	-536.5
Costs of Scheduler Labour	0.0	-0.6	-0.6	-0.6
Total Costs	**-2.5**	**-537.1**	**-539.6**	**-539.6**
Direct Effects				
Educational Accessibility	-3471.8	0.0	-1695.3	-1049.2
Comfort Benefits	1084.7 to 1136.1	855.7 to 895.7	967.5 to 1013.0	741.7 to 776.1
Travel Time Reliability	0.0	0.0	0.0	0.0
Governmental Savings on Student Mobility	2346.8	183.1	716.8	170.5
Benefits of Overtime Education for Employees	0.0	89.4	89.4	89.4
Operational Savings for Railway Companies	10.7 to 15.1	3.9 to 5.6	5.9 to 8.3	4.2 to 5.9
Total Direct Effects	**-29.6 to 26.3**	**1132.2 to 1173.8**	**84.4 to 132.3**	**-43.4 to -7.2**
Indirect Effects				
Side Job Income	++	+	+	+
Sports	++	+	+	++
Social Activities	+	+	0	+
Impact of Digital Education	-498.3	-154.5	-169.4	-84.7
Mental Health & Wellbeing	-	+	0	0
Total Indirect Effects	**-498.3**	**-154.5**	**-169.4**	**-84.7**
External Effects				
Costs of Traffic Safety Risks	-624.6 to -620.5	335.0 to 337.2	-358.0 to -355.5	-90.6 to -88.7
Costs of Greenhouse Gas Emissions	-36.7 to -145.8	4.8 to 19.5	-24.0 to -95.5	-9.5 to -37.7
Costs of Air Pollution	-9.0 to 21.2	0.5 to 1.2	-6.7 to -15.7	-3.5 to -8.2
Total External Effects	**-670.3 to -787.5**	**340.2 to 357.9**	**-388.7 to -466.8**	**-103.6 to -134.6**
Total Effects	**-1198.1 to -1259.5**	**1317.9 to 1377.2**	**-388.7 to -466.8**	**-103.6 to -134.6**
Net Present Value	**-1200.6 to -1262.0**	**780.8 to 840.1**	**-1013.4 to -1043.5**	**-771.3 to -766.2**
Benefit-Cost Ratio	0.74 to 0.73	2.13 to 2.21	0.58 to 0.57	0.54

Table F.4: Full CBA Technological Rail Innovations without Financial Study Support (Present Value)

Effects in million €	**Paid Peak Hour Travel**	**Shift Lecture Hours**	**40% Peak Discount + Shift Lecture Hours**	**Weekend + Weekday Free After 09:00 Pass + Lecture Time Shift**
Costs				
Costs of Student Travel				
Product Implementation	-2.5	0.0	-2.5	-2.5
Costs of Employee Overtime Hours	0.0	-536.5	-536.5	-536.5
Costs of Scheduler Labour	0.0	-0.6	-0.6	-0.6
Total Costs	**-2.5**	**-537.1**	**-539.6**	**-539.6**
Direct Effects				
Educational Accessibility	-3471.8	0.0	-1695.3	-1049.2
Comfort Benefits	747.5 to 783.0	589.7 to 617.3	666.8 to 698.1	511.1 to 534.8
Travel Time Reliability	0.0	0.0	0.0	0.0
Governmental Savings on Student Mobility	2346.8	183.1	716.8	170.5
Benefits of Overtime Education for Employees	0.0	89.4	89.4	89.4
Operational Savings for Railway Companies	0	0	0	0
Total Direct Effects	**-377.4 to -432.0**	**862.2 to 889.8**	**-222.3 to -190.9**	**-278.1 to -254.4**
Indirect Effects				
Side Job Income	++	+	+	+
Sports	++	+	+	++
Social Activities	+	+	0	+
Impact of Digital Education	-498.3	-154.5	-169.4	-84.7
Mental Health & Wellbeing	-	+	0	0
Total Indirect Effects	**-498.3**	**-154.5**	**-169.4**	**-84.7**
External Effects				
Costs of Traffic Safety Risks	-624.6 to -620.5	335.0 to 337.2	-358.0 to -355.5	-90.6 to -88.7
Costs of Greenhouse Gas Emissions	-39.7 to -158.0	5.8 to 23.7	-24.2 to -96.2	-8.7 to -34.3
Costs of Air Pollution	-8.0 to -18.8	0.4 to 0.9	-6.7 to -15.7	-3.6 to -8.4
Total External Effects	**-672.3 to -797.3**	**341.2 to 361.8**	**-388.9 to -467.4**	**-102.8 to -131.3**
Total Effects	**-1548.0 to -1637.6**	**1048.9 to 1097.1**	**-780.5 to -827.7**	**-465.6 to -470.4**
Net Present Value	**-1550.5 to -1640.1**	**511.8 to 560.0**	**-1320.2 to -1367.3**	**-1005.2 to -1010.1**
Benefit-Cost Ratio	0.67 to 0.66	1.74 to 1.81	0.45 to 0.43	0.40