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Does introducing an e-moped scooter sharing system result in lower carbon travel mode choices?

A muncipality of Groningen case study

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Colophon

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Abstract

Shared micromobility is growing rapidly in the world to include sustainable mobility systems into urban infrastructure. There is no country in the world where the market for shared electric moped scooters has grown faster than in the Netherlands. However, where the scientific literature concerning shared electric kick scooters is increasing, the literature concerning shared electric moped scooters (shared e-mopeds) is still scarce. Therefore, an explorative case study has been conducted in the municipality of Groningen to investigate the effects of introducing shared e-mopeds into an urban area. The research questions have been answered by using a quantitative research method for which both primary and secondary data has been collected.

This study has found out that introducing shared e-mopeds results in an unsustainable modal shift. Shared e-mopeds are used by a relatively young population. Users of shared e-mopeds relatively often replace walking, cycling or the (electric) bus for shared e-mopeds and less often a moped or car. On average, shared e-mopeds are used for relatively short trips and users of shared e-mopeds replace only a fraction of their weekly trips with a shared e-moped. The emission of a shared e-moped system is comparable to that of electric buses. If the energy used to charge and distribute the batteries of shared e-mopeds becomes more sustainable, the emission will decrease and the mode becomes more sustainable.

1. Introduction

1.1 Background

Over the past years, there have been significant shifts in the planning, design, and funding of urban infrastructure projects to include sustainable mobility systems (Sheller, 2011). Multiple niche-level changes have taken place. Niche-level cultural experimentation, innovation, and improvisation are at the heart of thinking about new transitions in mobility systems. One of the newest shifts in sustainable mobility is that of shared micromobility. This shift is facilitated by developments in electrification, automation, and real-time transactions (Fitt & Curl, 2020). However, the existing system of automobility continues to be the dominant mode of transportation, despite for example the rise in the price of fuel and the global discussion on global warming (Eurostat, 2021).

There is no country in the world where the market for shared electric scooters has grown relatively faster than in the Netherlands. In 2020 the number of shared e-scooters increased by 794 percent (NU.nl, 2020). In 2017 the first e-moped scooter sharing platform was introduced in Amsterdam by a company called Felyx. Nowadays, the service has already spread across 30 different cities and is provided by multiple competing companies (Laconi, 2021). These companies are all advertising that their users travel through the city in a sustainable way (e.g. Felyx, 2021; GO-sharing, 2021; Check., 2021). However, a recently conducted study shows that e-moped sharing has a similar environmental impact on global warming potential as public transport (Schelte et al., 2021). Therefore, it depends on which mode of transport is replaced for a shared e-scooter whether the shift in mode choice is sustainable.

1.2 Research problem

The emergence of this mode of transport has been a subject of debate in many urban areas. Yet relatively little is known about e-scooter sharing practices compared to other modes of transport or forms of mobility (Fitt & Curl, 2020). The literature around shared e-scooters is growing rapidly. However, this literature often focuses on electric kick scooter sharing systems (e.g. Dias et al., 2021; Fit & Curl, 2020; Hollingsworth et al., 2019) rather than on electric moped scooter (mopeds instead of kick scooters) sharing systems. The latter being dominantly present over electric kick scooters in the urban environment of the Netherlands (Laconi, 2021).

Therefore, the aim of this research is to perform an explorative quantitative case study to investigate whether the introduction of an e-moped scooter sharing system results in a modal shift. The subsequent secondary aim is to investigate whether implementing such a micromobility sharing system contributes effectively to the sustainable ambitions with which the companies providing these scooters are advertising. Do the former modes of travel of e-moped scooter sharing system users emit more than the new mode? Then this would make it a sustainable modal shift when it comes to emissions. Or do the former modes of travel emit less? This would make it an unsustainable modal shift.

The central question of this research is:

- *"How does introducing an electric moped scooter sharing system change the mode choice in the municipality of Groningen?"*

In this research, the following secondary questions will be used to perform the case study:

- SubQ1: Which modes of transport are being replaced by shared electric moped scooters in the municipality of Groningen, and does introducing shared electric moped scooters create new trips?
- SubQ2: What is the average distance of trips made by shared e-mopeds in the municipality of Groningen?
- SubQ3: What percentage of trips is replaced by shared electric moped scooters in the municipality of Groningen?
- SubQ4: What are the emissions of using an electric moped scooter sharing system and its alternatives in the municipality of Groningen?

1.3 Structure of this thesis

This thesis consists of six chapters. In chapter two the core concepts and definitions will be defined. Chapter three explains the methodology used to perform the case study in the municipality of Groningen. In the fourth chapter the results of the case study are presented. Chapter five elaborates on the conclusions of this research. And in the sixth chapter the strengths and weaknesses of this study are discussed together with recommendations for further research and policy recommendations.

2. Theoretical framework

2.1 Shared micromobility

Shared mobility can be defined as the shared use of a car, bicycle, or other modes of transport (Jiao, 2021). Next to this, shared mobility includes modes like carsharing and personal vehicle sharing, and it is an innovative transportation strategy (Shaheen & Chan, 2016). This sector of the sharing economy is growing at a fast pace. Transportation availability has a significant impact on access to for example jobs, housing, healthcare, and education. Shared mobility can provide greater access to transportation and is therefore beneficial for communities (Jiao, 2021). It allows users to access transportation for a short-term on an as-needed basis without requiring ownership (Shaheen & Chan, 2016). Therefore, besides an increase in accessibility of transport, shared mobility is also capable to decrease ownership of vehicles. This could be beneficial for the climate and usage of space in urban areas.

Micromobility can be defined as the use of low-speed, small, lightweight vehicles with a mass of less than 350 kg and a speed up to 45 km/h (Schelte et al., 2021). Examples of micromobility are (e-)scooters and (e-)bikes.

Thus, shared micromobility can be defined as the shared use of a low-speed, small, lightweight vehicle with a mass of less than 350 kg and a speed up to 45 km/h.

2.2 Mode choice & modal shift

The mode of travel choice, also referred to as mode choice, can be defined as the process in which the means of travelling is determined (Travel Forecasting Resource, 2021). The means of travel is also referred to as the travel mode. Studies have found out that the mode choice is influenced by multiple factors. These factors are: traveller characteristics, modal availability and characteristics, mode characteristics, characteristics of the journey, and land use.

Modal shift is defined as a shift from available modes of transport such as walking, cycling, public transport, mopeds, and cars to another specific mode of transport (Ma et al., 2020). This can either be in a single or multiple trips.

2.3 Rise of e-scooter sharing systems

There have been significant shifts in the planning, design, and funding of major urban infrastructure projects to include sustainable mobility systems (Sheller, 2011). Nevertheless, none of these changes has seriously challenged automobility as the dominant mode of transportation.

However, e-scooter sharing systems are widely expected to accomplish a substantive change in urban transport systems. This shift is facilitated by developments in electrification, automation, and web technologies for real-time transactions. The initial trigger for people to start using an e-scooter rental scheme is the increased availability of a relatively new material. Furthermore, factors such as the ease of access and relatively low costs compared to buying an e-scooter have stimulated the spread and usage of e-scooter sharing systems (Fitt & Curl, 2020).

E-scooters have a relatively low speed compared to other modes of transport, for example cars or public transport. As a result, scooter sharing systems remain to be used in urban areas only (Shaheen & Chan, 2016).

Shared e-scooters could be a solution to the last-mile problem in urban environments (Hollingsworth et al., 2019). The last mile refers to the last leg of people's travels within a city from a hub to their destination. And the problem refers mainly to urban congestion and emissions. E-scooter sharing systems have the potential as a means of transport to reduce traffic congestion and emissions because light electric vehicles are space-efficient and could serve as an eco-friendly alternative for mobility in urban areas (Schelte et al., 2021).

2.4 Electric moped scooters

This study focuses on electric moped scooter sharing systems. According to the guidelines of the European Union, electric moped scooters can be defined as motor vehicles with two wheels, a top speed of up to 45 km/h, and up to 4 kW electric motors (Schelte et al., 2021)

2.5 Emissions of e-moped scooter sharing system and its alternatives

In their recently conducted study, Schelte et al. (2021) have found out that using an electric moped scooter sharing system has a lower emission per driven kilometer than electric kick (stand-up) scooter sharing (see figure 1). Furthermore, the emission of e-moped sharing systems is comparable to that of electric buses. Moreover, privately owned mopeds have a larger emission than shared e-mopeds. In the figure below, the emissions of all modes of transport present in urban areas are illustrated, expressed in carbon dioxide emissions per kilometer per passenger (g CO_2-eq./pkm). This emission consists out of a complete life cycle assessment. Therefore, it also includes indirect emissions of sharing platforms such as the emissions needed to recharge the batteries and the emissions of vehicles used for battery swapping. The dashed lines in figure 1 represent a range that varies based on whether the electric vehicles are either recharged by sustainable energy sources (e.g. solar power) or unsustainable sources (e.g. fossil fuels).

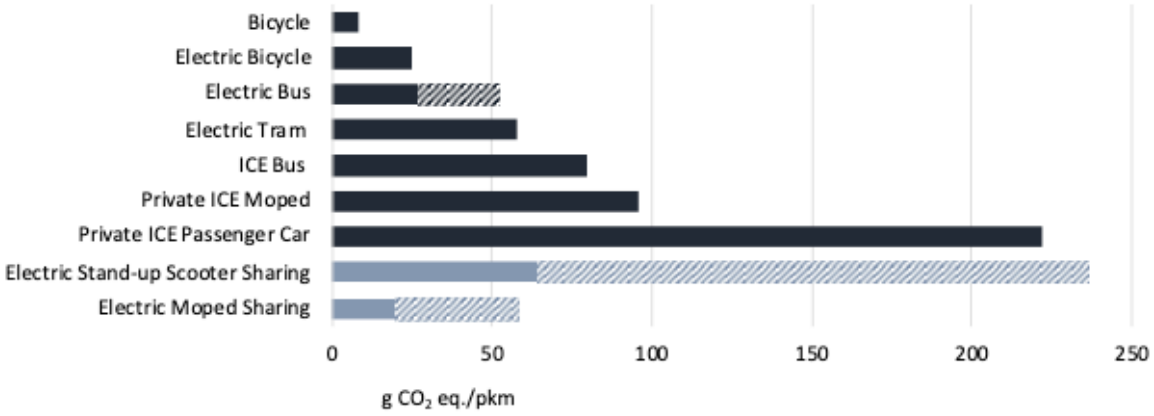


Figure 1. Life cycle emissions of shared electric mopeds compared to alternative modes of transport (Schelte et al., 2021).

2.6 Conceptual model

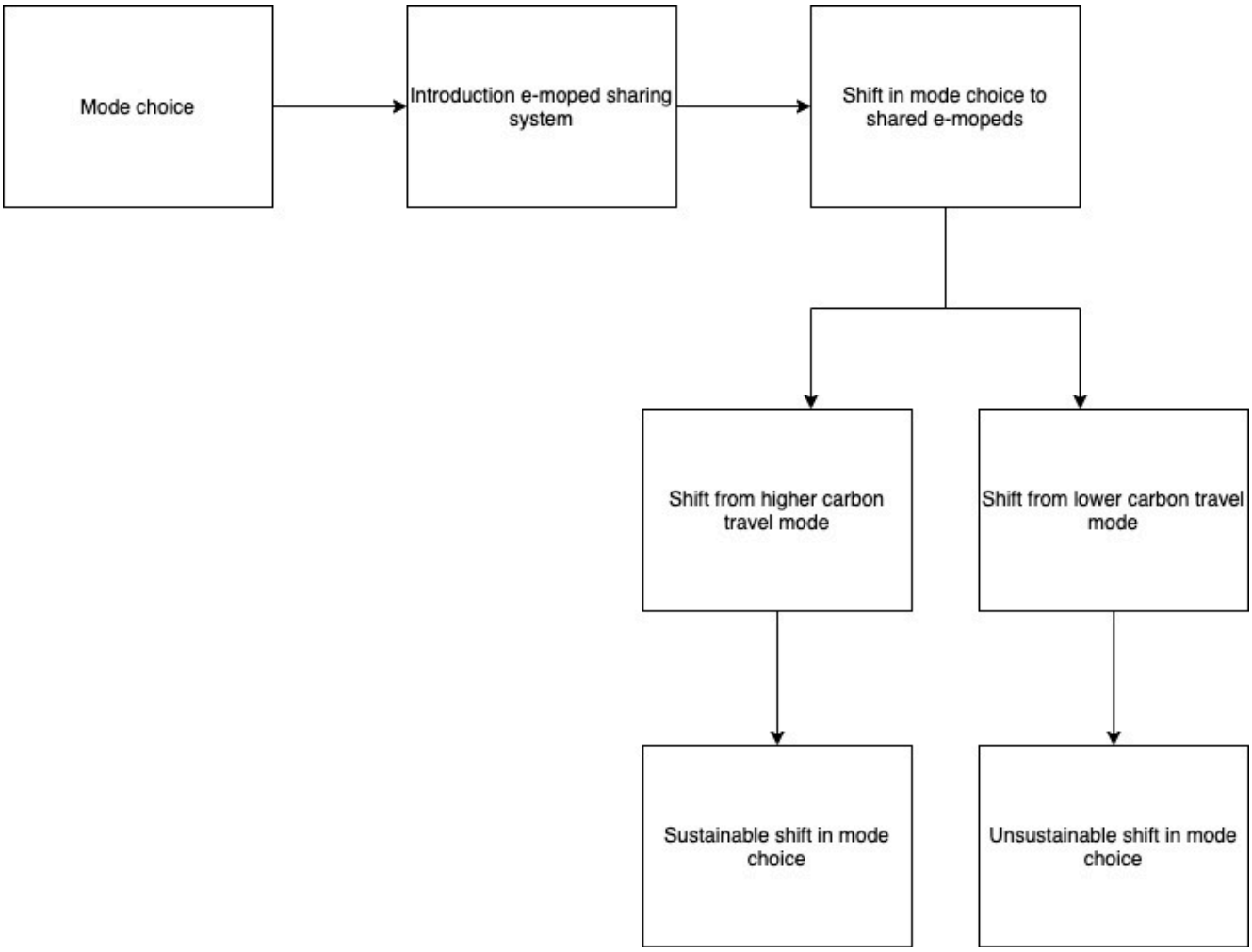


Figure 2. Conceptual model.

2.7 Hypotheses

In their study, Hollingsworth et al. (2019) have found out that introducing an electric kick scooter sharing system in a city results in higher carbon travel mode choices compared to the average blend of alternative travel modes, with which the trip would be covered otherwise. However, a recently conducted study has concluded that the emissions of electric kick scooter sharing systems are considerably higher than those of electric moped scooter sharing systems (see figure 1) (Schelte et al., 2021). Therefore, in contrast to electric kick scooter sharing systems, the introduction of e-moped sharing systems could result in lower overall carbon travel mode choices.

3. Methodology

3.1 Case study method

3.1.1 Case selection

Case studies offer the possibility to gain profound and integral knowledge on a specific process in practice (Rice, 2010). Given the aim of this research, a case study will be conducted in the Netherlands. To be precise, the municipality of Groningen has been chosen as the focus area of study since multiple e-moped sharing platforms have been implemented here since the spring of 2020 (Valkema, 2020). In addition, these platforms have passed their trial phase and are now fully operating. Therefore, this case study is seen as a representative area of study to investigate the impact of introducing shared e-mopeds in terms of mode choice and the associated effects on carbon emissions.

3.1.2 Case description

In the municipality of Groningen, trips with shared e-mopeds can only be activated and deactivated within the service area (Felyx, 2021). The service area of the e-moped sharing companies in the municipality of Groningen is visualised in purple in figure 3. Since January 2021, the municipality of Groningen has decided that companies which provide shared e-mopeds are required to have a permit (Valkema, 2020). Those permits are only provided under strict conditions, which are: a maximum of two companies providing shared e-mopeds within the municipality of Groningen, a maximum of 200 e-mopeds may be provided per company, the minimum age of renting a shared e-moped is 18 years old, it is banned to use shared e-mopeds during night-time, it is not allowed to park shared e-mopeds in the inner city of Groningen, and shared e-mopeds should always be available at stations and Park & Ride areas (Overheid.nl, 2021). These regulations have been put in place to better enforce e-moped sharing companies based on the outcomes of the trial phase.

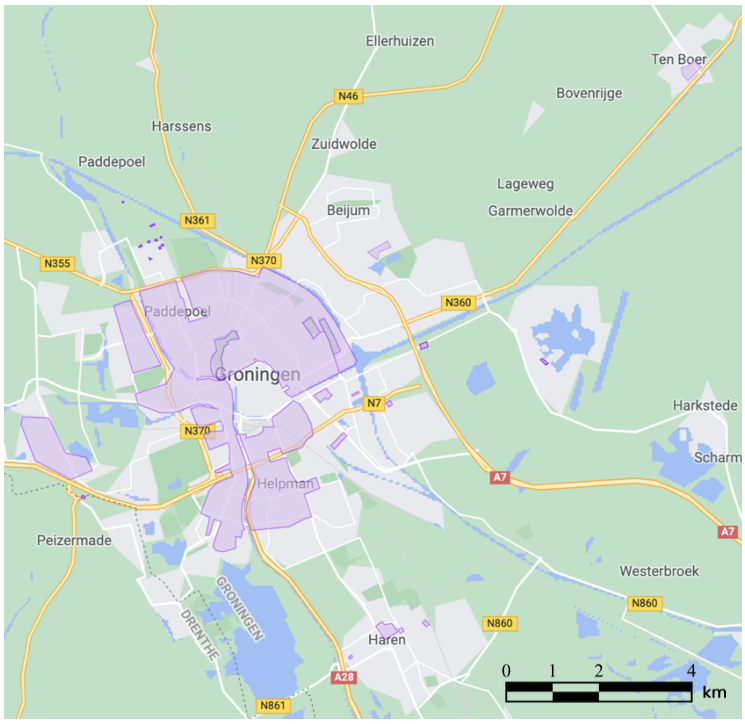


Figure 3. Service area shared e-mopeds municipality of Groningen (adapted from Check., 2021).

Since January 2021, only two companies within the municipality of Groningen are allowed to operate the service of shared e-mopeds. The permit for operating shared e-mopeds is handed out to companies based on a comparative test (Overheid.nl, 2021). This test includes the following categories: the handling of complaints, maintenance of the vehicles, redistribution of the vehicles, interoperability in other mobility systems and initiatives, utilisation of providing the vehicles at hubs, and a plan regarding data and privacy. The companies that obtained such a permit are Check. and Felyx. Another measure included in the permit is that users of shared e-mopeds are obliged to send a photo of their vehicle to deactivate a trip. Via this way, the companies can monitor whether their vehicles are parked correctly. This measure has been put in place because during the trial phase the municipality of Groningen received many complaints about the parking behaviour of shared e-moped users (NOS, 2020). The providers Check. and Felyx use different rates to charge their customers. Check. uses an unlock fee of €0.50 per ride, driving a Check. scooter costs €0.25/min., and pausing a trip costs €0.10/min. (Check., 2021). Felyx does not charge an unlock fee, driving a Felyx scooter costs €0.30/min., and the pausing costs are €0.10/min. (Felyx, 2021).

3.2 Data collection

To investigate the modal shift to shared e-mopeds in the municipality of Groningen and answer the first three sub-questions of this research, primary data needs to be collected from the users of shared e-mopeds in Groningen. Besides that, literature on the emissions of e-moped sharing systems and its alternatives in urban environments is needed to be able to answer the fourth sub-question. Therefore, secondary data on the recharging and distribution of batteries by the providers of shared e-mopeds and electric busses is collected to determine the life cycle emissions of these modes of transport in this case study (see figure 1). By combining both primary and secondary data, it can be investigated whether the modal shift is sustainable or not.

3.2.1 Literature review

First, a literature review is conducted to get an understanding of the concepts, definitions, and theories used in this research. Then, since this study is a case study, literature is needed to provide background information for the case study performed in the municipality of Groningen.

3.2.2 Primary data collection

To investigate the shift in mode choice due to the introduction of shared e-moped systems, a quantitative study has been conducted. The practice of shared e-moped users in the municipality of Groningen has been taken as the unit of analysis and individual shared e-moped users as the unit of observation. The primary data is gathered by using a quantitative survey approach and the data collection has been performed by using Qualtrics, this is a tool for online surveys provided by the University of Groningen. The survey consists out of blocks of questions focused on demographics, most common alternative to shared e-mopeds, average distance of the trips covered by shared e-mopeds, percentage of trips that are replaced by shared e-mopeds, and the most common origin and destinations of shared e-moped users (see appendix 1).

The survey was available for completion from October to November 2021. The distribution of the survey has been performed through social media and the networks of the researcher via a convenience sampling method, resulting in a snowballing effect (Punch, 2014). There could be demographic differences between the population of shared e-mopeds users and the wider population of the municipality of Groningen. For this reason, this study acknowledges that it cannot be representative for the wider population of the municipality of Groningen, but only for those using shared e-mopeds.

3.2.3 Secondary data collection

To answer sub-question 4, data on the emissions of the modes of transport available within the municipality of Groningen is needed. To be precise, the life cycle emissions of shared e-mopeds and electric busses must be determined. This namely depends on the electricity that is used to recharge these electric vehicles (see dashed lines figure 1). Besides that, secondary demographic, and other interesting data of shared e-moped users within the municipality of Groningen has been collected. Access to this data must be negotiated with the relevant gatekeepers (Punch, 2014). Gathering this data is done by getting in contact with the responsible department of mobility in the municipality of Groningen. The municipality of Groningen has agreements with the companies providing shared e-mopeds stating that the companies must provide them with data for research purposes when asked (Overheid.nl, 2021).

Research Sub-Question	Answered by
1. SubQ1: Which modes of transport are being replaced by shared electric moped scooters in the municipality of Groningen, and does introducing shared electric moped scooters create new trips?	Primary data collection: question block 2 of the questionnaire
2. SubQ2: What is the average distance of the trips that are being replaced by shared e-mopeds in the municipality of Groningen?	Primary data collection: question block 3 of the questionnaire
3. SubQ3: What percentage of trips is replaced by shared electric moped scooters in the municipality of Groningen?	Primary data collection: question block 4 of the questionnaire
4. SubQ4: What are the emissions of using an electric moped scooter sharing system and its alternatives in the municipality of Groningen?	Secondary data collection: data from mobility department municipality of Groningen

Figure 4. Overview research methods used to answer sub-questions.

3.3 Data analysis

Data analysis will be performed by extracting the conducted surveys from Qualtrics into SPSS. The research sub-questions, the main research question, and its subsequent secondary aim can be answered by analysing the imported data (see figure 4).

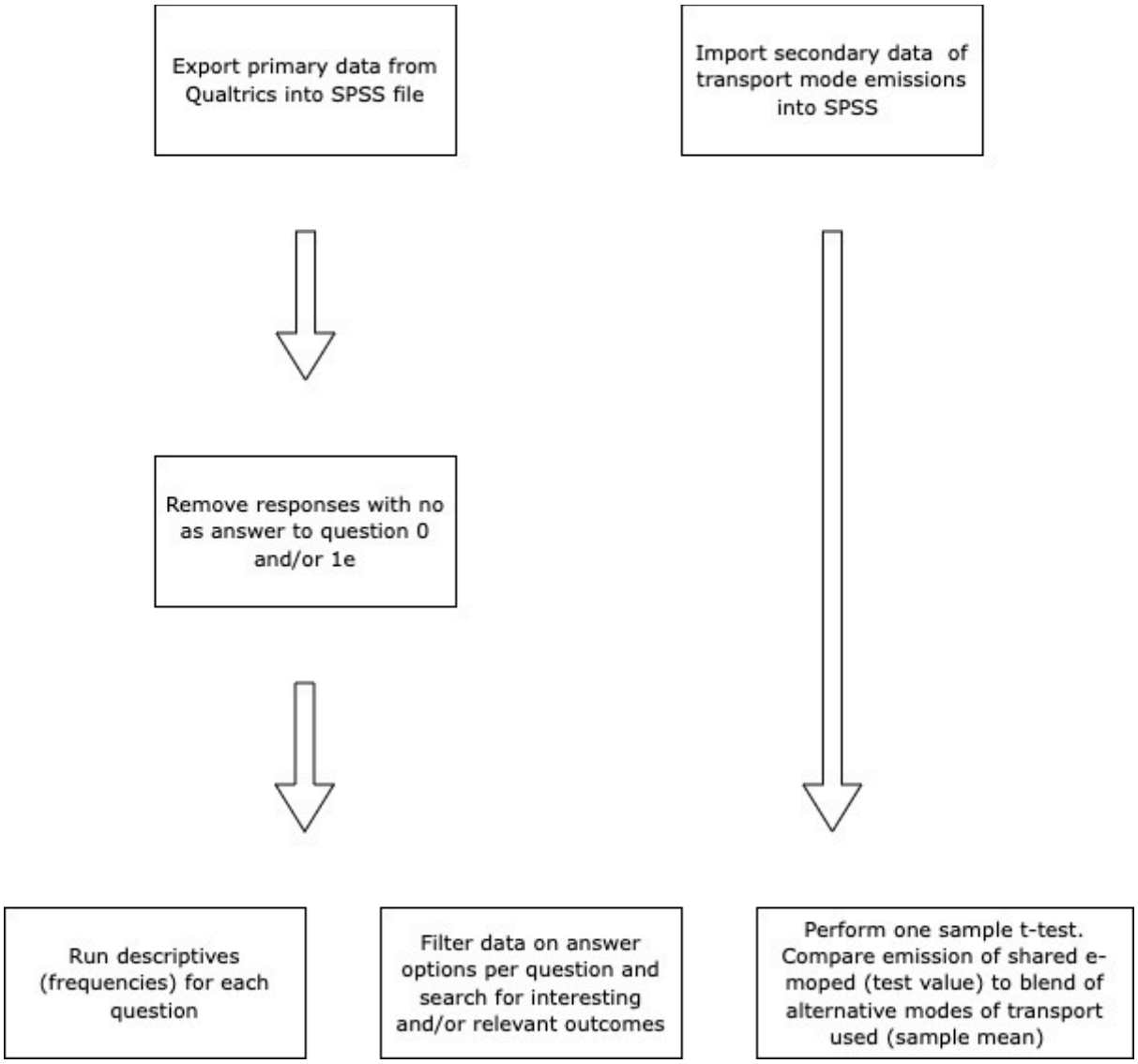


Figure 5. Data analysis scheme.

3.4 Ethical considerations

Ethical considerations need to be addressed to this methodology. In this study, both primary and secondary data are used to answer the research questions. As a researcher, it is important to bear in mind that secondary data has been gathered by someone else. Furthermore, the data is gathered for another purpose at another place and point in time. Secondary data is namely often spatially referenced (Rice, 2010).

In this quantitative study, the roles of researcher and subject are mutually exclusive. As a researcher in this study, human phenomena are objectively investigated. The power relations are highly hierarchical, it is important to be aware of this. The thinking that goes into the project is contributed by the researcher, and the subjects contribute the phenomenon to be studied (Karnieli-Miller, et al., 2009). The author of this study is an insider. The researcher himself has experience with using an e-moped sharing system and lives in the municipality of Groningen. Therefore, it is important to be aware of this to assure the objectivity of the study.

To protect the privacy of the participants in this research, data from the participants only includes general demographic characteristics and when a respondent prefers not to answer a certain question this has been made possible. Besides that, the conducted surveys start with a block of questions to assure that respondents participate on a voluntary basis with informed consent (see appendix 2) (Business Research Methodology, 2021).

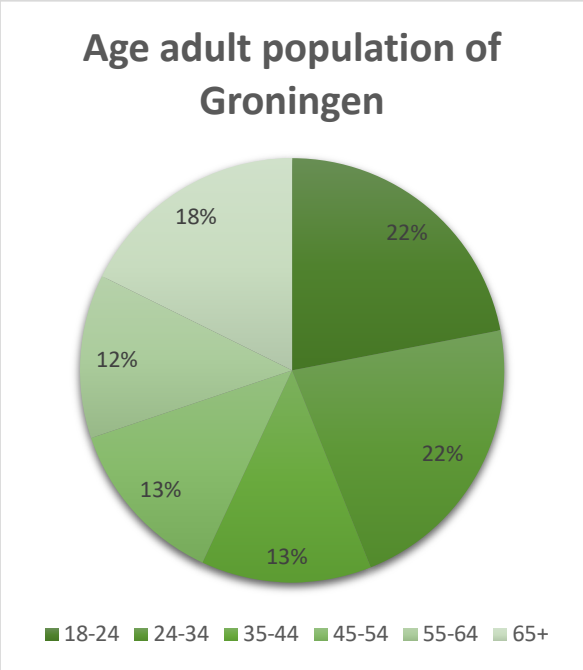
4. Results

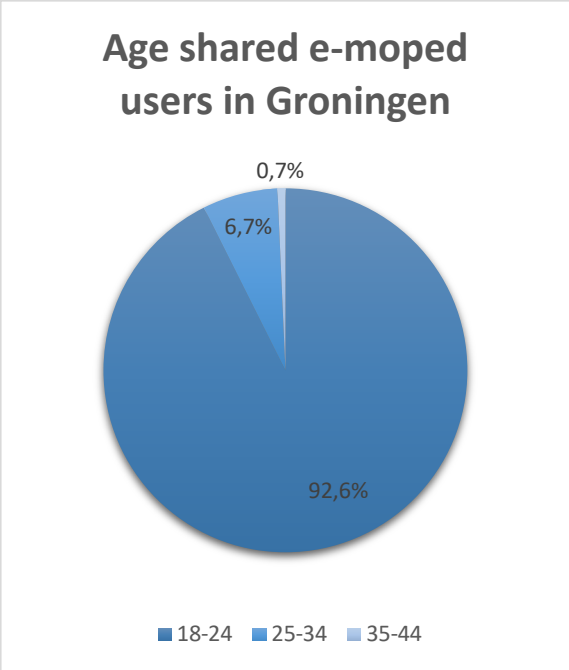
In this chapter, the results of the data collection and data analysis are being discussed. First, the outcomes of the primary data collection are discussed. Then the outcomes of the secondary data collection are discussed. In addition, the research questions are being answered at the relevant paragraphs.

4.1 Primary data collection

4.1.1 Demographics

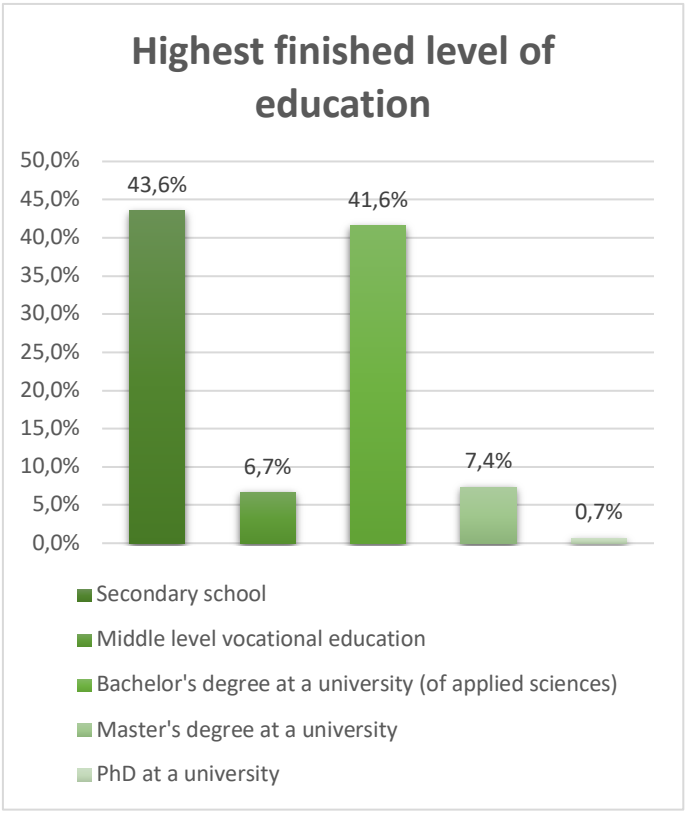
A total of 175 responses have been collected via Qualtrics. After exporting the data into SPSS and cleaning it, there were 156 usable responses. In the figures below, the demographic characteristics of the sample are shown and discussed in-text.

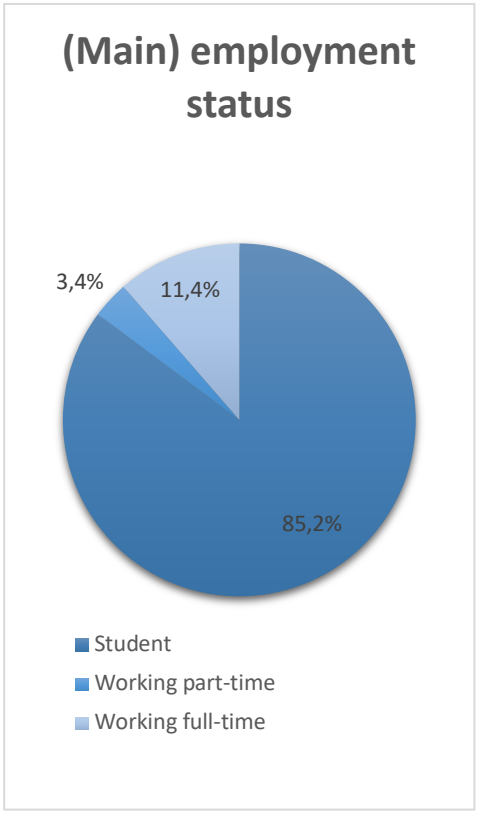




Figures 6 & 7. Age adult population municipality of Groningen and age shared e-moped users.

In the figures 6 & 7, the age categories of the sample have been compared to the adult population of the municipality of Groningen (Gronometer, 2021). When looking at those numbers, it becomes clearly visible that the sample of this study is not representative for the wider population of the municipality of Groningen. Thus, as already mentioned in the methodology, this study can only be representative for the population that is using shared e-mopeds in the municipality of Groningen. The sample of this study consists out of a relatively young population, which suggests that the population that is making use of shared e-mopeds is relatively young compared to the wider population of the municipality of Groningen. The service is mainly used by people who are 18-24 years old, 92.6% of the respondents belong to this age category. A previous conducted survey by the municipality of Groningen during the trial phase of shared e-mopeds corresponds to what is concluded in this research. The figures of that survey show that the largest group of shared e-moped users is between 20 and 30 years old and the average age is around 25.5 years (Ringnalda, 2021).





Figures 8 & 9. Highest finished level of education and (main) employment status shared e-moped users.

According to figure 8, the population that is using shared e-mopeds in the municipality of Groningen is relatively well-educated compared to the wider population of the municipality of Groningen. 49.7% of the sample has at least finished a bachelor's degree in higher education. Furthermore, 43.6% of the sample has secondary school as their highest finished level of education and a large part of that group is likely to still study in higher education. In the municipality of Groningen, 42.5% of the people is studying or has finished higher education (AlleCijfers.nl, 2021). Higher education can be defined as education on the level of a university or a university of applied sciences (CBS, 2021). Another interesting outcome of the primary data collection is that the lion's share of shared e-moped users is a student (see figure 9). 85.2% of the respondents filled in student as their main employment status. Furthermore, none of the respondents has filled in that they are not employed. The results of the age categories and the level of education in the sample will most likely be influenced by the fact that Groningen is a university town (Groningen.nl, 2021).

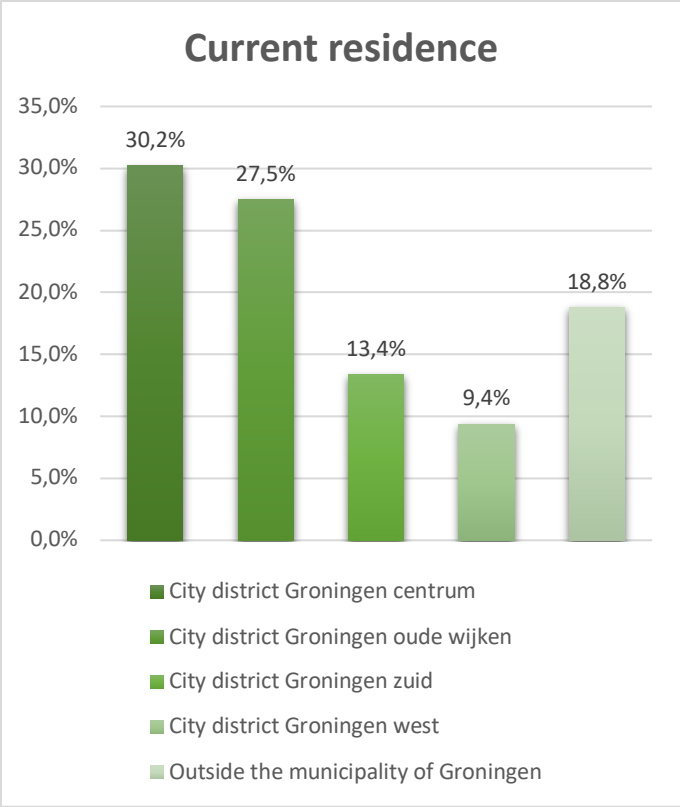


Figure 10. Current residence of shared e-moped users.

Most common location of origin (%)	Most common location of destination (%)				
	Home	*Work*	*Education*	*Leisure*	*Total*
Home	3,2	5,6	16,7	49,3	74,6
Work	0,8	0	0	0	0,8
Education	0,8	0,8	2,4	2,4	6,3
Leisure	4	0	0	14,3	18,3
Total	8,7	6,3	19	65,9	100

Figure 11. Most common location of origin and destination shared e-moped trips.

The residence of the population that is using shared e-mopeds in the municipality of Groningen seems to be spread out quite evenly throughout the municipality and its surroundings (see figure 10). In figure 11 the most common locations of origin and the most common locations of destination of shared e-moped users in the municipality of Groningen are visualised in a cross-table. The most common location of origin is home, followed by leisure, and then education. Relatively few people have stated that their most common location of origin is work. The most common location of destination is leisure, this suggests that shared e-mopeds are most often used for recreational purposes. After that education, home, and then work follow as the most common location of destination.

4.1.2 Alternative modes of transport

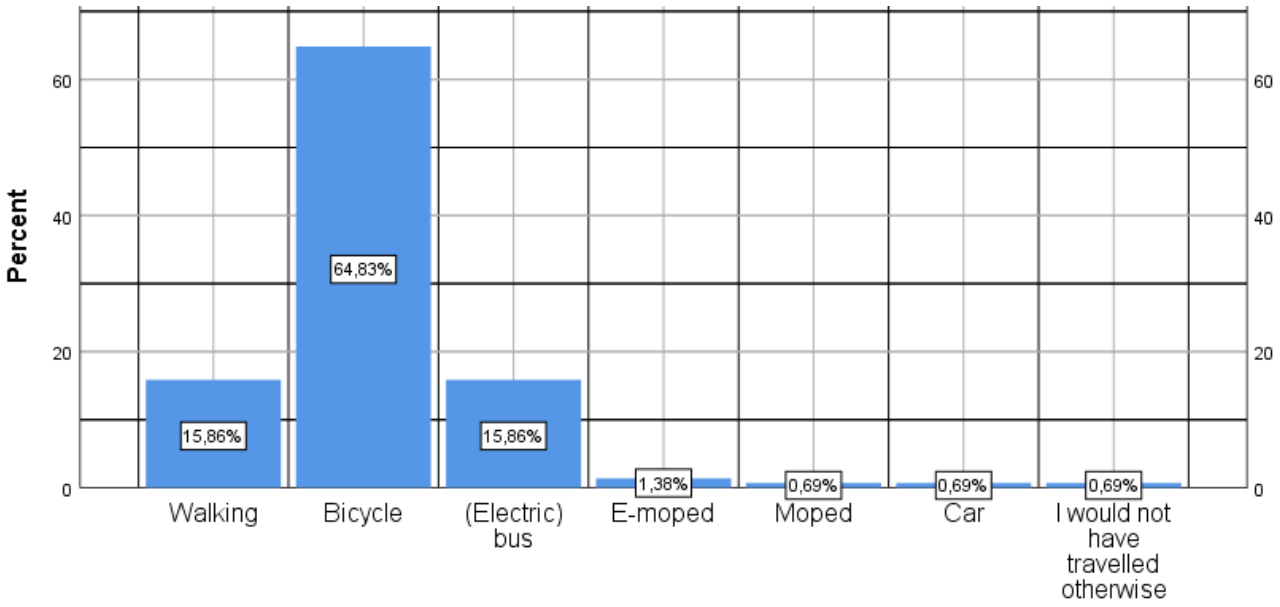
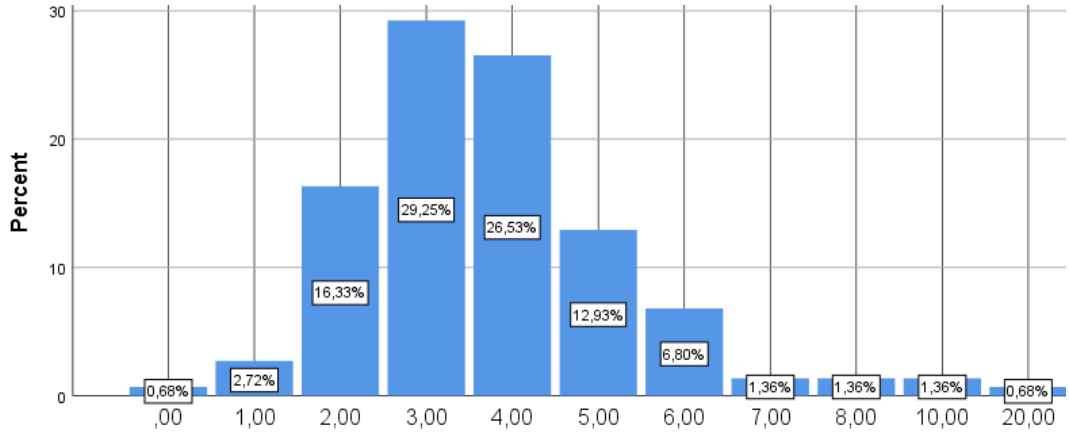


Figure 12. Alternative modes of transport.

Sub-Question 1: Which modes of transport are being replaced by shared electric moped scooters in the municipality of Groningen, and does introducing shared electric moped scooters create new trips?

As visible in figure 12, mainly bicycles are replaced by shared e-mopeds, followed by walking and electric buses. Private e-mopeds, mopeds, and cars are relatively rarely replaced by shared e-mopeds. Besides that, 0.69% of the sample has filled in that they would not have travelled otherwise. Thus, although being few, shared e-mopeds do create new trips.
The modes of transport in figure 8 are ranked from left to right based on their lifecycle emissions expressed in carbon dioxide emissions per kilometer per passenger (see figure 1). Therefore, this figure seems to give a first impression that due to the introduction of shared e-moped sharing systems, an unsustainable modal shift in travel mode choices has taken place within the municipality of Groningen (see figure 2).

4.1.3 Average distance of trips with shared e-mopeds.



N	147
Mean	3,8231
Median	4,0000
Mode	3,00

Figures 13 & 14. Average distance covered with shared e-mopeds.

Sub-Question 2: What is the average distance of trips made by shared electric moped scooters in the municipality of Groningen?

As visible in figure 14, the mean average distance covered by shared e-mopeds within the municipality of Groningen is 3.8 km. In figure 13 it becomes clearly visible that, in general, shared e-mopeds are used for relatively short trips. Only few respondents have filled in that their average trip length is larger than 6 kilometers.

4.1.4 Percentage of trips replaced by shared e-mopeds

N	146
Mean	8,8151
Median	5,0000
Mode	5,00
Std. Deviation	13,83549
Range	80.00

Figure 15. Percentage of trips replaced by shared e-mopeds.

Sub-Question 3: What percentage of trips is replaced by shared electric moped scooters in the municipality of Groningen?

In figure 15 it is visualised what percentage of the weekly trips of shared e-moped users within the municipality of Groningen is replaced by a shared e-moped. As visible in the table above, approximately 8.8% of the trips are replaced by a shared e-moped. Meaning that, on average, less than $^{1}/_{10}$ of the weekly trips from the sample is replaced by a shared e-moped. Other interesting outcomes in this table are the standard deviation and range. Within the sample, the answers given to this question were dispersed and ranging from 1% to 81% of the weekly trips within the municipality of Groningen.

4.2 Secondary data collection

4.2.1 Emissions modes of transport

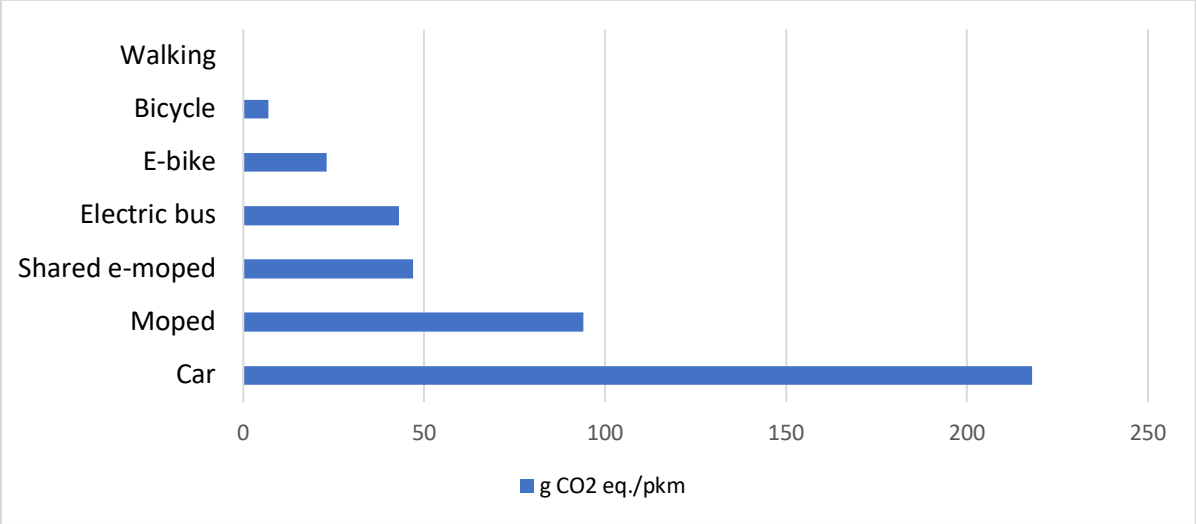


Figure 16. Life cycle emissions modes of transport municipality of Groningen.

Sub-Question 4: What are the emissions of using an electric moped scooter sharing system and its alternatives in the municipality of Groningen?

In figure 16 the life cycle emission of shared electric moped scooters is visualised together with the emissions of alternative modes of transport available within urban the municipality of Groningen. The exact life cycle emissions of shared e-mopeds and electric buses are dependent on the energy with which the batteries are recharged and distributed (see dashed line figure 1). According to Ringnalda (2021), shared e-moped systems and electric buses, within the municipality of Groningen, are recharged with electricity from the national grid. The most recent numbers from the Dutch Central Statistical Office indicate that approximately 25% of the Dutch electricity is produced out of renewable sources (CBS, 2021). This results in the life cycle emissions of the available modes of transport within the municipality of Groningen, visualised in figure 16.

4.3 Sustainability introduction e-moped sharing system

The subsequent secondary aim of this research is to investigate the sustainability of the modal shift that is accomplished due to the introduction of an electric moped scooter sharing system. To answer this question, a one-sample t-test has been performed on the data that is used to answer the sub-questions 1 and 4. The One-Sample t-Test examines whether there is a statistical difference between a sample mean and a test value, which is a known or hypothesized value of the mean in the population (Kent State University, 2021).

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
Emission mode of transport in municipality of Groningen	145	14,1586	23,39922	1,94320

One-Sample Test

	Test Value = 47					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Emission mode of transport in municipality of Groningen	-16,901	144	,000	-32,84138	-36,6823	-29,0005

Figures 17 & 18. Statistical test: sustainability of shared e-mopeds.

Figure 17 provides basic information about the sample mean, and figure 18 displays the results of the One-Sample t-Test. In this research, the sample mean is the average life cycle emission of the blend of alternative travel modes with which the trip would be covered otherwise instead of a shared e-moped, which is 14.1586 g CO_2-eq/km (see figure 17). The test value is the life cycle emission of a shared e-moped, which is 47 g CO_2-eq./km (see figure 16).
When looking at those numbers, it becomes clear that due to the introduction of the shared e-moped system there is a modal shift towards higher carbon travel mode choices, which would make it an unsustainable shift in mode choice (see figure 19). By using these numbers in a One-Sample t-Test, it can be determined whether this is a statistically significant difference. The outcome of the One-Sample t-Test shows a significance of 0.000, and it can thus be concluded that the emission of a shared electric moped scooter is significantly higher than the average emission of the alternative travel modes. Another interesting outcome is the mean difference, which shows that, on average, the emission of a shared e-moped is 32.84138 g CO_2-eq./km higher than the average emission of the alternative mode of transport that would have been used otherwise.

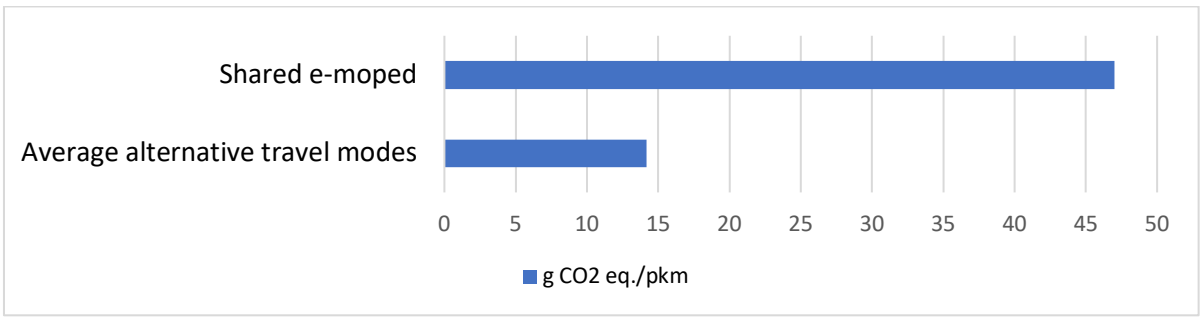


Figure 19. Life cycle emissions shared e-moped and average of alternative travel modes.

5. Conclusions

The central question in this study was: *How does introducing an electric moped scooter sharing systems change the mode choice in the municipality of Groningen?* This research question has been formulated since this form of mobility is growing rapidly, but the scientific literature around electric moped scooter sharing systems is still scarce. The subsequent secondary aim of this research was to investigate whether implementing this micromobility sharing system contributes effectively to its sustainable ambitions. The research questions have been answered by conducting an explorative case study.

This study has found out that, in the municipality of Groningen, shared e-mopeds are used by a relatively young population compared to the wider population of the municipality. The people using shared e-mopeds most often replace cycling, walking, or the bus for shared e-mopeds, and relatively few replace their private moped or car for shared e-mopeds. Although being few, shared e-mopeds do create new trips. Shared e-mopeds are most often used for relatively short trips. Users of shared e-moped systems replace only a fraction of their weekly trips within the municipality of Groningen by a shared e-moped. This means that, in general, shared e-mopeds are not used as a structural means of transport for trips covered within the municipality. The life cycle emissions of shared e-mopeds, per kilometer per passenger, are almost the same as that of electric buses. Walking, cycling, and electric cycling have lower emissions than shared e-mopeds. Cars and (private owned) mopeds have higher emissions than shared e-mopeds.

Hollingsworth et al. (2019) have found out that introducing an electric kick scooter sharing system results in higher carbon travel mode choices. The emissions of electric moped scooter systems are considerably lower than that of kick scooter sharing systems (Schelte et al., 2021). Therefore, this mobility system could result in lower carbon travel mode choices. However, this study has found out that despite the lower emissions of shared electric moped scooters the introduction of this mobility system still results in higher carbon travel mode choices, and thus an unsustainable modal shift (see figure 2).

This research has been performed as a case study in a specific geographical context. Therefore, the results cannot be generalised to speak for other or larger geographical areas. However, this research has shown that introducing an electric moped scooter sharing system does not result in more sustainable travel mode choices. Nevertheless, this does not mean that electric moped scooter sharing systems will remain unsustainable in the future. If the energy that is used to charge and distribute the batteries of this mobility system gets more sustainable, its emissions will become lower. Because of this, there still is some great potential in the system of shared electric moped scooters.

6. Discussion: limitations and recommendations

6.1 Limitations of the study

This study has been performed from September 2021 until January 2022. Meaning that this study could be influenced by the effects of the global COVID-19 pandemic. It is therefore important to bear in mind that this pandemic could have influenced the travel mode choices, travel patterns, and travel behaviour of individuals and therefore the results of this study.
The article of Schelte et al. (2021) has been used as a tool to determine the emissions of the available modes of transport within the municipality of Groningen. Although these numbers do help to get a general idea about the emission of the modes of transport in the case study, these numbers could not be totally representative. This is because the numbers are based on the life cycle emissions of transport modes within Germany. Therefore, the energy mix and emissions of the vehicles could be different compared to that of modes used within the municipality of Groningen.

6.2 Policy recommendations

As visible in the results, within the municipality of Groningen shared electric moped scooters are used for relatively short trips (see figures 13 & 14). This seems to be related to the modes of transport that are replaced for shared electric moped scooters (see figure 12). Modes of transport which are, in general, used for relatively short trips are more sustainable than the modes used for longer trips (see figures 1 & 16). Relatively few people replace their car or private moped with shared e-mopeds, and most of the people in the sample replace walking, cycling or the electric bus. This results in an unsustainable modal shift. A possible policy to stimulate the sustainability of e-moped sharing platforms is to encourage longer trips and discourage shorter trips. This can be done by increasing the unlock fee of shared e-mopeds and at the same time decrease the fee per kilometer for every extra kilometer that is covered. In figure 1 it is visible that the sustainability of shared e-mopeds is highly dependent on the energy which is used to charge and distribute the batteries. Through the collection of secondary data at the department of mobility of the municipality of Groningen, it has become evident that they are not aware of the sustainability of the shared e-moped platforms. Although, the municipality does recognize that shared mobility offers opportunities to make mobility more sustainable (Valkema, 2021). Therefore, I suggest adding a section with a focus on the sustainability of the mobility system besides the rules enforcing shared e-moped companies that have been put in place since January 2021. For example, requirements for the energy mix that is used to charge and distribute the batteries of shared e-mopeds can be included. These rules would be capable to increase the sustainability of this mobility system.

6.3 Recommendations for further research

As mentioned before, this study has used data on the emission of shared e-mopeds in Germany, which is based on shared e-mopeds which are manufactured and driven within German urban areas (Schelte et al., 2021). This data has been used because there is no scientific literature yet on the emissions of shared e-mopeds within the Netherlands. Therefore, a suggestion for further research is to investigate the emissions of shared e-mopeds used within Dutch urban areas.

In this study, it is assumed that shared e-mopeds are used by one person at a time, while in practice a part of the trips is performed by two persons at a time. Since this study has measured the emissions of the vehicles in carbon dioxide emissions per kilometer per passenger (g CO_2-eq./pkm), trips performed by two persons at a time contribute to half of the emission compared to trips carried out by one person. Therefore, in practice, the emission of shared e-mopeds within the municipality of Groningen could be lower than what is concluded in this research, which would increase the sustainability of this mobility system. Thus, possible further research could investigate the share of trips with shared e-mopeds that is carried out by two persons at a time.

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Appendix 1: questionnaire design

Question	Measurement level	Answer options	What does the question aim to identify?
1a. What is your age category?/ Wat is uw leeftijdsgroep?	Ordinal	18-24, 25-34, 35-44, 45-55, 55-64, 65+, prefer not to say/zeg ik liever niet	This question will gather general demographic information about the sample. Furthermore, it is possible to separate the sample in age groups during the data analysis to check for interesting outcomes.
1b. What is your highest finished level of education?/ Wat is uw hoogst genoten opleiding?	Ordinal	None/geen, secondary school/middelbare school, middle level vocational education/MBO, bachelor degree at a university (of applied sciences)/bachelor diploma op een universiteit of hogeschool, master degree at a university/master diploma op een universiteit, prefer not to say/zeg ik liever niet	This question will gather general demographic information about the sample. Furthermore, level of education does tell something about the income of the respondent without asking about it since this could be a sensitive subject.
1c. Which of the following categories best describes your current employment status?/ Welk antwoord beschrijft het beste uw huidige arbeidssituatie?	Nominal	Student/student, working part-time/deeltijd aan het werk, working full-time/voltijd aan het werk, none/geen, prefer not to say/zeg ik liever niet	This question will gather general demographic information about the sample.
1d. Where do you currently live?/ Waar woont u momenteel?	Nominal	City district Groningen centrum (A-kwartier, Binnenstad, Binnenstad-Oost, Hortusbuurt, Ebbingekwartier, Westerhaven Stationsgebied), City District Groningen Oude Wijken (De Hoogte, Korrewegwijk, Noorderplantsoenbuurt, Oosterparkwijk, Oranjebuurt, Schildersbuurt, Kostverloren, Woonschepenhaven), City district Groningen Oost (Beijum, Drielanden, Engelbert, De Hunze, Van Starkenborgh, Lewenborg, Middelbert, Noorderhoogebrug	This question will gather general demographic information about the sample. Furthermore, it gives information about the residence of the population that is using shared e-mopeds in the municipality of Groningen.

		Oosterhoogebrug, Ruischerbrug, Meerstad, Harkstede GN, Noorddijk, Ulgersmaborg, Ruischerwaard), City district Groningen Zuid (Badstratenbuurt, Coendersborg, Corpus den Hoorn, Grunobuurt, Helpermaar, Helpman, Herewegbuurt, Hoornse Meer, Hoornse Park, Laanhuizen, Rivierenbuurt, Oosterpoortbuurt, De Linie, Europapark, Piccardthof, De Wijert, Zeeheldenbuurt, Klein Martijn, De Meeuwen, Villabuurt, Kop van Oost), City district Groningen West (De Buitenhof, Dorkwerd, Gravenburg, De Held, Hoogkerk, Leegkerk, Paddepoel, Reitdiep, Selwerd, Tuinwijk, Vinkhuizen), Haren (Glimmen, Haren, Noordlaren, Onnen), Ten Boer (Garmerwolde, Lellens, Sint Annen, Ten Boer, Ten Post, Thesinge, Winneweer, Wittewierum, Woltersum), Outside the municipality of Groningen/buiten de gemeente Groningen, prefer not to say/zeg ik liever niet	
1e. Have you ever made use of a shared e-moped in the municipality of Groningen?/ Heeft u ooit gebruik gemaakt van een elektrische deelscooter in de gemeente Groningen?	Nominal (binary)	Yes/Ja, No/Nee	Prefer not to say is not an option in this question. This study is designed to only include users of shared e-mopeds in the municipality of Groningen and this question is used to be able to filter out respondents who have not.
2. When using a shared e-moped in the municipality of Groningen, which alternative mode of transport has (mainly) been replaced for it?/ Wanneer u gebruikt maakt van een elektrische deelscooter in de gemeente Groningen, welk vervoersmiddel heft u hiervoor dan (voornamelijk) vervangen?	Ordinal	Walking/lopen, bike/fiets, e-bike/elektrische fiets, (electric) bus/(elektrische) bus, e-moped/elektrische scooter, moped/scooter, car/auto, I would not have travelled otherwise/Ik zou anders niet hebben gereisd,	Answers SubQ1. This question identifies the (main) alternative mode of transport which is replaced by a shared e-moped user.

		prefer not to say/zeg ik liever niet	
3. When using a shared e-moped in the municipality of Groningen, what is your (estimated) average distance covered during a trip?/Wanneer u gebruik maakt van een elektrische deelscooter in de gemeente Groningen, wat is uw (geschatte) gemiddeld afgelegde afstand per reis?	Ratio	0-20km, prefer not to say/zeg ik liever niet	Answers SubQ2. This question identifies the average trip length of a shared e-moped.
4. What (estimated) percentage of all your trips weekly within the municipality of Groningen is carried out with a shared e-moped?/Welk (geschatte) percentage van al je reizen per week binnen de gemeente Groningen voert u uit met een elektrische deelscooter?	Ratio	0-100%, prefer not to say/zeg ik liever niet	Answers SubQ3. This question identifies what percentage of trips of users of shared e-mopeds within the municipality of Groningen is replaced by shared e-mopeds.
5a. When using a shared e-moped in the municipality of Groningen, what is your most common location of origin?/Wanneer u gebruik maakt van een elektrische deelscooter in de gemeente Groningen, wat is uw meest voorkomende vertrekpunt	Nominal	Home/thuis, education/opleiding, work/werk, leisure (visiting friends, sports, bars, etc.)/recreatieve doeleinden (vrienden bezoeken, sport, horeca, etc.), other:…/anders:… prefer not to say/zeg ik liever niet	This question gathers general characteristics of the origin of travel of rides with shared e-mopeds.
5b. When using a shared e-moped in the municipality of Groningen, what is your most common location of destination?/Wanneer u gebruik maakt van een elektrische deelscooter in de gmeente Groningen, wat is uw meest voorkomende bestemming van de reis?	Nominal	Home/thuis, education/opleiding, work/werk, leisure (visiting friends, sports, bars, etc.)/recreatieve doeleinden (vrienden bezoeken, sport, horeca, etc.), other:…/anders:… prefer not to say/zeg ik liever niet	This question gathers general characteristicsc of the destination of travel of rides with shared e-mopeds
6. Thank you for participating in this research. If you have any comments and/or suggestions you can write this in the text box below./ Bedankt voor het deelnemen aan dit onderzoek. Eventuele opmerkingen en/of suggesties kunt u kwijt in onderstaande tekstvak.			

Appendix 2: questionnaire consent form

Participation agreement

You are being invited to participate in a research study titled:
'Does introducing an e-moped scooter sharing system result in lower carbon travel mode choices? A municipality of Groningen case study.'

The requirements to participate in this research are that you are 18 years or older, in possession of a moped driver's license and have made use of a shared e-moped in the municipality of Groningen. This study is performed by Bouke Kamphuis from the University of Groningen.

The aim of this survey is to perform an explorative case study to investigate whether the introduction of an e-moped scooter sharing system accomplishes a shift in mode choice, and it will take you approximately 5 minutes to complete.

Participation in this survey is voluntarily and it is possible to withdraw at any time. The answers in this survey only include general personal information to assure your privacy. All transmitted data is encrypted and only the researcher and his supervisor have access to this data via a password.

Contact details:
- Bouke Kamphuis (researcher): b.h.kamphuis@student.rug.nl
- Farzaneh Bahrami (research supervisor): f.bahrami@rug.nl

Question	Measurement level	Answer options	What does the question aim to identify?
0. Hereby I declare that I have read the participation agreement and participate in this research on a voluntary basis with informed consent./ Hierbij verklaar ik de overeenkomst van deelname te hebben gelezen en vrijwillig met geïnformeerde toestemming deelneem aan dit onderzoek.	Nominal (binary)	Yes/Ja, No/Nee (forced to answer this question)	This question assures that respondents participate in the research on a voluntary basis with informed consent. It also informs participants on privacy considerations.

Overeenkomst van deelname

U bent uitgenodigd om deel te nemen aan een onderzoek met de titel:
'Resulteert de introductie van een deelsysteem voor elektrische bromfietsen in koolstofarmere vervoerskeuzes? Een casestudie in de gemeente Groningen.'

Voorwaarden voor deelname aan dit onderzoek zijn dat je 18 jaar of ouder bent, in het bezit van een bromfietsrijbewijs en ooit gebruik hebt gemaakt van een elektrische deelscooter in de gemeente Groningen. Dit onderzoek wordt uitgevoerd door Bouke Kamphuis van de Rijksuniversiteit Groningen.

Het doel van deze enquête is om een verkennende casestudie uit te voeren om te onderzoeken of de introductie van een deelsysteem voor e-scooters een verschuiving in de vervoersmodus keuze teweegbrengt. Het duurt ongeveer 5 minuten om de enquête te voltooien.

Deelname aan dit onderzoek is vrijwillig en u kunt zich op elk moment terugtrekken. De antwoorden bevatten alleen algemene persoonlijke informatie om uw privacy te waarborgen. Alle verzonden gegevens zijn versleuteld en alleen de onderzoeker en zijn begeleider hebben via een wachtwoord toegang tot deze gegevens.

Contactgegevens:
- Bouke Kamphuis (onderzoeker): b.h.kamphuis@student.rug.nl
- Farzaneh Bahrami (onderzoeksbegeleider): f.bahrami@rug.nl