Impact of e-scooter ownership on mode choice behaviour for access and egress trips: a stated preference study in the Netherlands

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Frontfigure: (Segway, n.d.)

Preface

This thesis is part of the curriculum of the master study transport, infrastructure and logistics at the Delft University of Technology. The start of the thesis was in 2023. At the same I did a new master at the VU and finished that in oktober 2024. Since then, I have worked on this thesis.

The initial thesis committee consisted of three persons, dr. Ir. Niels van Oort, dr. Jan Ann Annema and Nejc Gerzinic. From 2024 onwards the committee changed slightly. Instead of Nejc Gerzinic, Jie Gao took part. The committee was very helpful during the project. Due to the numerous feedback and the personal meetings, the thesis quality was improved.

Dr. Ir. Niels van Oort, was the chair of the thesis committee. His feedback is always direct and clear, which I could immediately use to improve the thesis quality. Also, the numerous times, that he led the meetings, were very well structured.

Dr. Jan Ann Annema was the daily supervisor where I got help from frequently. Dr Jan Ann Annema gave feedback that has also improved the work very much. Together we have made several decisions when I was stuck and that proved to be very valuable in continuing the research.

Dr. Jie Gao was also a very helpful person. She also helped with especially the stated choice experiment in which the overall design had to defined.

A special thanks to also Nejc Gerzinic, who helped a lot with especially defining the research.

The research was very challenging and time consuming, but it increased my knowledge on access and egress mode choice, the stated choice experiment, discrete choice modelling and writing the results in such a way that normal people who have no knowledge on the topic can read it. I hope that when reading this report, the reader will increase his or her knowledge and get more insight on the potential that the private e-scooter has and what influences this potential.

At last, I would like to say thank you to my mother who always supported me in what I do and always keeps asking "when are you done with school?"

With this having said, I would like to say, enjoy reading the report.

<div align="right">Bobby Kartoidjojo</div>

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Abstract

Private e-scooters are a recently introduced mode of travel for access and egress travelling in the Netherlands. The impact of owning such an e-scooter on the mode choice for access and egress is still very scarcely defined in literature with especially the mode shift and the determinants causing this mode shift. In this research a stated preference choice experiment was designed by means of a three-step approach which proved to be very flexible. The important constraint was to implement the constraint of when someone uses the e-scooter for access, that they will also use it for the egress trip. After this a discrete choice modelling was defined for both the access and egress trip. The result was that there is huge mode shift potential caused by mostly travel time savings and people who are young (18-35 years old) and highly educated. This huge potential can also have effects on aspects such as safety.

1 Introduction

Travelling from and to the train station, the so-called access and egress, several transport alternatives exist, each with its own characteristics and suitability for the traveller. For especially access and egress travelling, micro-modes such as bikes, mopeds and shared modes are suitable. Recently in the Netherlands, new micro-modes such as the private e-scooter have made its entrance and are suitable for especially short distances (König et al., 2022; Oeschger et al., 2020). This new micro-mode has many advantages as well a few disadvantages. The e-scooter can be brought into the train and thus be used for both the access as well the egress trip, avoiding waiting and walking times for public transport, is faster than bike and walking, does not require physical energy, it is an environmentally friendly alternative and are cost saving (Cao et al., 2021; Félix et al., 2023; Le Boennec & Salladarré, 2023; Yan et al., 2023). In literature, safety has been mentioned several times as an issue in cities where the e-scooter is operational. Drivers do not have to wear a helmet, making them vulnerable, cities are more crowded and makes cities thus less pleasurable to visit (Hirst, 2021).

When train travellers arrive at their destination stop, they still must travel a distance at the egress stage. Private modes here are problematic since, since they leave their private modes at the access stage, or distance is to too large for walking or public transport is scarce (van Kuijk et al., 2022). The private e-scooter could be a solution in solving these travelling issues. For both access as well egress, several mode alternatives exists both shared as well private. According to KiM (2023), bike (40%) is most used for access trips in the Netherlands followed by walking (30%) and btm (20%). For the egress stage a different mode split is observed. For the egress trip walking is the dominant mode (60%), followed by btm (22%) and bike (12%). As mentioned earlier, the e-scooter is a new mode in the Netherlands. The extend to which this private e-scooter can potentially replace other modes for both access as well egress trips (mode shift) as well the factors that influence this mode

shift is unclear in the Netherlands. This is the gap that has been filled in this research.

The report is structured as follows. In Chapter 2, the current literature on access as well egress mode choice is covered with a focus on the private e-scooter with the goal of extracting the mode choice factors that influences the mode choice for the private e-scooter. In Chapter 3, the methodology has been discussed to carry out this research. Then in Chapter 4, the results are discussed that has been obtained through applying the methodology of chapter 3 and finally in chapter 5, the main points are discussed.

2 Literature review

The private e-scooter is categorized as a micro-mode according to the internal transport forum (Santacreu et al., 2020). It is available shared as well private. In the Netherlands the private e-scooter is categorized as a Light Electrical Vehicle (LEV) which has the purpose to ensure safety and for customers to have an overview which e-scooters are allowed.

There are many literatures on access and egress mode choice in which private and/or shared micro-modes are included. Reck et al. (2022) and Azimi et al. (2021) showed that the personal e-scooter, replaces public transport, bike and car trips more as the distance increases. For short walking trips these are also replaced by the private e-scooter. Similar results was obtained by Le Boennec and Salladarré (2023), in which micro-modes substitute btm, but functions as a complimentary mode for the train, since there is more vehicle carrying capacity in the train. In Moinse et al. (2024) showed that 85% of e-scooter owners would like to use the e-scooter for both the access as well egress trips. In Oostendorp and Hardinghaus (2023) this share was even higher, 94%. Within a city, cars are also used for short distance trips. Glavić et al. (2021) and Oostendorp and Hardinghaus (2023) indicated that private e-scooters could replace car trips. The private e-scooter is an easy to carry mode into the train, since it can be folded and stored under the seat. The conventional bike on the other hand can be carried into the train, but depends on the

available capacity in the train, which makes the bike unattractive (Oeschger et al., 2020).

The method that dominates such mode choice modelling research is the stated preference methodology in which an alternative is shown as a hypothetical alternative including factors and numbers. In such a way, the importance can be derived that contribute to a mode choice. Research such as in Oeschger et al. (2023); Torabi et al. (2022); van Kuijk et al. (2022) have applied such methodology.

In literature many factors exist that contribute to a mode choice. Through a extensive literature review, seven categories were defined that encompasses the respective mode choice factors.

1. User characteristics. People younger than 35 years old use the private e-scooter and also people with a high income, a high education and people with a full-time job use the private e-scooter (Arias-Molinares et al., 2021; Christoforou et al., 2021; Reck et al., 2022).
2. Trip characteristics. The e-scooter is being used for mostly leisure, work and school. People use it for travel time savings and cost saving (Glavić et al., 2021; Hardt & Bogenberger, 2019).
3. Mode characteristics. Users of the e-scooters use it since it is environmentally friendly and for its convenience (Glavić et al., 2021; van Kuijk et al., 2022).
4. Build-environment characteristics. There is low e-scooter ridership around areas with high public transport density and a low e-scooter usage is observed where the proximity to the city centre if high (Lu et al., 2024).
5. Socio-psychological characteristics. Aspects such as previous experience, convenience, cost savings and environmental friendliness lead to the private e-scooter being used (Abdullah et al., 2025; Carroll, 2022; Kopplin et al., 2021; Oeschger et al., 2023; Roig-Costa et al., 2024).
6. External factors. Factors such as weather condition shows to have influence on the choice for the private e-scooter (Hardt & Bogenberger, 2019; Lu et al., 2024;

Oostendorp & Hardinghaus, 2023; Reck et al., 2022).
7. Unique factors. There was less literature on this category, but the private e-scooter feature of foldability can be seen as such a distinct factor. Due to this the private e-scooter can be stored easily in the train (Le Boennec & Salladarré, 2023).

These categories led to the conceptual model as can be seen in figure 1. This model served as the mode for the methodology and the design of the eventual survey that has been discussed in the next section. In this conceptual model, the relationship between the identified factors is shown. Eventually all the factors have influence on the outcome, the mode choice.

Many literatures on the mode choice for access or egress could be found, but for the Netherlands, no research could be found where both the access and egress have been jointly modelled through a stated preference study in which the private e-scooter is used for both the access and egress trip. Through the extensive literature review, the following gap was identified for the Netherlands.

1. The potential mode shift that the e-scooter might cause for multimodal trips.
2. The factors causing a mode shift.
3. The methodology of designing such experiment.

3 Methodology

During the discussion of the literature review, the most dominant method applied was the stated preference method, which on its turn is part of a survey. For the purpose of this research, the stated preference method was also applied. The reason for this method is because there is no revealed preference data available of the usage of the private e-scooter in the Netherlands and the factors influencing the choice for the private e-scooter can be assessed. This method adds the flexibility to assess the mode shift, the factors affecting this mode shift and analysing additional information. Designing the survey involves several actions. These involve determining the alternatives, attributes, attribute values, prior values and the experimental design. For this
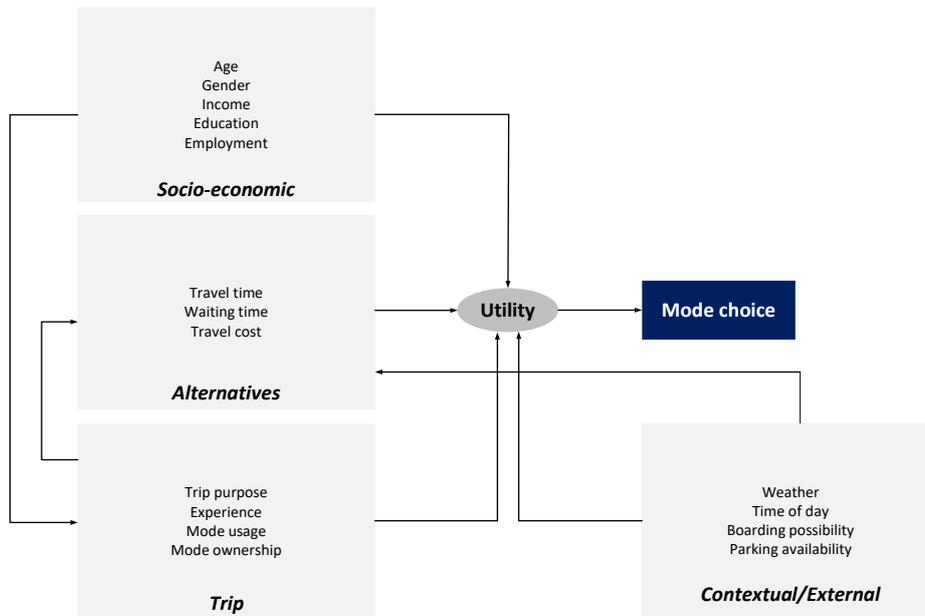
Figure 1 Conceptual Model

research for both the access and egress trip, the alternatives considered are btm (bus, tram, metro), bike, walking and the private e-scooter. As mentioned in KiM (2023), btm, bike, walking are the most used most in the Netherlands for access and egress trips. During the literature review several factors where mentioned and several has been used as well.

In table 1 the several alternatives are shown including alternative attributes and their levels.. All the attribute levels are numerical expect the comfort attribute which is a binary attribute level. The underlined attributes are egress in table 1.

The design is a stated preference experiment and to minimize correlation between attributes, prior values are necessary that have been obtained through literature as in (Arentze & Molin, 2013; Geržinič, Cats, et al., 2024; Geržinič, van Hagen, et al., 2024; Geržinič et al., 2023; Shelat et al., 2022; Singh et al., 2023; van Kuijk et al., 2022; Yap et al., 2020).

As mentioned earlier, the stated preference experiment is part of a survey. The survey starts with questions on the user their personal information such as their age, gender, education and income. After that, the respondent answers questions on their weekly travel behaviour such as train travel frequency, driver license ownership, current access and

Tabel 1 Attribute levels

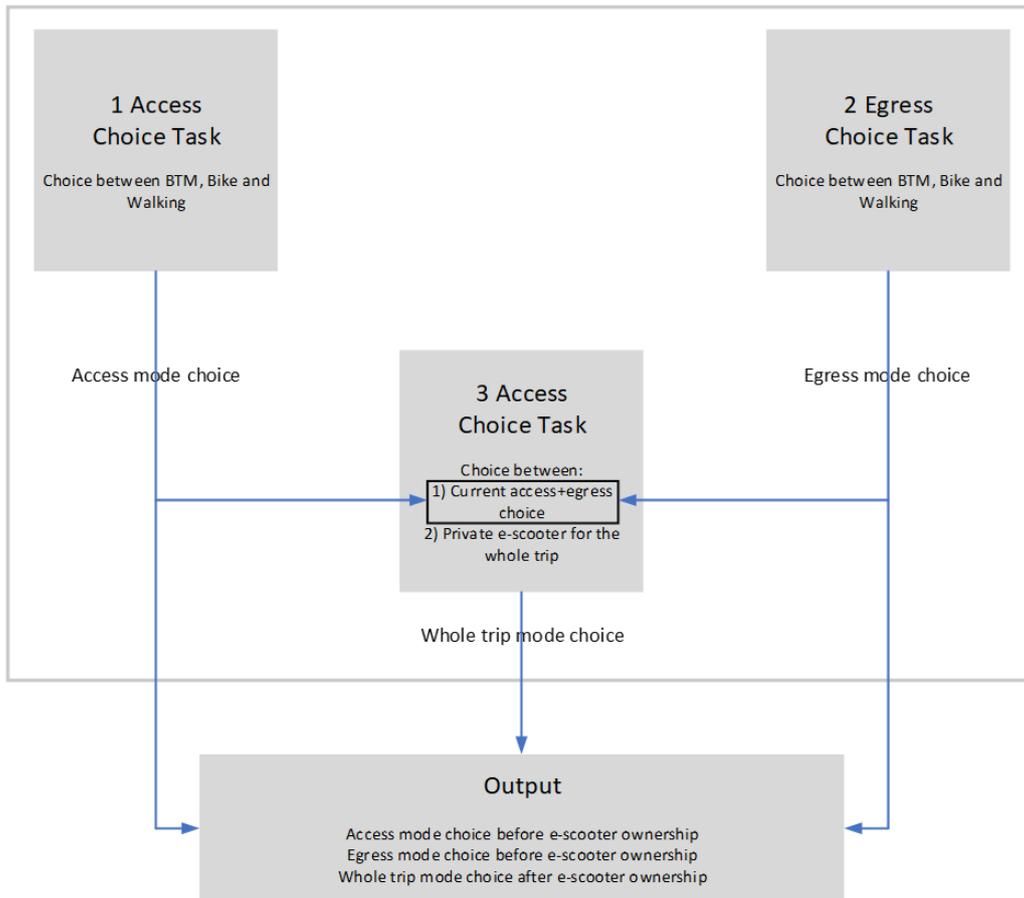| Attribute	Attribute level
Private e-scooter	
1 Access in-vehicle time	4, 8, 12
2 Comfort on the train	Stored, Holding
3 Egress in-vehicle time	4, 8, 12
4 PE space search time at destination	1, 3, 5
Bike	
5 Access in-vehicle time	4, 8, 12
6 Access bike parking search time	1, 3, 5
7 Egress in-vehicle time	4, 8, 12
8 Egress bike parking search time	1, 3, 5
BTM	
9 Access walking time BTM	2, 4, 6
10 Access In-vehicle time	3, 6, 9
11 Waiting time train	3, 6, 9
12 Access Travel cost access	1, 2, 3
13 Egress waiting time for BTM	3, 6, 9
14 Egress In-vehicle time	3, 6, 9
15 Walking time to destination	2, 4, 6
16 Egress Travel cost	1, 2, 3
Walking	
17 Access walking time	12, 18, 24
18 Egress walking time	12, 18, 24

Figure 2 Three step approach for the stated preference experiment

egress mode and their travel purpose. The third and last part of the survey, is the stated preference

For the stated preference part of the survey, a three-step approach is chosen (figure 2). Each respondent is shown 12 scenarios. Each scenario consists of three questions, access, egress and a whole trip question. The access and egress questions consists of the alternatives btm, bike and walking. The whole trip question had 2 alternatives. The first alternative is a combination between the respondent access and egress answer, and the second alternative is the private e-scooter. In this way the constraint of the e-scooter of using it for both the access and egress trip is satisfied. The private e-scooter cannot be combined with other modes.

In figure 4 an example of a stated preference choice scenario is shown. If someone chooses btm for access and bike for egress, then in question 3, the person can choose between the

two alternatives for the whole trip, btm + bike or private e-scooter + private e-scooter. In such way the potential mode shift can be assessed and the factors influencing this mode shift. The travel circumstances in which the respondents should pretend to be when answering these scenarios are shown in figure 3.

	Het weer	Droge zonnige dag met zomerse temperaturen en geen sterkte wind.
	Dag van reizen	Doordeweekse dagen, overdag.
	Treinreis duur	Het betreft een treinreis van ongeveer een uur.
	Baggage	U reist met een rugtas.
	Access en Egress afstand	De reisafstand voor de access en egress gedeelte is tussen de 1 en 2 km.
	Fiets en e-step bezit	U bezit een e-step. U bezit ook een fiets zowel aan de access als de egress zijde.

Figure 3 Travel circumstances

Scenario 1

Vraag 1: Welke vervoerswijze zou u kiezen om te reizen vanaf uw huis naar het treinstation (*access*)?

		BTM	Fiets	Lopen
🚶	Looptijd naar een BTM halte (minuten)	6		
🕐	Reistijd (minuten)	3	12	24
⏳	Wachtijd voor de trein (minuten)	3	3	3
🔍	Parkeerplek zoektijd (minuten)		1	
€	Reiskosten (euro's)	1		

🔘 BTM

⭕ Fiets

⭕ Lopen

Vraag 2: welke vervoerswijze zou u kiezen om te reizen vanaf het treinstation naar uw bestemming (*egress*)?

		BTM	Fiets	Lopen
⏳	Wachttijd voor de BTM (minuten)	9		
🕐	Reistijd (min)	3	12	24
🚶	Looptijd naar eindbestemming	6		
🔍	Parkeerplek zoektijd (minuten)		1	
€	Reiskosten (euro's)	1		

⭕ BTM

🔘 Fiets

⭕ Lopen

Vraag 3: bij deze vraag kijken we naar de gehele reis dus access en egress en trein ertussen. Stel dat u een **e-step bezit.** Zou u deze e-step gebruiken voor de gehele reis of zou u nog steeds de vervoerswijze kiezen die u gekozen hebt bij de vragen 1 en 2 hierboven?

		BTM	Privé e-step
🚶	Looptijd naar een BTM halte (minuten)	6	
🕐	Reistijd (minuten)	3	8
⏳	Wachtijd voor de trein (minuten)	3	3
🔍	Parkeerplek zoektijd (minuten)		
€	Reiskosten (euro's)	1	
🛡	Comfort in de trein met de e-step		Comfortabele treinrit omdat de e-scooter geborgen is.
		+	+

		Fiets	Privé e-step
⏳	Wachttijd voor de BTM (minuten)		
🕐	Reistijd (min)	12	4
🚶	Looptijd naar eindbestemming		
🔍	Parkeerplek zoektijd (minuten)	1	5
€	Reiskosten (euro's)		

🔘 Ik zou de e-step kiezen voor de gehele reis

⭕ Ik zou dezelfde vervoerswijze kiezen zoals ik gekozen heb bij de vragen 1 (BTM) en 2 (fiets)

Figure 4 A choice scenario example

4 Descriptive statistics

As said earlier the survey was divided in three parts, user characteristics, trip characteristics and the stated preference survey. In table 2 the division in answers from the sample considering user characteristics is shown and in table 3, the division of the trip characteristics answers. A total of 145 responses were collected of which 118 responses were eligible for analysis. The survey was designed and distributed online through Qualtrics.

Tabel 2 Trip characteristics sample size

User characteristic	Category	Sample
Age	Younger than 18	0 %
	Between 18 and 35	95 %
	Older than 35	5 %
Gender	Male	41 %
	Female	59 %
	Non-binary	0 %
	Prefer not to say	0 %
Education	Primary school	0 %
	High school	16 %
	Undergraduate	49 %
	Graduate	31 %
	PhD or higher	1 %
	Prefer not to say	3 %
Average monthly income	2500 and lower	45 %
	Between 2500 and 4500	26 %
	Higher than 4500	8 %
	Prefer not to say	21 %
Occupation	Part-time job	13 %
	Full-time job	41 %
	Jobseeker	1 %
	Student	44 %
	Volunteer	0 %
	Retired	0 %
	Unable to work	0 %
	Prefer not to say	1 %

Especially undergraduate students took part in the survey. Most of the respondents have a low-income. Many of the respondents have a full-time job. To be mentioned is that the survey was particularly distributed to young people (<35 years) who are students. These are the specific group that uses the e-scooter as also was the result in Christoforou et al. (2021); Glavić et al. (2021); Oeschger et al. (2023)

Tabel 3 Trip characteristics sample

Trip characteristic	Possible answers to choose from	Sample
Train travel frequency	0–1	42 %
	2–4	45 %
	5--7	13 %
Travel purpose	Work	30 %
	School	28 %
	Leisure	32 %
	Other	10 %
Current access mode	Walking	26 %
	BTM (bus, tram, metro)	36 %
	Bike	20 %
	Shared modes (e-moped, bike, e-bike, e-car)	3 %
	Light-electric vehicles, LEV (e-bike, e-scooter, e-moped)	0 %
	Car as a driver	11 %
	Car as a passenger	3 %
	Other	1 %
Current egress mode	Walking	41 %
	BTM (bus, tram, metro)	47 %
	Bike	3 %
	Shared modes (e-moped, bike, e-bike, e-car)	2 %
	Light-electric vehicles, LEV (e-bike, e-scooter, e-moped)	0 %
	Car as a passenger	4 %
	Other	3 %
E-scooter ownership	Yes	1 %
	No and I have no intention to buy one	83 %
	No, but I am considering to buy one	16 %
E-scooter driving experience	Yes	55 %
	No	45 %
Driving license ownership	No	20 %
	Yes and I own a car	41 %
	Yes, but I do not own a car	39 %
Micro-vehicle ownership	Yes	65 %
	No	35 %

Considering trip characteristics, people travel around three times per week by train. The dominant access mode of the respondents is btm (36%), followed by walking (26%) and bike (20%). The dominant egress mode of the respondent is btm (47%), followed by walking (41%). These divisions are in line with the observations in KiM (2023). Furthermore

around 80% of the respondents own a driving license.

Considering the potential mode shift to the private e-scooter in terms of the whole trip (access + egress) are shown in table 4. The largest shift towards the private e-scooter is observed at the bike-bike chain, amounting to 13% of all the trips made. In table 5, The mode split of access and egress separately is shown. The private e-scooter has the highest mode share in access and egress, around 37% of all the trips would be made with the private e-scooter when people would own one. Compared to results in other literature in which the usage was between 80 and 95% (Moinse et al., 2024; Oostendorp & Hardinghaus, 2023), the mode share of 37% for the private e-scooter in the Netherlands is much lower, but still the potential dominant alternative when train travellers would own one.

Table 4 Potentieel mode shift due to the private e-scooter

	Chain	N	Shifted to PE-PE by chain (%)	Shifted to PE-PE by total N (%)
1	BTM-BTM	193	32%	6%
2	BTM-BIKE	119	45%	5%
3	BTM-WALKING	56	29%	2%
4	BIKE-BTM	65	35%	2%
5	BIKE-BIKE	344	39%	13%
6	BIKE-WALKING	77	40%	3%
7	WALKING-BTM	32	38%	1%
8	WALKING-BIKE	78	42%	3%
9	WALKING-WALKING	93	25%	2%

Table 5 Access and egress, mode split

Mode	Access		Egress	
	N	(%)	N	(%)
BTM	238	22%	194	18%
Bike	297	28%	320	30%
Walking	135	13%	156	15%
Private e-scooter	387	37%	387	37%

Discrete choice modelling

The data obtained from the survey has been analysed through discrete choice modelling. Through this method the influence of the alternative attributes, user and trip characteristics on the mode choice can be analysed. Several choice models exist. In this research the mixed logit model (ML) and the nested logit model (NL) have been applied. The ML model is suitable since the data obtained is of a panel structure and to minimize correlation among alternatives, this model is suitable. The access and egress trips have been analysed separately with the ML model and the whole trip has been analysed with the NL model. Through a NL model, similarities between alternatives can be considered.

For both models, utility theory plays an important part. According to utility theory a person selects the alternative that has the highest utility. In equation 1, the utility is shown (Ben-Akiva & Bierlaire, 1999).

$$U_{in} = V_{in} + \varepsilon_{in} \ (1)$$

In equation 2, the part can be observed V_{in} is shown in equation 2. In this equation, the attributes that were included in the choice experiment are included in equation 2. In the error term part ε_{in}, all other not-observed variables are captured.

$$V_{in} = \sum_{k} \beta_k * x_{ink} \ (2)$$

Each alternative has an alternative specific constant, which indicates the average effect of unobserved factors, so when all other observed factors are zero. Eventually equation 3 is formed.

$$U_{in} = ASC_i + \sum_{k} (\beta_k * x_{ink}) + \varepsilon_{in} \ (3)$$

These three equations serve as a base for the ML and NL model. For access, the equations 4,5,6,7 were constructed and for egress, equations 8,9,10,11. In table 6 and table 7, a description of the access variables is shown

and in table 8 a description of the egress variables.

Access utility functions

$$V_{a\_btm} = ASC_{a\_btm} + \beta_{a\_btm\_wktb} * a\_btm\_wktb + \beta_{a\_btm\_tt} * a\_btm\_tt + \beta_{a\_btm\_wat} * a\_btm\_wat + \beta_{a\_btm\_c} * a\_btm\_c + \varepsilon_{a,btm} \quad (4)$$

$$V_{a\_bike} = ASC_{a\_bike} + \beta_{a\_bike\_tt} * a\_bike\_tt + \beta_{a\_bike\_pst} * a\_bike\_pst + \varepsilon_{a,bike} \quad (5)$$

$$V_{a\_pe} = ASC_{a\_pe} + \beta_{a\_pe\_tt} * a\_pe\_tt + \beta_{com_{pe}} * com\_pe + \varepsilon_{a,pe} \quad (6)$$

$$V_{a\_walking} = ASC_{a\_walking} + \beta_{a\_walk\_tt} * a\_walk\_tt + \varepsilon_{a,walking} \quad (7)$$

Egress utility functions

$$V_{e\_btm} = ASC_{e\_btm} + \beta_{e\_btm\_wab} * e\_btm\_wab + \beta_{e\_btm\_tt} * e\_btm\_tt + \beta_{e\_btm\_wktd} * e\_btm\_wktd + \beta_{e\_btm\_c} * e\_btm\_c + \varepsilon_{e,btm} \quad (8)$$

$$V_{e\_bike} = ASC_{e\_bike} + \beta_{e\_bike\_tt} * e\_bike\_tt + \beta_{e\_bike\_pst} * e\_bike\_pst + \varepsilon_{e,bike} \quad (9)$$

$$V_{e\_pe} = ASC_{e\_pe} + \beta_{e\_pe\_tt} * e\_pe\_tt + \beta_{e_{pe_{pst}}} * e\_pe\_pst + \varepsilon_{e,pe} \quad (10)$$

$$V_{e\_walking} = ASC_{e\_walking} + \beta_{e\_walk\_tt} * e\_walk\_tt + \varepsilon_{e,walking} \quad (11)$$

Access ML model

By using the obtained stated preference experiment data and the utility functions, the attributes could be estimated by using biogeme. Besides the observed alternative attributes, the trip characteristics were also considered and coded as dummy variables (table 6), in which one of the level is the base, to avoid the dummy variable trap (Stock & Watson, 2019). The results are shown in table 7.

Tabel 6 Description of the access variables

Trip attributes	Coefficient	Levels
Current access mode (cam)	$\beta_{access\_pe\_cam\#}$	3 Walking (base) 0 bike (base) 1 BTM
Current egress mode (cem)	$\beta_{egress\_pe\_cem\#}$	0 Walking (base) 1 BTM
E-scooter driving experience (ee)	$\beta_{pe\_ee\#}$	0 Yes (base) 1 No
Travel purpose (tp)	$\beta_{pe\_tp\#}$	0 Work (base) 1 Leisure 2 Education
Driving license (d)	$\beta_{pe\_d\#}$	1 No (base) 0 Yes, but no car 2 Yes and I also own a car
Train frequency (tf)	$\beta_{pe\_tf\#}$	2 0 − 1 (base) 0 2 − 4 1 5 - 7

Table 7 Access ML model results

	Estimate	p-value
ASC		
$ASC_{a,bike}$	**-2.01***	0.00
$ASC_{a,btm}$	-1.36	0.14
$ASC_{a,pe}$	**-5.22***	0.00
Alternative attributes		
$\beta_{a\_bike\_pst}$	**-0.364***	0.00
$\beta_{a\_bike\_tt}$	**-0.29***	0.00
$\beta_{a\_btm\_c}$	**-0.40**	0.02
$\beta_{a\_btm\_tt}$	**-0.15***	0.00
$\beta_{a\_btm\_wat}$	**-0.18**	0.02
$\beta_{a\_btm\_wktb}$	**-0.42***	0.00
$\beta_{a\_pe\_tt}$	**-0.16***	0.00
β_{com_pe}	0.33	0.22
$\beta_{a\_walk\_tt}$	**-0.41***	0.00
Explanatory variables		
$\beta_{access\_pe\_cam3}$	0 (base)	
$\beta_{access\_pe\_cam0}$	-0.39	0.64
$\beta_{access\_pe\_cam1}$	**-1.77***	0.00
$\beta_{egress\_pe\_cem0}$	0 (base)	
$\beta_{egress\_pe\_cem1}$	0.26	0.65
β_{pe_d1}	0 (base)	
β_{pe_d0}	0.74	0.24
β_{pe_d2}	**1.32**	0.04
β_{pe_ee1}	0 (base)	

$\boldsymbol{\beta_{pe\_ee0}}$	**1.58***	*0.01*
$\boldsymbol{\beta_{pe\_tf2}}$	*0 (base)*	
$\boldsymbol{\beta_{pe\_tf0}}$	**1.03***	*0.07*
$\boldsymbol{\beta_{pe\_tf1}}$	*0.59*	*0.58*

In table 7, the results of the ML access model Is shown. Considering ASC's, the private e-scooter has the highest base utility, compared to the other alternatives, but in reality, the mode choice is also influences by other factors such as shown in the conceptual model of figure 1. People who travel 2-4 times per week, who have previous e-scooter experience and who own a driving license are more likely to choose the private e-scooter. The statistically significant result for driving license and car ownership is an indication on the potential shift from car to the private e-scooter. This is still a gap that needs more empirical research. Unfortunately, the comfort level for the private e-scooter is not statistically significant, although it has positive contribution in choosing the private e-scooter and a small standard deviation, it is also likely that people will choose the private e-scooter if someone can store the private e-scooter in the train. The travel time coefficient for private e-scooter shows a strong effect compared to the travel time coefficient of other alternatives when also considering the levels that were defined during the stated preference design. This could mean that people who choose the private e-scooter, are likely to do so because of travel time savings. Other factors such as btm costs, walking time and parking search time have strong negative effect, meaning that due to these factors the other modes are less likely to be chosen.

Egress ML model
In table 9, the results of the egress ML model is shown. Almost all variables are not statistically significant. For this, there are several explanations. 1) The sample size was too small, making it harder for the model to achieve optimality, 2) Irrational answering of the egress questions. It is likely that people did not choose the best answer for the egress choice tasks, 3) Correlation of the egress attributes with variables that are not included in the model. This could lead to an incomplete

model. For the egress model, trip characteristics were not included since it is enough to see the influence of these variables on the choice for the private e-scooter. The private e-scooter as mentioned numerous times, is used for both access and egress.

Table 8 Egress variables

Term	Description
V_{e_btm}	Utility of egress BTM
V_{e_bike}	Utility of egress Bike
V_{e_pe}	Utility of egress private e-scooter
$ASC_{e,btm}$	Alternative specific constant for egress BTM
$ASC_{e,bike}$	Alternative specific constant for egress bike
$ASC_{e,pe}$	Alternative specific constant for egress PE
$ASC_{e,walking}$	Alternative specific constant for egress walking
$\beta_{e\_btm\_wab}$	Egress waiting time for bus coefficient
$\beta_{e\_btm\_tt}$	Egress BTM in-vehicle time coefficient
$\beta_{e\_btm\_wktd}$	Egress walking time to destination coefficient
$\beta_{e\_btm\_c}$	Egress BTM travel cost coefficient
$\varepsilon_{e,btm}$	Error term for egress BTM
$\beta_{e\_bike\_tt}$	Egress bike travel time coefficient
$\beta_{e\_bike\_pst}$	Egress bike parking search time coefficient
$\varepsilon_{e,bike}$	Error term for egress bike
$\beta_{e\_pe\_tt}$	Egress private e-scooter travel time coefficient
$\beta_{e\_pe\_pst}$	Egress parking search time for the private e-scooter coefficient
$\varepsilon_{e,pe}$	Error term for egress private e-scooter
$\beta_{e\_walk\_tt}$	Egress walking travel time coefficient
$\varepsilon_{e,walking}$	Error term for egress walking

Table 9 Egress ML model results

Alternative attributes	Estimate	p-value
$ASC_{e,bike}$	0.63	0.24
$ASC_{e,btm}$	**-2.63****	0.02
$ASC_{e,pe}$	-0.39	0.49
$ASC_{e,walking}$	**0 (base)**	-
$\beta_{e\_bike\_pst}$	-0.02	0.73
$\beta_{e\_bike\_tt}$	-0.02	0.50
$\beta_{e\_btm\_c}$	0.20	0.27
$\beta_{e\_btm\_tt}$	0.04	0.47
$\beta_{e\_btm\_wab}$	0.14**	0.01
$\beta_{e\_btm\_wktd}$	0.03	0.71
$\beta_{a\_pe\_tt}$	0.08***	0.01
$\beta_{e\_walk\_tt}$	**-0.06***	0.07
$\beta_{e\_pe\_pst}$	0.09	0.11

Cross-sensitivity analysis

To know how the choice for the private e-scooter would change when the time attribute of other alternatives would change, the cross-sensitivity method can be applied shown in equation 13 (Goolsbee et al., 2019).

$$E_{ij}^P = \frac{\%\Delta P_i}{\%\Delta tt_j} = \frac{\Delta P_i}{\Delta tt_j} * \frac{tt_j}{P_i}$$
$$= \frac{P(t2) - P(t1)}{t2 - t1} * \frac{tt_1}{P1} \quad (13)$$

For this method the MNL is the underying method in which the error term can be neglected when computing the probabilitie, since the error terms are of extreme value 1 distribution or Gumbel distribution and the MNL has the IIA property. The statistically significant values of the ML base model were used.

The travel times were varied between 5-30 minutes with a time interval of 1 minute. Due to this the probability changes in choosing the private e-scooter could be determined and shown in figure 6. For all the three alternatives, the biggest change in choosing the private e-scooter is observed when the travel times are between 5-15 minutes and the travel times are changed there. At 5 minutes the highest change in probability is observed. At that time point, a 1% travel time change at 5 min for walking causes an

increase of 0.2281% likelihood of choosing the private e-scooter. So changes at small travel times, causes most increases in the likelihood of choosing the private e-scooter.

6 Conclusion

The three-step approach of the choice experiment showed to prove very beneficial when defining the mode choice due to the e-scooter ownership. The important constraint was that people who use the private e-scooter for the access, use it also for the egress stage. However, this approach needs improvement on especially how to eventually achieve the optimal mix of respondents, statistical significance of determinants for both the access and egress experiment. The results presented are more applicable for a specific group. I would also be interesting to also include a more diversified group to see which user and trip characteristics cause this mode shift to the private e-scooter. This huge potential cause by e-scooter ownership for access and egress trips should be carefully taken into consideration when designing policies for improved access and egress travelling.
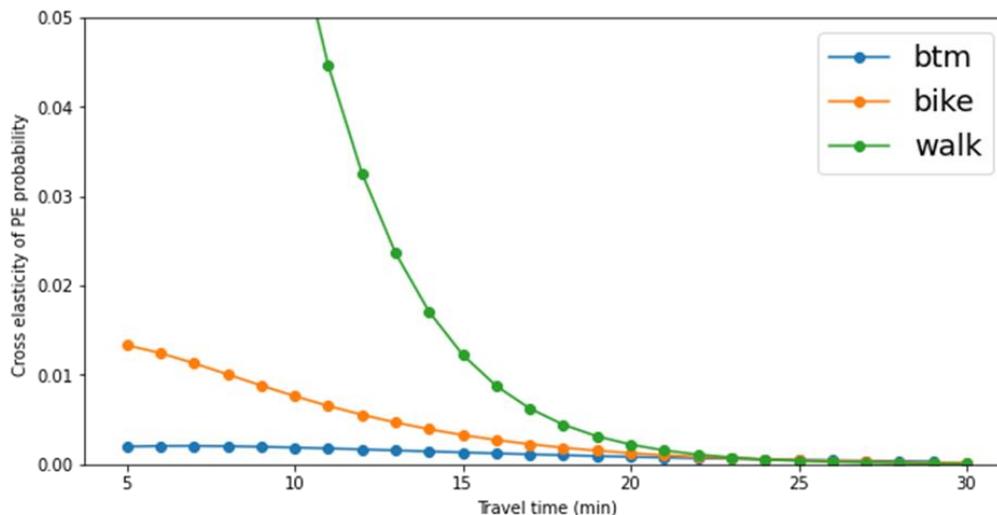
Figure 5 Cross-sensitivity due to travel time change

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Summary

In this summary the research has been discussed in short, including the background of this research, the methodology, the results and finally a discussion of the results has been provided.

Introduction

Access/first mile is when someone travels from home to the public transport station and egress/last mile is when someone travels from the public transport station to a destination. Many transport alternatives exist for these trips. Recently, new alternatives are available that are suitable for short distances such as the shared/private e-scooter. Literature on shared mode choice is in abundance, but literature in the Netherlands concerning mode choice behaviour due to e-scooter ownership is very scarce. From the 1st of July, the e-scooter is allowed in the Netherlands only if it is approved and provided with a license plate. By using the private e-scooter, the user, avoids waiting times, walking times and can use a route of its choice and it is electrically driven. The major advantage is that the e-scooter can be brought into the train and stored by folding it and thus can be used for both the access and egress trip. The point that is unclear concerning the private e-scooter in the Netherlands, is its mode shift potential for access and egress trips when train users own such an e-scooter and the characteristics that influences the mode choice for these e-scooters.

Literature review

During the literature several aspects were reviewed such as access/egress mode choice, research methodologies and mode choice determinants. From literature it was clear that the e-scooter is used for short distances mostly, is a complement to the train for long distance travel and the e-scooter replaces walking, bike and car trips. Concerning methodology, the stated preference methodology is mostly used, to see what the influence is of user and alternative characteristics on the mode choice. Also, literature review was carried out to identify attributes that has an influence on the mode choice for access and egress trips. These were categorized in seven group characteristics: user (age, gender), trip (travel time, travel cost), mode (comfort, safety), build-environment (public transport density), socio-psychological (experience, emotion), external (weather) and unique (boarding possibility). The e-scooter is mostly used by young, highly educated people, who would like to save especially on travel time and are environmentally conscious. They use the e-scooter for especially education and leisure trips, since the e-scooter offers convenience and the e-scooter can be taken onto the train.

Methodology

The stated preference methodology was applied, since in the Netherlands there is no data available on the usage of the private e-scooter. Through the stated preference methodology, the e-scooter can be added as a hypothetical alternative and every person that took part in the survey was told to assume that they own an e-scooter. The stated preference experiment was divided into three parts, an access question, an egress question and a whole trip question. In the first two questions the alternatives are BTM, bike and walking. In the third question, two alternatives are shown, 1) a combination between the first two questions, 2) private e-scooter that can be used for both access and egress. Also, attributes such as travel time, travel cost, walking time and comfort were added to the alternatives. The attributes and its levels were chosen as realistically as possible. The survey was furthermore accompanied by questions on the user characteristics and their trip characteristics. Through this method of three questions, an indication on the mode shift potential could be determined and the factors that have an influence on the mode choice for the private e-scooter.

Results

After the stated choice experiment was carried out, data was collected and analysed through discrete choice modelling. Since the collected data was of a panel structure, because each person answered 12

choice scenarios', the mixed-logit model was applied. In the mixed logit model, every error term was varied instead and correlations among choice situations can be taken into account as well.

The results show that especially people who travel by bike on access and bike on egress are likely to switch to the private e-scooter in 13% of the trips if they would own a private e-scooter. The next group are the BTM-BTM travellers who would like to switch to the private e-scooter in 6% of the scenarios. When looking at the access and egress trips separately, train travellers would like to switch to the private e-scooter in 37% of the trips, since train travellers can take the e-scooter onto the train and use it for both access and egress. Choosing the private e-scooter in 37% of the trips is an indication of the probability of choosing the private e-scooter. Compared to literature, this percentage is much lower, since in literature the percentage of people who use their privately owned e-scooter is around 80% to 95%. The user factors that contribute to this mode choice are people who travel 2-4 days per week by train, people who own a driver's license and a car, people who would like to save on travel time and people who have experience with such an e-scooter. The likely switchers are young people between 18 to 35 years old, have a high education or are full-time employed. Furthermore, the travel time valuation is much higher for the private e-scooter and btm than that of walking and bike, indicating that people prefer faster travelling for access and egress. Determinants such as parking search time and btm travel cost leads to less probability of choosing the bike or btm. The egress data was also analysed, but not relevant results could be obtained, probability because of a small sample size, not rational answers, or other determinants necessary to improve the model. Based on a sensitivity analyses it was seen that when the travel time increases for walking at around 5 min, the probability of choosing the private e-scooter increases. Less sensitivity was observed when the travel time of btm and bike were increased. Only travel time was included for the sensitivity analysis.

Conclusion
The three-step approach is a very solid method of defining the mode shift caused by the private e-scooter and at the same time the factors influencing the mode choice can be defined. This approach however needs a large sample size to obtain robust statistically significant estimations. This approach can be further improved by finding the optimal mix of sample size, choice for attributes, attribute levels and alternatives. The results presented are based on the hypothetical introduced alternative of the private e-scooter. After some time, a follow-up research can be conducted by collecting revealed preference data to see the actual mode shift caused by the private e-scooter for access and egress trips, since the private e-scooter is allowed from the 1st of July 2025 by approval and are provided with a license plate. Concerning policy, there is a huge mode shift potential when train travellers own a private e-scooter. People can bring the e-scooter into the train. These benefits of owning the private e-scooter can have its effects on capacity in the train, but also on safety on street, where the private e-scooter and the bike share the same bike lane. Also, liveability in cities can be affected, since these e-scooters can make the city centre crowded. So, decision makers should take into account the mode shift potential as well the effects caused by these e-scooters when wanting to improve access and egress travelling.

Contents

Tables

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1 Introduction

In this chapter, the motivation for carrying out this research has been discussed including a short background of the research, the research goal, the research questions and finally the structure of the research.

1.1 Research background

There are a wide range of transport options available within a city for different purposes. When travelling from home to a train station and from a train station to a destination and back, also known as access/egress, several transport options are available to choose from such as public transport (bus, tram, metro), walking and cycling. More recently, shared options are available such as shared e-car, shared e-bike, and shared e-moped. The newest transport modes are more focused on short distances which are the micromobility vehicles consisting of vehicles such as the e-scooter, e-bike, e-moped and self-balancing-vehicles (König et al., 2022; Oeschger et al., 2020).

Many literature exist which have done research into access and egress in which different modes are involved privately and/or shared for different countries (Azimi et al., 2021; Meng et al., 2016; Mo et al., 2018; Oeschger et al., 2023). Generally, the conclusion was that the mode choice for access/egress is influenced by the user characteristics, trip characteristics and the build environment. Concerning user characteristics, Oeschger et al. (2023) found that younger (<35 years) people and males are more likely to choose the more recent modes such as e-scooter and e-bike, whereas females and older people, are more likely to choose walking. Considering trip characteristics, Meng et al. (2016) mentioned that for short distances, people tend to walk, for longer distances, travellers use bicycle and for even longer distances, people use public transport. Considering land-use and build-environment characteristics people who live close to a transit station, but also in an area with high socioeconomic activities, have a higher preference for walking for access and egress (Mo et al., 2018). So, several factors can have influence on which mode someone chooses for which trip purpose.

Mode choice for access/egress including public transport, private modes (walking, cycling), shared-modes (e-scooter, e-bike) have been well explored. The emerging modes have been less well explored. The shared e-scooters have been well explored despite its recent entrance into the transport market, which was first introduced in 2017 by the company Bird and later Lime (Aarhaug et al., 2023; König et al., 2022). The shared e-scooters are accepted differently across various countries. Many countries have allowed the e-scooter to be used, but also cities have banned the e-scooter. Paris has banned the shared e-scooter from 2023, and Madrid and Copenhagen had initially banned the e-scooter but reversed the ban with additional conditions. Private e-scooter are however allowed in Paris. Since the 1st of July 2025 the private e-scooters are allowed in the Netherlands which must be approved and provided by a license plate. On the other hand, the private e-scooter, has been less well explored especially when used for access/egress.

E-scooters have numerous benefits. The e-scooters are substitutes for short car trips, reducing greenhouse gas emissions and the e-scooters can serve as access/egress transport (Yan et al., 2023). The e-scooters require little space for parking and usage (Wang et al., 2023). Also, the e-scooters are cost saving (Félix et al., 2023). Besides the benefits, e-scooters also have several disadvantages. Safety is a major issue when dealing with e-scooters, safety of the driver and safety of the other road users (Hirst, 2021). Drivers do not have to wear a helmet, makes them vulnerable in case of an accident. Other road users can be injured if a driver on a e-scooter collide with them. More e-scooters emerge on the streets, making a city more crowded and as a result, less pleasurable to visit. A benefit of owning

a e-scooter, is that a person can use it anytime and anywhere including using the e-scooter for access and egress trips and even bringing the e-scooter along in the (public) transport vehicle (Le Boennec & Salladarré, 2023; Oeschger et al., 2020).

1.2 Research motivation and research gap

Through travelling by train, people can be brought from one city to another. Accessing a train station involves bridging a distance usually from home to the train station known as the access trip, which can be done with a private mode, shared mode or with public transport. When arrived at the destination stop with train, the traveller must also bridge a distance to the destination, by means of one or several modes. Private modes could be problematic here, as their bicycle is left at the access side, or the distance is too large for walking or public transport is just scarce or there is too much waiting time (van Kuijk et al., 2022). In this case, the private e-scooter could be a solution, which can be used for an access trip, be brough into the train and be used for the egress trip as well (Le Boennec & Salladarré, 2023; Oeschger et al., 2020). When using the e-scooter both shared as well private, waiting time for public transport can be avoided, also indirect travel is avoided and walking times to car or public transport at both access and egress side is avoided (Cao et al., 2021). So, when someone owns a e-scooter, what impact does this have on the usage of other modes for access/egress.

Considering the e-scooter, these are available shared as well private. There has been much research on the potential and preference of shared e-scooter for egress/access (Christoforou et al., 2021; Fearnley et al., 2020; Le Boennec & Salladarré, 2023; Oeschger et al., 2023; van Kuijk et al., 2022). Very few papers have addressed the influence of choosing a private e-scooter as an access/egress mode (Christoforou et al., 2021; Le Boennec & Salladarré, 2023; Reck et al., 2022). These papers are all based on revealed preference and not stated preference data. With revealed preference data is meant, data collected through a survey in which people are asked on their actual trip characteristics and with stated preference data is meant, data collected through a survey in which people are asked to make a mode choice including possible hypothetical alternatives. There has been one paper, Oeschger et al. (2023), who did research into the private-e-scooter using stated preference, but only for the first-mile. There is another paper that uses revealed preference data, in which they analysed the access and egress trip separately by including trip and user characteristics Azimi et al. (2021)There are also papers who did research into the mode substitution effect of the private e-scooter on unimodal modes such as car (Christoforou et al., 2021; Oostendorp & Hardinghaus, 2023). The results show that the private e-scooter replaces car trips, but it is still unclear on the potential mode shift from car to private e-scooter in combination with train. So, the travel behaviour concerning mode choice of the private e-scooter for both multimodal and unimodal trips have not been explored till the authors "best knowledge". But in this research only multimodal trips have been considered. This is the gap, that has been tried to be filled in this research.

To see what impact, owning a e-scooter might have on the mode choice for access/egress and its implication of mode shift, the Netherlands has been chosen to do this research. The reason for the Netherlands, is because of its high usage of bicycles for access trips and walking for egress trips as indicated in table 1 (KiM, 2023). On the egress part, walking trips are mostly observed, followed by public transport (bus, tram, metro). On the egress part, the share in bike is lower compared to the access part. This could be due to bike ownership, being lower on the egress side. Furthermore, in the Netherlands, no shared e-scooters are available, however some e-scooters that are approved by the government are allowed. In the Netherlands the e-scooters are called e-steps, but for convenience in this research and consistency with English literature, the term e-scooter has been used from here onwards. The e-scooters are categorized in the light electric vehicles (LEV) category in the Netherlands which includes other micromobility vehicles. A lot of e-scooters, apart from some e-scooter brands,

were banned in the Netherlands, after the accident in 2018 in which four children died involving a carrier e-bike that became uncontrollable and crashed against a train (NOS, 2018). As mentioned earlier from the 1st of July 2025, private e-scooters are allowed in the Netherlands. Research on these private e-scooters in the Netherlands has been scarce on especially the travel behaviour for access and egress trips when owning an e-scooter.

Table 1 Mode share on access/egress modes in the Netherlands

Mode	Access trip (%)	Egress trip (%)
Walking	30	60
Car (as passenger or as driver)	8	5
Bus, tram, metro	20	22
Bike	40	12
Other	2	1

In short, this research contributes to the following two research gaps:
1) **The potential mode shift that the private e-scooter might cause for multimodal trips**
2) **Influence of mode choice determinants (user, trip and attribute) on the choice for the private e-scooter**

1.3 Research questions and scope

In this section the research scope and research questions have been discussed.

Scope
Modality: in this research multimodal trips are considered. A multimodal trip is defined as a chain of trips consisting of various modes. The various trips that are considered in this research are access, main, and egress trip. Note that a multimodal trip can also be a trip consisting of just two different modes (Hamersma & de Haas, 2020).

Region: for this research, the Netherlands has been chosen, due to high train usage and high bike usage for access trips, and no research has been done previously on the impact of these private e-scooters on the mode choice for multimodal trips. Focusing on a city only would not be suitable, since the focus is on train travellers who go to and from the train station.

Travel behaviour aspect: travel behaviour is a very abstract term which is influenced by factors such as perceptions, attitudes, preferences, habits and lifestyle (Van Acker et al., 2010). In De Vos et al. (2022) mode choice is seen as travel behaviour. When placed in a bigger picture, mode choice is related to intention, satisfaction, desire, and attitude directly and indirectly. In this paper, they have done a literature review on travel behaviour and concluded that the literature considering travel behaviour can be categorized in travel attitudes, travel mode choice and travel satisfaction. In this research the focus is on travel mode choice since the aim is to examine the impact of owning a e-scooter on the mode choice for access and egress trips.

Main research question
"What is the potential impact on the travel behaviour for multi-modal trips when train travellers own an e-scooter?"

The main research question should give an answer based on these three aspects:
- The factors that determine using the private e-scooter
- The potential mode shift for multimodal (access and egress) trips due to owning a e-scooter
- The profiles of the private e-scooter users

These three aspects are covered during the three sub-research questions as discussed below.

Sub-research question 1: *what are travellers their behaviour concerning mode choice for access/egress trips when owning a private mode?*
During this sub-research question, the current knowledge on access/egress travel behaviour concerning mode choice to train stations are reviewed by means of a literature review. During the literature review the focus was not only on private modes including private e-scooters, but also on other modes that the private modes compete with such as shared modes.

Sub-research question 2: *Which factors are relevant for access and egress mode choice in which the private e-scooter is chosen?*
The factors that have been explored during this sub-question by means of a literature review are factors that can have influence on the mode choice for access and egress including user, trip and alternative mode factors.

Sub-research question 3: *Which determinants contribute to a mode shift due to e-scooter ownership?*
During this sub-research question, the actual mode choice determinants for the private e-scooter, user profile and potential mode shift should be obtained. The main approach is the stated preference methodology, because there is no revealed preference data available of private e-scooter mode choice in the Netherlands and by using the stated preference experiment, the private e-scooter can be added as a hypothetical alternative and thus be able to obtain the potential mode shift of the private -scooter.

In figure 1, the connection between the research questions has been shown.
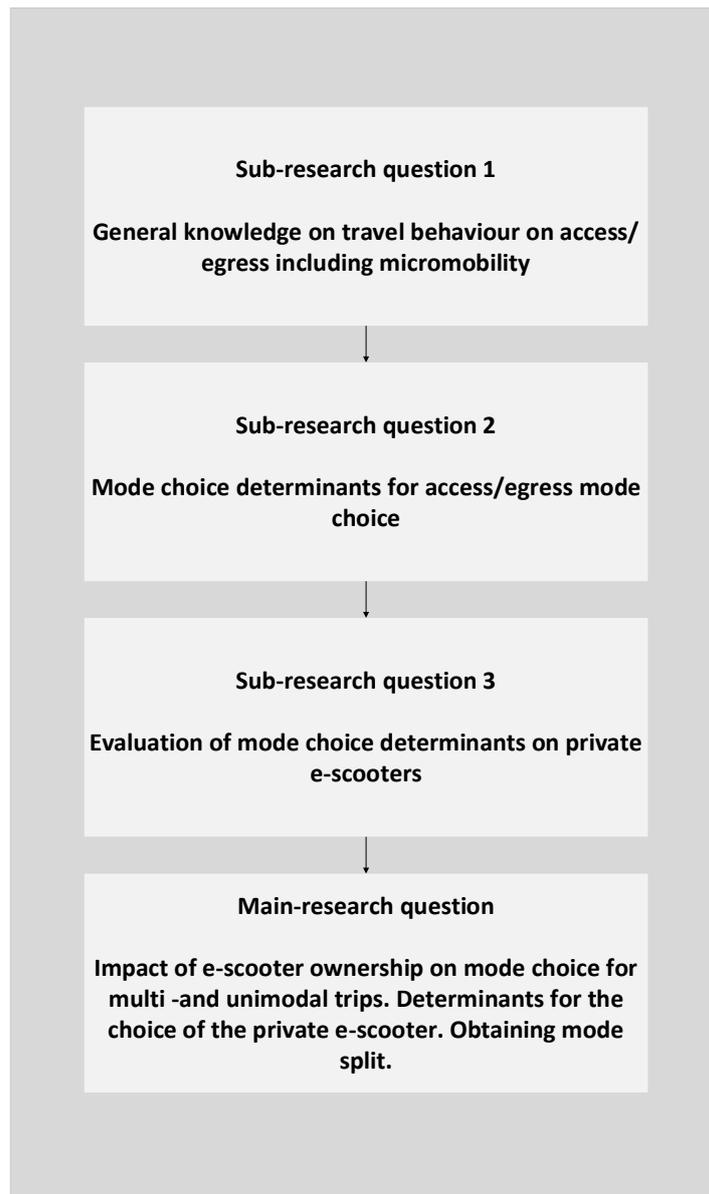
Figure 1 Connection between research questions

1.4 Social and scientific relevance

Scientific relevance

Through this research, insights into the travel behaviour of the owners of e-scooters for access and egress and full trips can be gained. Literature on the travel behaviour concerning mode choice for private e-scooter for access and egress could not be found in literature, making this research a contribution to science on access/egress mode choice. Mode choice preference and the user profile for the private e-scooter could help other scholars on designing their future surveys or integrating results or methodology of this research into their own research.

Social relevance

In the Netherlands there is an ongoing debate on micromobility/light electric vehicles, especially for lawmaking and the energy transition, which holds that more sustainable alternatives should be implemented. When policymakers have the results of this research, then these might help in decision

making on laws regarding people who would like to use or are already using these e-scooters/micromobility vehicles on aspects such as safety and infrastructure. As said earlier micromobility is one of the options for access and/or egress trips. Knowing what the impact of the e-scooters for access/egress mode choice is, might also give the policymakers additional insight, into decision making. For society this research is very relevant, since in the Netherlands the e-scooter is a relatively recent introduced micro mode and in the past many incidents have occurred with micro vehicles involved. In 2018, an incident occurred involving a e-bike with a carriage, where four children died. This was a headline, which might have influenced the public opinion on these vehicles. Through this research people can know more about the private e-scooter, and they can see who the likely users of these modes are and what that means for mode choices, making them think on their preferences for mode alternatives, which might lead to a mode shift as well.

1.5 Research outline

In figure 2, the research flow has been depicted, showing the several stages of this research in order. Defining the research (Chapter 1) and the literature review (Chapter 3) have a connection. In the methodology (Chapter 3), the tools to carry out this research has been discussed, based on the motivation and research questions as defined in the introduction. The motivation and research questions were defined based on the findings of the literature review. After defining the research questions and carrying out the literature review, the survey was designed (Chapter 4), of which the motivation for the survey is given in the methodology. After designing the survey, the actual choice experiment can be carried out (Chapter 4), by finding respondents to fill the survey. When enough respondents are found, then the responses are collected, and the results are analysed based on the methodology to analyse the survey responses (Chapter 5, 6). After the analysis, the results can be discussed and finally a conclusion is provided (Chapter 7).
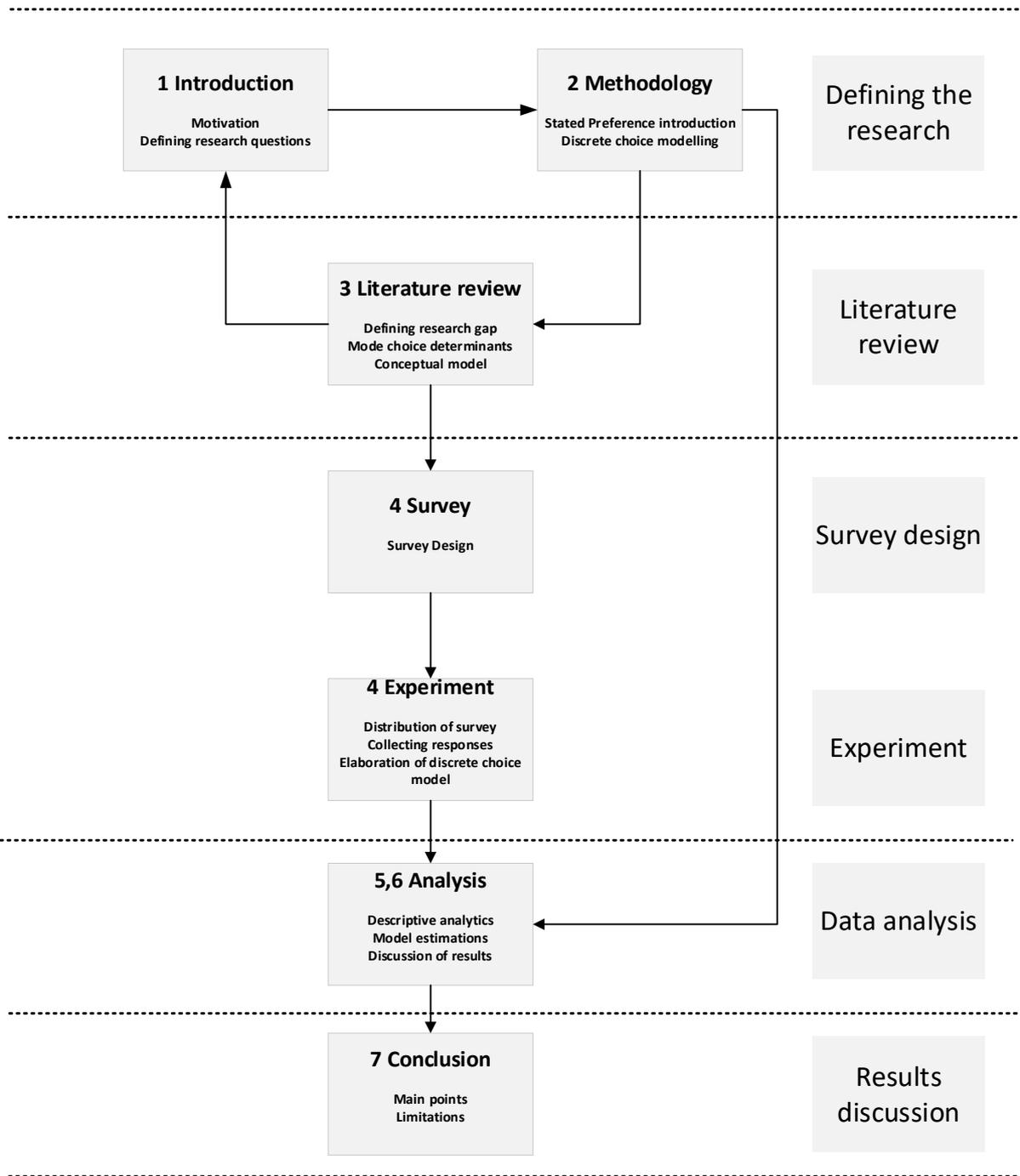
Figure 2 Research flow

2 Methodology

In this section, the methodology has been discussed to answer the sub-questions, before eventually answering the main research question. In table 2, the sub-research questions have been mentioned including the method that have been applied for the sub-research questions.

Table 2 Methods that have been applied for the sub-research questions

Sub-research questions	Method
1 what are travellers their behaviour concerning mode choice for access/egress trips when owning a private mode?	**Literature review**
2 Which factors are relevant for access and egress mode choice in which the private e-scooter is chosen?	**Literature review**
3 Which determinants contribute to a mode shift due to e-scooter ownership?	**Survey** including **choice experiment** and **discrete choice modelling**

2.1 Literature review

To answer the sub-research questions 1 and 2, a literature review should be carried out. The list of literature on the topic of access/egress mode choice is enormous and due to this, the literature review has been carried out based on a literature search method. The literature search method is shown in table 3. In this table, the concept group, keywords and truncations are mentioned. The concept group is the group which is the parent group containing several factors. Furthermore, the keywords that is suitable for this research and at last, the truncations which are combinations of the keywords, have been used to find relevant literature. The source that has been used to find relevant literature was google scholar, which provides links to other sources of scientific literature. Not all literature on google scholar might be relevant, only those that reflect closeness to this research were considered.

Table 3 Literature search method

Concept group	Transport mode, trip, Impact, method
Keywords	Transport mode: shared e-scooter, private e-scooter, micromobility
	Travel behaviour: mode choice
	Trip: access, egress, first-mile, last-mile
	Method: discrete choice modelling, stated preference, hypothetical
Truncation	**1** (shared OR private) AND (e-scooter OR micromobility) AND mode choice
	2 (stated preference) AND (mode choice)

Based on sub-research question 2, a conceptual model has been built, that shows the relationship in mode choice factors that affect people their mode choice for the private e-scooter. Before the conceptual model could be built, a literature review has been carried out on mode choice determinants of travel behaviour concerning access/egress trips in which private mode alternatives are included. These are needed to be able to design the stated choice experiment for sub-research question 3.

Also, during the literature review, a section is dedicated to methodology references, so how other research have carried out their research. This is to see which factors and which method(s) they have applied in their research.

2.2 Survey and stated choice experiment

The aim of this research as mentioned earlier is to see what mode shift potential the private e-scooter has for access and egress trips. The stated choice experiment is a very suitable method to capture this purpose. In stated choice experiments considering mode choice, people are asked to answer questions in which several modes are presented including various attributes such as travel time and travel cost (Rose & Bliemer, 2007). The purpose of the stated choice experiment is to see what the influence is of certain attributes on the outcome such as the influence of distance on the choice for the private e-scooter (ChoiceMetrics, 2024). These attributes can be varied, so called attribute levels, according to the designer of the survey. A major advantage of the stated preference experiment is that hypothetical options can be added. The term "potential" has been mentioned, which can only be captured by making the important assumption that the respondent owns an e-scooter. In that way every person who takes part in the choice experiment, "owns" an e-scooter and the potential effect of owning an e-scooter can be captured.

There is another reason to choose the stated preference method. For this research, the method, stated choice experiment has specifically been choses, because in the Netherlands, there is no data available on private e-scooters, both revealed as well stated preference for both access as well egress. Revealed preference data could be data on people their actual behaviour such as their actual daily means of travel for access/egress to train stations in which they use the private e-scooter. Stated preference data can be obtained by collecting people their mode choice for access/egress trips in which the private e-scooter is included as an option. There is however data on how many people probably uses the e-scooter in the Netherlands and also who uses the e-scooter (Multiscope, 2021; SWOV, 2021). Also, other research is available on e-scooter of the Netherlands, but related to safety, which is not the focus of this research (Goede & C. Mons, 2021; SWOV, 2021).

For this research only the multimodal trip is considered. The multimodal trip involves an access, egress, and main mode trip, including the various possible means of transport (figure 3). The main mode in this research in the multimodal chain is the train. There is an important assumption and that is that when someone uses the private e-scooter on the access part, the person will also use the private e-scooter on the egress part. This should also be implemented in the stated choice experiment. Considering the design of the stated choice experiment, this has several design methods, most notably are Orthogonal designs and efficient designs (ChoiceMetrics, 2024; Rose & Bliemer, 2007).
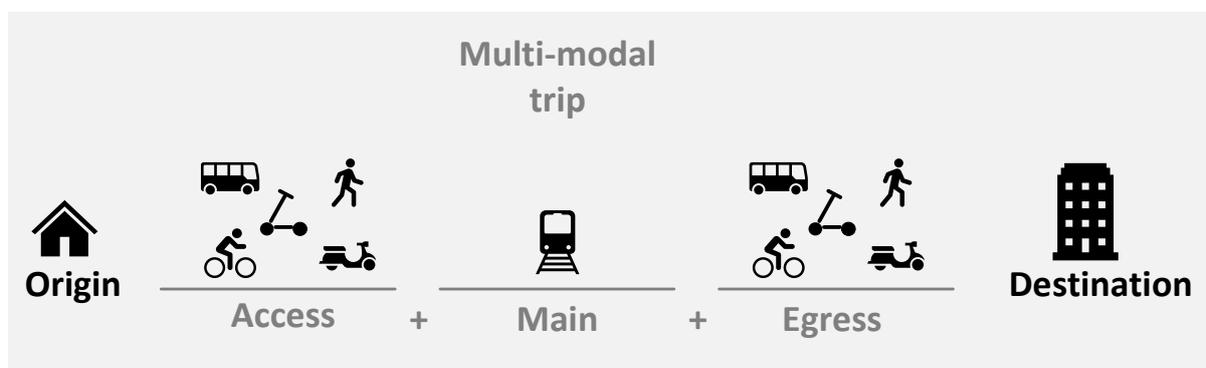

Figure 3 Mode options for access and egress.

The stated choice experiment is part of the survey that has been distributed to train travellers. The survey itself consists of three parts.

1) The user characteristics part, in which respondents should answer questions on their personal characteristics.
2) The trip characteristics part, in which respondents should answer questions on their travel behaviour
3) The stated choice experiment, in which several choice scenarios are shown including alternatives and attributes and values. Here the private e-scooter is an hypothetical alternative.

The software that is suitable to design the stated choice experiment is Ngene. In section 4, the actual stated preference design has been discussed in more detail including, model specification, attributes and their levels, alternatives, experimental design and finally the whole survey. To distribute the survey, the platform Qualtrics is suitable to design the survey and through several social media platforms, the survey was distributed.

2.3 Discrete choice modelling

In econometrics two types of choice models exists, continuous and discrete choice models. Continuous choice models are used on outcomes that have continuous data such as predicting the probability that someone will choose an e-scooter based on variables such as income and distance to train station. Continuous choice models are suitable on revealed preference data. Discrete choice models are models that are used on outcomes that have discrete data such as whether someone chooses the private e-scooter or not based on variables such as travel time. For this research discrete choice modelling has been applied, since a stated choice experiment has been carried out as explained in section 2.2. Through the discrete choice model, the answers that are obtained through the stated choice experiment can be analysed. To be more specific, through the discrete choice model, the influence of attributes (time, cost) on the outcome, which are the mode choices that people make (choice for e-scooter, btm, bike or walking), can be evaluated. In this way the importance of attributes can be captured to see what the effect is of these on the mode choice. Also, through discrete choice modelling, the mode split/mode shift can be determined.

2.3.1 Utility theory

The general discrete choice model has four assumptions (Ben-Akiva & Bierlaire, 1999):

1) Decision-maker: the person or a group of people who takes part in the choice experiment. In the case of a group of people, there is one decision, not multiple.
2) Alternatives: these are the options that someone can choose from within a choice set. For example, in a choice set someone can choose between bike, private e-scooter, walking, shared e-bike and public transport.
3) Attributes: attributes are variables that are related to the alternatives such as travel time. The attributes could hold for all the alternatives, but there are also alternative-specific attributes that hold only for a specific alternative.
4) Decision rule: decision rule is the process leading to a choice. This holds that a person evaluates all the alternatives and consequently chooses his or hers "best" option. In consumer theory of micro-economics, choosing the best option, means the option with the highest utility.

Utility is a value that has no dimension but is an important concept in economic research. The designer of the choice experiment does not have all information when a respondent makes a decision. The

uncertainty should be considered when modelling the choices of respondents. The utility is therefore modelled as a random variable in order to capture the uncertainty, which is shown in equation 1, showing the utility of individual n of alternative i (Ben-Akiva & Bierlaire, 1999). Eventually the alternative with the highest utility is chosen.

$$U_{in} = V_{in} + \varepsilon_{in} \ (1)$$

V_{in}: *this is the deterministic part of the utility, which can be determined based on known information.*
ε_{in}: *this is the uncertainty that should be considered.*

The deterministic part, V_{in} of the utility function is a function of the attributes:

$$V_{in} = \sum_k \beta_k * x_{ink} \ (2)$$

β_k: *coefficient of the attribute k, explaining the contribution/weight of this attribute to the utility.*
x_{ink}: *this is the attribute value k belonging to the chosen alternative i of individual n*

Another term that is added to the utility function and especially to the deterministic part is the alternative specific constant (ASC). This is the expected value of the error term, or in other words the mean of the error term (Ben-Akiva & Bierlaire, 1999; Bierlaire et al., 1997; Hess et al., 2005). The ASC is needed to find market shares of alternatives in case the model is used for forecasting (Hess et al., 2005). With ASC's defined, one alternative can be set as base. So, the final equation for the random utility model becomes:

$$U_{in} = ASC_i + \sum_k (\beta_k * x_{ink}) + \varepsilon_{in} \ (3)$$

2.3.2 Data analysis

To analyse the data from the choice experiment, discrete choice models are applied to assess the effect of attributes on choices. Also, the discrete choice models are necessary to determine the mode split. In this section several models are discussed to analyse choice data and afterwards the method to determine the mode shift or mode split has been discussed.

Multinomial Logit Model (MNL)
When in a choice set, two alternatives are present, a logit model is used. When more than two alternatives are present, the MNL model is used. The utility computed for each alternative is the same as in equation 3. The main assumption of this model is that the error terms of the utility function is of extreme value 1 distribution or Gumbel distributed and are referred to as independently and identically distributed (i.i.d.) (Ben-Akiva & Bierlaire, 1999). When the utilities have been computed, the probabilities can be computed, showing what the probability of an alternative is when being chosen. The probability can be computed through equation 4.

$$P(i|C_n) = \frac{e^{\mu V_{in}}}{\sum_{j \in C_n} e^{\mu V_{jn}}} \ (4)$$

A property of this model is the IIA property, Independence from Irrelevant alternatives, meaning that when calculating ratios in probabilities of two alternatives, these are not affected by the utilities of other alternatives (Ben-Akiva & Bierlaire, 1999; McFadden et al., 1977). Drawbacks of the MNL model are that it cannot deal with independent alternatives, when having multiple answers per individual in

case of panel data or when there are variations in tastes of attributes, for example different weights for perceived travel costs based on income (de Dios Ortúzar & Willumsen, 2011).

Nested logit (NL)

The MNL model does not take similarities in alternatives into account. Through the Nested Logit model, similarity between alternatives can be considered. In the nested logit model, alternatives are placed in nests based on common characteristics. The utility function of this model is shown in equation 5 (Train, 2002):

$$U_{nj} = V_{nk} + V_{nj} + \varepsilon_{nj} \ (5)$$

U_{nj}: utility of alternative j of person n
V_{nk}: observed utility of nest k of person n
V_{nj}: observed utility of alternative j of person n
ε_{nj}: unobserved/error term of alternative j of person n

Within a nest, the V_{nk} is the same for each alternative but differs across nests. The V_{nj} however differs across alternatives within a nest. The error terms are identically and independent distributed, meaning that they are independent (Train, 2002). Each nest in the choice set has a utility computed differently. The ε_{nj} are correlated within a nest, but are uncorrelated between nests.

To compute the probability of an alternative i that belongs to a nest B_k, equation 6 holds. This equation states that the probability that an alternative i belong to a nest B_k times the probability of the nest B_k gives the probability of an alternative. The nest parameter λ_k shows the weight of the correlation between the unobserved utilities of the alternatives within a nest (Train, 2002). A value of 1 means no correlation between the alternatives and a value of 0 means full correlation between the alternatives. So, when nests are being made the aim is to obtain the lowest possible λ_k.

$$P_{ni} = P_{ni|B_k} \cdot P_{nB_k} \ (6)$$
$$P_{nB_k} = \frac{e^{V_{nk} + \lambda_k I_{nk}}}{\sum_{l=1}^{K} e^{V_{nl} + \lambda_l I_{nl}}} \ (7)$$
$$P_{niB_k} = \frac{e^{V_{ni}/\lambda_k}}{\sum_{j \in B_k} e^{V_{nj}/\lambda_k}} \ (8)$$

$$I_{nk} = ln \sum_{j \in B_k} e^{V_{nj}/\lambda_k} \ (9)$$

Mixed Logit (ML)

The mixed logit model allows for random taste variation and can deal with correlation in unobserved factors over time. This model is suitable for panel data. The utility term of the ML model is shown in equation 10 (Ben-Akiva & Bierlaire, 1999). The ξ_{in} captures correlation among alternatives and is normally distributed and the v_{in} is an i.i.d. extreme value error term (Train, 2002).

$$U_{in} = V_{in} + \xi_{in} + v_{in} \ (10)$$

In equation 11, how to compute the probability of an alternative i belonging to a choice set n is shown (Ben-Akiva & Bierlaire, 1999). In this function the $f(\xi_n)$ is the probability density function (pdf) of ξ_n.

$$P(i|C_n) = \int_{\xi_n} P(i|C_n, \xi_n). f(\xi_n). d\xi_n \quad (11)$$

$$P(i|C_n, \xi_n) = \frac{e^{V_{in}+\xi_{in}}}{\sum_{\xi_n} e^{V_{jn}+\xi_{jn}}} \quad (12)$$

2.3.3 Mode shift

To capture the potential mode shift, the choice experiment should be designed in such a way that the mode shift can be determined. One of the manners is to design the experiment in a before and after situation such as in Sohoni et al. (2017). The before situation in this research is when people do not own a private e-scooter. The after situation in this research is when people own a e-scooter.

When the data from the choice experiment has been collected, the potential mode shift can be captured and the factors causing this mode shift can be analysed. The mode shift can be determined by just observing the choice frequencies of the chosen modes or by determining probabilities of the chosen alternatives in both the before and after situation (Chen et al., 2013; Sohoni et al., 2017; Weschke et al., 2022).

2.3.4 Sensitivity analysis

Earlier, the utility theory was discussed including computing probabilities based on the discrete choice models. When the data from the stated choice experiment has been analysed through a discrete choice model such as the mixed-logit model (ML), values have been obtained for the several factors from the respective alternatives. Because these are known, a sensitivity analysis can be carried out to see how the choice probability of the private e-scooter changes when the values of the attributes other alternatives are varied. This type of sensitivity analysis is the so called cross-sensitivity analysis (Litman, 2004). This is to see how well the private e-scooter performs in terms of mode choice robustness when an attribute its value changes of other alternatives.

2.3.5 Testing model performance

To test which model, performs best, several indicators exist, such as the well-known McFadden's Rho squared (ρ^2). The equation for the McFadden's rho squared is shown in equation 13 (McFadden, 1972).

$$\rho^2 = 1 - \frac{LL(\beta)}{LL(0)} \quad (13)$$

$LL(\beta)$ is the log-likelihood of the estimated model and $LL(0)$ is the log-likehood of the zero model. The value of rho can be between 0 and 1. If the rho is 0, this means that the coefficients that have been estimated are not different than the zero coefficients. If the rho is 1, this means that there is perfect fit of predicted choices due to the estimated parameters (Train, 2002).

2.4 Summary of the methodology

In the previous sections the methodology has been discussed. In this section a summary of the methodology has been given. This methodology can also be seen in the flowchart of figure 2.

The research starts with conducting a literature review as discussed in section 2.1 for sub research question 1 and 2 on travel behaviour concerning train station access/egress mode choice in which private modes are included. The literature review is necessary to see what research has already been done in the field of access/egress mode choice in which private modes are included. Also the determinants concerning the mode choice for access/egress trips when private modes are chosen with the focus on the private e-scooter are collected and categorized. Several aspects have been considered, mode substitution, mode choice determinants, stated preference methodology and the mode split/shift methodology. At the end of the literature review the conceptual model has been build based on the knowledge on the mode choice determinants.

After the literature review, the stated choice experiment can be designed as discussed in section 2.2. During the stated choice experiment several choice scenarios are shown to observe people their mode choice in which various determinants and alternatives including the private e-scooter are included. Eventually the mode shift should be determined based on the answers of the respondents in which private e-scooters are included.

When the stated choice experiment has been designed, the survey can be distributed to train travellers. The answers collected can then be analysed by means of discrete choice modelling techniques as discussed in section 2.3, to see the effect of factors on the mode choice, but also to determine the mode shift. Also, a sensitivity analysis has been carried out to see how the probability of the e-scooter changes when the attribute of other alternatives is changed.

3 Literature review

In this section, a comprehensive literature review has been conducted to eventually identify the research gap, determine attributes and to be able to build a conceptual model. The following points have been discussed in this chapter:

1. A short background on the e-scooter including both shared and private
2. Literature review on the travel behaviour concerning access/egress mode choice to train stations including private modes.
3. Literature review on the methodology in other research
4. Mode choice determinants for the private e-scooter
5. A conceptual model in which a relationship between the various determinants of mode choice towards private e-scooters has been build
6. The research gap

3.1 Background of the e-scooter

Within a city nowadays new transport systems are being developed and optimized besides the mass transport systems that already exist, and which are especially suitable for short distance travel. These are categorized as micro-mobility modes. Micro mobility is in principle mobility for the local market consisting of short distance trips (König et al., 2022; Oeschger et al., 2020). According to the international transport forum, micromobility are a range of vehicles that are for shared or private use and especially for short distances (Santacreu et al., 2020). In the same report of Santacreu et al. (2020), the international transport forum defines micromobility in four types based on speed and weight (figure 4). This classification is a general overview of micromobility around the world, but when looking at specific regions, for example Europe, this differs. In figure 5, several of these micromobility vehicles are shown.
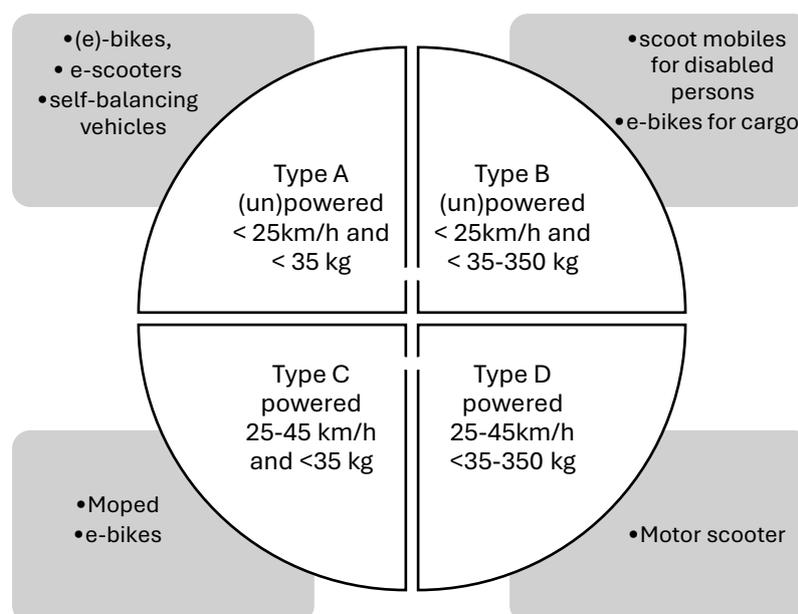
Figure 4 Classification of micromobility.

Segway Self balancing vehicle   Niu e-moped

Segway e-scooter   Gazelle e-bike

Segway self-balancing vehicle   Mango Scoot mobile for disabled persons

Figure 5 Micromobility vehicles.

These micromobility vehicles can be bought for own use or can be rented from a micromobility service provider (shared micromobility). Shared micromobility are commercial systems that require users to book the system via an app or an internet device on which the service can be booked. Shared micromobility services are for example shared e-scooters (figure 6), shared vehicles, ride sharing and other forms of shared transport (Shaheen et al., 2020). Two of the well-known micromobility vehicles are e-bikes and e-scooters. The shared e-scooter is a new shared vehicle, being deployed commercially since 2017 by the company Bird and later Lime (Aarhaug et al., 2023; König et al., 2022) . As the name says, the e-scooter is powered by electricity. Shared-e-scooters are dockless but are limited to certain areas, meaning that the shared e-scooters can be dropped or picked up anywhere but within certain

areas. Nowadays more of these commercial e-scooter companies exist that offer shared e-scooters. Besides the shared e-scooter, e-scooters can be bought and be used privately. A benefit of owning a e-scooter, is that a person can use it anytime and anywhere including using the e-scooter for access and egress trips and even bringing the e-scooter along in the (public) transport vehicle (Le Boennec & Salladarré, 2023; Oeschger et al., 2020).

E-scooters have numerous benefits. The e-scooters are substitutes for short car trips, reducing greenhouse gas emissions and the e-scooters can serve as access/egress transport (Yan et al., 2023). The e-scooters require little space for parking and usage (Wang et al., 2023). Also, the e-scooters are cost saving (Félix et al., 2023). Besides the benefits, e-scooters also have several disadvantages. Safety is a major issue when dealing with e-scooters, safety of the driver and safety of the other road users (Hirst, 2021). The drivers do not have to wear a helmet, making them vulnerable in case of an accident. Other road users can be injured if a driver on an e-scooter collide with them. More e-scooters emerge on the streets, making a city more crowded and as a result, less pleasurable to visit.

Figure 6 e-scooter from the company Lime.

Many countries have allowed the e-scooter to be used, but also cities have banned the e-scooter. Paris has banned the shared e-scooter from 2023, and Madrid and Copenhagen had initially banned the e-scooter but reversed the ban with additional conditions. Private e-scooter are however allowed in Paris. In the Netherlands, which is the focus of this research, the number of e-scooter owners is growing, and public transport is being used a lot as well, besides the high use of bicycles. In the Netherlands the shared e-scooters are also not allowed, but some private e-scooters are allowed if they are approved based on regulations and till now only the e-scooters from Segway and Swing are only allowed. In the Netherlands the e-scooters are placed in the category of "special moped". In the Netherlands, the category LEV (Light Electric Vehicles) exist, which is related to vehicles that do not fall under EU laws of vehicle approvals and consists of electric vehicles that are suitable for short distances, under which the e-scooter also belongs. The LEV category exists to ensure that LEVs are allowed in the Netherlands, are technically safe and are safe between existing traffic (IenW, 2023). Another important point why the LEV category exist, is for consumers to have a clear view of which e-scooters are allowed.

3.2 Access/egress mode choice behaviour due to e-scooter ownership

In this section, the literature review on travel behaviour concerning train station access/egress mode choice has been reviewed with the focus on the private e-scooter. The literature that has been used for this section and for section 3.3 is shown in table 4.

Table 4 Relevant literature on train station access/egress mode choice

Literature	Location	Topic	Mode	Method
Aguilera-García et al. (2024)	Madrid (Spain)	Influence of sociodemographic and mobility variables on e-scooter usage	Shared e-scooter, private e-scooter	Structural equation modelling and discrete choice modelling based on a questionnaire
Torabi et al. (2022)	Delft (Netherlands)	Impact of emerging modes on first/last-mile transport to and from a multimodal hub	Shared bicycles, e-scooters, e-mopeds, and automatic vehicles	Stated preference and analysing this data using MNL and NL models.
Azimi et al. (2021)	Orlando, Florida (USA)	Factors that influence mode choice for access/egress	Micromobility, taxi, carpool, public transport	Applying multinomial logit model on revealed preference data
Christoforou et al. (2021)	Paris (France)	User profile and travel habits of e-scooter users.	Shared and private e-scooters	Defining logit model based on survey on user profile and travel habits to obtain e-scooter ownership, trip frequencies and durations.
Glavić et al. (2021)	Belgrade (Serbia)	E-scooter users' willingness to switch to e-scooter	Car, public transport, walking, cycling	Descriptive analysis, multinomial regression based on a questionnaire
Hoogendoorn-Lanser et al. (2006)	The Netherlands	Analysing multimodal trips	Public transport and private modes (car, bicycle, walk)	Developing a discrete choice model and applying on multimodal trip data.
Kager et al. (2016)	Amsterdam (Netherlands)	Characteristics of bicycles-train combination	Bicycles	Combining train GTFS and cycling infrastructure data and calculate travel times for ODs.
Laa and Leth (2020)	Vienna (Austria)	Exploring e-scooter usage between owners and renters. Also, analysis of trip purpose using e-scooter.	Private e-scooter, shared e-scooter	Data analysis by obtaining data through online survey and field observations
Le Boennec and Salladarré (2023)	France, Germany, Spain, United Kingdom	Analysing the usage of micromobility for commuting in relation to traditional transport modes	Private micromobility excluding (e-)bike	Survey on usage of micromobility. Using an econometric model.
Lu, Kimpton, et al. (2024)	-	Identifying factors that influence first-mile and last-mile transport including conventional, exogenous and unique factors.	Private modes, shared modes, micromobility modes, emerging modes	Literature review
Moinse et al. (2024)	Provence-Alpes-Côte d'Azur, France	Analysing the impact of the combination between private e-scooter and train on catchment areas	Train, private e-scooter, shared e-scooter, bike, public transport	Descriptive analysis based on an available questionnaire dataset
Oeschger et al. (2020)	-	Integration of micromobility and public transport systems	bicycles and bicycles sharing	Literature review

Oeschger et al. (2023)	Dublin (Ireland)	Impact of micromobility on first and last mile trips in connection with public transport	Private e-scooter, shared e-scooter, private bicycle, shared bicycle, and walking	Stated choice experiment and estimating MNL and ML models
Oostendorp and Hardinghaus (2023)	Germany	Comparing user characteristics and usage of shared vs. private e-scooter	Private e-scooter, shared e-scooter	Descriptive analysis based on a questionnaire
Reck et al. (2022)	Zurich (Switzerland)	Mode choice concerning micromobility	Shared (e-scooters, e-bikes), PT, private (bike, car, e-bike, e-scooter), walking	Estimating choice model based on GPS, booking and survey data.
van Kuijk et al. (2022)	Utrecht (The Netherlands)	User preference for shared modes as first and last mile option	Shared bicycles, e-bikes, e-scooters, e-mopeds, light-electric vehicles (LEV), e-cars and demand responsive taxi	Stated choice experiment for urban and suburban areas
This research	**The Netherlands**	**Potential mode shift and the influencing factors due to e-scooter ownership for multimodal trips**	**Private e-scooter, shared modes, BTM (bus, tram, metro), walking, cycling and car.**	**Stated choice experiment and discrete choice modelling**

Access/egress trips can be done through various transportation means:
- Public-transport: this service is available to everyone including bus, tram, metro, and train. These have fixed routes and schedules, and these involve waiting and transfer time at a transit station.
- Shared modes: these services can be used by booking services such as e-scooters, e-bike and e-car.
- Private modes: these are vehicles that users own such as e-scooters, (e-)bike or car. Also walking is a private mode.
- On-demand services: these services are flexible, meaning that they must be booked in advance and the service has (no) fixed routes and (no) fixed schedules and the pick-up location is flexible as well. The vehicles are shared/private (Alonso-González et al., 2018).

It can be that someone uses one of these modes for the whole trip (mono-modality) or someone uses different modes for the whole trip (multi-modality) as stated in Le Boennec and Salladarré (2023). The terms access/egress are similar to the first mile/last-mile problem. The first mile/last-mile problem is the "difficulty in connecting users from transit stations to their points of origin or destination" (Romm et al., 2022). Kåresdotter et al. (2022) describes the first mile, the distance between origin and public transport and last mile as the distance between public transport and destination.

Oeschger et al. (2020) did an elaborate literature review on the integration between micromobility and public transport. They made a distinction for the integration between shared micro-vehicle and public transport and between private micro-vehicle and public transport. Besides the flexibility of the micro vehicle and the fast transport by train, there is another advantage, which is that the owner of the micro-vehicle can take the vehicle aboard the train and thus it can be used for both first and last mile. For this type of integration, the e-scooter is suitable, whereas micro-vehicles such as bicycles require enough space inside the public transport vehicle. Shared micro-vehicles on the other hand, should be left before boarding the public transport vehicle and for the last mile, another transport mode should be used. Similar results were obtained by Kager et al. (2016), where the combination between bicycles and train has been assessed. The results show that there is a strong synergy when bicycle and train are combined. Synergy means that the benefit of a combination is greater than the sum of the benefits of the two modes separately. The reason for this strong synergy is due to the high speeds of the train and the flexibility of the bike. The bike performs well on short distances and the train on longer distances. This allows the travellers to fill in their needs.

In Le Boennec and Salladarré (2023), the use of private micromobility modes was analysed for commuting. The benefit of ownership is that these micromobility vehicles can be taken into the public transport vehicle, whereas shared micromobility modes should be left on the street. The results show that micromobility substitutes bus and tram, while train, taxi and ride-hailing services are the main complementary modes. So, micromobility is used for short distances as a substitute for public transport and as a complementary mode for longer distances with train. The reason that micromobility is used as complementary option is because trains have more micro vehicle carrying capacity compared to bus or tram. In the research of Moinse et al. (2024), the result show that 85% of (e)-scooter owners used the (e)-scooter for both access and egress. Furthermore, the result also showed that (e)-scooter in combination with train can have a time advantage over car in dense areas.

Reck et al. (2022) did research into distance-based substitution patterns due to shared and personal micromobility. The private e-scooter was also included besides other shared modes. The results show that as the distance increase, personal e-scooters replace public transport, bike, and car trips more. The same holds for the substitution pattern of e-bikes. For short trips walking is replaced by the micromobility modes, personal and shared e-bike, shared and personal e-scooter. Personal e-bikes replace more car trips compared to the substitution pattern of the other three micro modes. In the paper of Reck et al. (2022), substitution of the considered modes was not modelled explicitly for access and egress trips. Instead, they added a penalty for the access distance towards the shared e-scooter, public transport, and shared e-bikes. The penalty for shared e-scooter is much higher than for public transport, since people are willing to walk longer to reach a public transport stop. A higher penalty contributes to a higher disutility.

Literature shows that shared e-scooters are primarily used on corridors where public transport is scarce (van Kuijk et al., 2022). But also in a city as Paris where public transport serves the city very well with its elaborate metro and bus network, users of shared e-scooters mainly shifted from walking and public transport (Christoforou et al., 2021). Also a portion of the respondents in the research of Christoforou et al. (2021), shifted away from private cars, taxi and motorcycle. So, in less covered public transport areas as well in well covered public transport areas, people would switch to shared e-scooters largely. Also the private e-scooter can play an important role in replacing private vehicles for short distance trips, since more cars can lead to negative results on the road (Glavić et al., 2021).

Azimi et al. (2021) did research into mode choice for access and egress to transit. They focused on the impacts of sociodemographic attributes, trip characteristics (travel distance) and the build environment characteristics on mode choice for access/egress. For two-way trips, park and ride were desirable. For medical trips, park and ride and carpool modes were desirable, biking and walking were not viable, whereas public transport had a poor connection to medical services. For airport access and egress, public transport was desirable. The longer the distances for access and egress trips, became, the higher the probability that the usage of micromobility, public transport and motorized vehicle became, and walking became less likely. This research of Azimi et al. (2021) shows that based on the trip motive, the mode choice is different and several attributes are related to the mode choice based on trip motive.

van Kuijk et al. (2022) also analysed the user preference for shared modes for access and egress trips and specifically focused on shared modes. The study area, the province of Utrecht in The Netherlands, was divided into an urban and sub-urban region and for both areas a stated preference study was conducted. The results show that most of the public transport travellers prefer walking over shared-modes for first and last-mile and is especially the case for urban than for sub-urban areas. These results are for the Netherlands which has a high usage of cycling and in Utrecht the public transport density is high, meaning short stops and line spacing. This could be a reason people prefer walking more as public transport is close. A limitation in the research of van Kuijk et al. (2022) is that spatial-temporal

changes when the shared-vehicle should be left at a valid area or point, is not taken into account when analysing travel behaviour. For the private e-scooter, this point of bringing the e-scooter back is eliminated, because travellers can bring the private e-scooter into the public transport vehicle. Hoogendoorn-Lanser et al. (2006) mentioned, based on collected data, that the share of walking on the egress side is higher than at the access side and the share of bicycle and car at the access/home side is higher than at the egress side. Also, the availability of public transport can have an influence on the mode split. In areas where public transport is scarce, more private modes are utilized. The total share of private modes is thus higher on the egress/activity side than at the access/home side (Hoogendoorn-Lanser et al., 2006).

In the research of Oostendorp and Hardinghaus (2023), the user profiles and usage of shared and private e-scooters was analysed. The results show that owners of e-scooters especially replace car trips. Shared e-scooters are combined frequently with public transport. The private e-scooters on the other hand are used for longer trips and are used more frequently than shared e-scooters. In the research of Moinse et al. (2024), it was also mentioned that private e-scooters are used more frequently compared to shared e-scooters. Furthermore, the private and shared e-scooters are both used for short distances. 94% of the e-scooter owners used their e-scooter to reach the station followed by cycling (88%), car driving (86%), walking and bus (78%) and as passenger in car (63%). This shows that the emerging e-scooter is very attractive for access trips compared to the other modes. In Laa and Leth (2020) was also shown that e-scooter owners replace private cars considerably. Not only private car trips are replaced, also subway trips and walking trips are replaced. Also 70% of the respondents from the research of Laa and Leth (2020) indicated that they used the personal e-scooter multiple times a week. This is more than the users of shared e-scooters in that research. Also 80% of the e-scooter owners take the e-scooter in public transport sometimes or often. Laa and Leth (2020) mentioned that it is difficult to observe the multimodal aspect of the e-scooter for first and last mile. With asking the question whether someone takes the e-scooter in the public transport vehicle, an indication on multimodality was obtained.

A micro mode that shows resemblance to the private e-scooter are the private e-bikes. A drawback of the (e-)bike is the capacity issue in the train, since they take a considerable amount of space in the train and in the train there are separate, very limit space to take the bike along, which might taking the bicycle in the train very unattractive (Oeschger et al., 2020). So, for the access trip the (e-) bike is attractive, but for the egress part, it is not. Much research has been done on mode choices in which bicycles are included in combination with transit. One of the papers is Jonkeren et al. (2021), in which research was done on the choice for access/egress mode, station and which type of bicycle. The result shows that bicycle train travellers use the bicycle more on the access part than on the activity-end/egress part. On the activity-end shared bicycles are used more. A other paper, Lee et al. (2015), evaluated the substitution effect that the newly e-bike has in the Netherlands using revealed preference data. The results show that a majority of the respondents replaced trips that would be made with car, public transport and walking. Kroesen (2017) did research into the substitution effect of e-bike ownership and found that e-bike reduces the use of conventional bikes, car and public transport, more than conventional bikes and lastly e-bikes, substitute conventional e-bikes and not car. However in the research of Plazier et al. (2023) it is shown that e-bike users in rural areas can substitute both car and conventional bicycle. So, the area (build environment) of users might also play a role in mode choice.

3.3 Research methodology references

In this section, literature on how other scholars have designed their choice experiment in which private modes are included has been reviewed. This is necessary to get an indication of which variables are

included in the different parts of the survey including questions on the user characteristics, trip characteristics and the choice experiment including attributes, alternatives and levels involved. Also, how the modal split/ mode shift has been determined by other papers.

3.3.1 Choice experiment

Three papers were found to be very close to this research, namely, Oeschger et al. (2023); van Kuijk et al. (2022) and Torabi et al. (2022).

Oeschger et al. (2023), did research into what the impact of micromobility is on the connection to transit for first and last mile. They carried out a choice experiment on the combination of active modes and micromobility with public transport for the city of Dublin, Ireland. The first part of the survey was on collecting variables on mobility behaviour and patterns. The second part consisted of the choice experiment in which questions on first mile and private micromobility were asked and questions on last-mile and shared vehicle. The alternatives and attributes added were:

For first mile:
- Private e-scooter and personal bicycle: travel time, transfer time, secure parking availability
- Walking: travel time

For last mile:
- Shared e-scooter and shared bicycle: transfer time, travel time and cost of the service
- Walking: travel time.

The reason for shared scooter on the last mile is based on the paper of van Kuijk et al. (2022) in which was stated that there is low availability of private vehicles. The design was based on selecting a set of choice situations from a full factorial design such that the respondent would not be overwhelmed with many questions. To analyse the stated preference data, Oeschger et al. (2023), estimated a series of models including multinomial logit model and mixed logit models with different effects, since the stated preference data is panel data. Lastly, socio-demographics data was analysed including age, gender, education level, work status and car availability per household. Also, the trip characteristics data including reasons to use a mode was analysed. The essential part is that the choices of the first mile and last-mile part were modelled and analysed separately.

van Kuijk et al. (2022) did research into the preference for shared mobility options for first and last mile. This was done through a stated preference survey for the city of Utrecht, the Netherlands and was divided into an urban and sub-urban area. van Kuijk et al. (2022) included four shared alternatives for the urban areas (bicycle, e-bike, e-scooter, e-moped) and extended this to eight shared alternatives for the suburban context (light electric vehicles, e-car, DRT services with a volunteer or professional driver). The attributes involved for the urban context were travel time, travel cost, public transport frequency and public transport in-vehicle travel time. The attributes for the sub-urban context were travel time, travel cost, request time and public transport frequency. Furthermore, user and trip characteristics were part of the survey as well. To design the experiment, an orthogonal fractional factorial design was adopted, to reduce the number of choice situations presented to the respondent. To analyse the stated preference data, the following models were estimated, multinomial logit model, nested logit, panel-effect, and mixed logit models. For both the urban and sub-urban context, these models were estimated, and the user and trip characteristics were also included in the estimations. Unlike, Oeschger et al. (2023), van Kuijk et al. (2022) did not estimate models directly for first and last mile, but instead stated five hypothesis on first and last mile and after estimating the models for first and last mile, van Kuijk et al. (2022), tested the several hypothesis.

In the research of Arentze and Molin (2013), based on distances ranging from 5 km to 65 km, several multimodal stated choice experiments were designed. A total of 4 choice experiments including different combinations of modes. So, respondents who took part in the choice experiment were assigned to a choice experiment based on their trip details. The research of Arentze and Molin (2013), shows similarity in methodology with this research. Especially the experiment of 65 km's in which attributes as access time, egress time, waiting time, access travel cost, egress travel cost, main travel cost and transfer time.

In the research of Torabi et al. (2022), the impact of shared micromobility options and emerging modes (automatic vehicles) was analysed on people their mode preferences for first and last mile from and to multimodal hubs and was done for the city of Delft, the Netherlands. Two contextual situations were studied, namely weather conditions and carrying luggage affecting mode choice. The method applied was a survey divided into three sections consisting of revealed preference (trip characteristics), stated preference (choice situations for access and egress to and from the train station) and socio-economic characteristics. The stated choice experiment consisted of the alternatives shared bike, shared e-step, shared e-scooter, and automatic vehicles (individual and collective). The attributes implemented in the choice experiment were total travel time, travel cost and availability of modes. An efficient design was adopted instead of the orthogonal designs. Contextual situations were also implemented in the experiment using effects coding. The stated preference data was analysed by estimating a multinomial logit and a nested logit model.

In all the three papers mentioned above, after the discussion of the model results, additional analysis was carried out such as calculating the value of time (VOT), market shares of the modes, and elasticities. In the three papers, Oeschger et al. (2023); Torabi et al. (2022); van Kuijk et al. (2022) a survey was carried out for first mile and last-mile mode choices. Generally, these surveys were divided into three sections:
1) User characteristics: capturing users their characteristics such as age, gender, income, and education.
2) Trip variables: capturing trip characteristics.
3) Choice experiment: mode choice situations in which respondents must select their mode choices.

To design the survey, two of the three papers used orthogonal design (Oeschger et al., 2023; van Kuijk et al., 2022) and two papers used efficient design (Arentze & Molin, 2013; Torabi et al., 2022). Three papers divided the choice experiment into two parts, first mile and last-mile (Arentze & Molin, 2013; Oeschger et al., 2023; van Kuijk et al., 2022) and one paper did not make distinction in this (Torabi et al., 2022). All three papers afterwards estimated models such as multinomial logit, mixed logit, and nested logit to analyse the data collected from the choice experiment. The attributes generally used are travel time and travel cost and depending on the alternatives, specific attributes such as request time for a demand responsive transit service were used (van Kuijk et al., 2022).

3.3.2 Mode shift

When several modes are available for an access and/or egress trip or a whole trip, the share of these modes or combination of modes can be determined and is named mode share. When a new mode is introduced, this new mode can cause a potential shift in the share of the other modes and is called mode shift. For the mode shift or mode split, several papers were found that defined the mode split or mode shift caused due to a (new) mode. These papers are not mentioned in table 4, since the objective is to discuss how other papers define the mode split or mode shift.

In the paper of Chen et al. (2013), the mode split can be determined by applying discrete choice techniques. To be more specific the following steps are taken to arrive at the mode split:
- First, the utilities are determined based on the choices that individuals make and the attributes that correspond to these choices.
- Secondly, the probabilities of choosing an alternative are. During this step, several models are applied and based on these models the probabilities are determined. In section 2.3.2, several of these models have been explained.

In the paper of Chen et al. (2013), the mode split was determined based on discrete choice models. In the dissertation paper of Schatzmann (2023), a stated choice experiment was carried out. Here the mode split was determined based on the frequencies of the chosen choices.

Concerning mode shift, in the paper of Sohoni et al. (2017) the mode shift was explicitly modelled by asking the respondents questions regarding their travel behaviour before and after a new train service. This paper used both revealed preference data on the respondents their travel behaviour and stated preference data to analyse the attributes. In the paper of Weschke et al. (2022), revealed preference data was used and based on the MNL discrete choice model, the mode shift was determined as well the determinants causing the mode shift.

3.4 Mode choice determinants and selection of determinants

When discussing factors that influence mode choice, the literature is enormous, but the several factors that different literature uses, can be categorized into three main groups, sociodemographic attributes, trip characteristics and the build environment (Azimi et al., 2021; de Dios Ortúzar & Willumsen, 2011; De Witte et al., 2013; Le Boennec & Salladarré, 2023; Lu, Kimpton, et al., 2024); Mo et al. (2018); (Oeschger et al., 2023; van Kuijk et al., 2022). Besides these, other more specific factors are included in various research. In Lu, Kimpton, et al. (2024) exogenous factors such as weather and crime rate that influence public transport and active modes was mentioned as well unique factors that influence emerging modes and public transport. de Dios Ortúzar and Willumsen (2011) mentioned mode characteristics such as comfort, convenience and safety. De Witte et al. (2013) mentioned socio-psychological characteristics such as experience perception and lifestyle. All these categories are shown in table 5 and have been discussed in this section. These has been used for the conceptual model in section 3.4.2.

Table 5 Factors influencing train station access/egress mode choice

	Category	Reference
1	User characteristics	Arias-Molinares et al. (2021); Azimi et al. (2021); Christoforou et al. (2021); Glavić et al. (2021); Meng et al. (2016); Oeschger et al. (2023); Reck et al. (2022)
2	Trip characteristics	Azimi et al. (2021); Christoforou et al. (2021); Glavić et al. (2021); Hardt and Bogenberger (2019); Meng et al. (2016)
3	Mode characteristics	Glavić et al. (2021); Roig-Costa et al. (2024); van Kuijk et al. (2022)
4	Build-environment characteristics	Aguilera-García et al. (2024); Arias-Molinares et al. (2021); Kim et al. (2007); Mo et al. (2018); Roig-Costa et al. (2024)
5	Socio-psychological characteristics	Aguilera-García et al. (2024); Kopplin et al. (2021); Oeschger et al. (2023); Roig-Costa et al. (2024)

| 6 | External factors | Hardt and Bogenberger (2019); Lu, Zhang, et al. (2024); Oeschger et al. (2023); Reck et al. (2022) |
| 7 | Unique factors | Kazemzadeh and Sprei (2022); Lu, Kimpton, et al. (2024) |

User characteristics

Christoforou et al. (2021) did research into the user profiles and the travel motivations of e-scooter users. Owners of e-scooters are mostly people with high *income*, are *younger* and are more risk averse than shared e-scooter users. The users of these shared e-scooters are mostly *man* and have a high-*education*. Oeschger et al. (2023), concluded that people who are *younger* than 35 years old and *male*, are more likely to choose e-scooters and bicycles, whereas *females* and *older* people are more likely to walk. Azimi et al. (2021) did research into mode choice for access and egress to transit. They focused on the impacts of sociodemographic attributes, trip characteristics (travel distance) and the build environment characteristics on mode choice for access/egress. Micromobility options were mostly used by *young* adults. In Meng et al. (2016), the *ownership* factor was discussed and showed that people who do not *own* a private vehicle, the likelihood of walking and cycling are higher. For bike sharing-services, Arias-Molinares et al. (2021) showed that these services are mostly used by *males*, who are between 35-49 years of *age*, high *educated* (university), have a medium *income* and are *working*. In Glavić et al. (2021) usage profile of e-scooter users was evaluated. They showed that the users are mostly *male, aged* between 18-25, *graduate* and *employed.* Considering *employment status*, full-time employment positively influences mode choice for personal e-scooter, while this status influences mode choice for public transport, private car and bikes negatively (Reck et al., 2022).

Identified user determinants: age, income, education, gender, ownership, employment status (full-time).

Trip characteristics/purpose

Hardt and Bogenberger (2019) carried out a longitudinal survey in which travel diaries and attitudes towards e-scooters was analysed for the city of Munich in Germany. The trip diaries revealed that people used the e-scooter for especially *commuting* and *leisure* trips and even for *business* trips. In Christoforou et al. (2021) the results showed that owners of e-scooters use e-scooters more frequently and use it mainly for *travel time* savings and not for *cost* savings. The results in Azimi et al. (2021) showed that the trips with micromobility vehicles are mostly made for *education* (college, university) purposes. Also, when *distance* increased for access and egress trips, the higher the probability that micromobility, public transport and motorized vehicle became, and walking became less likely. Meng et al. (2016) mentioned that for short distances, people tend to walk, for longer *distances*, travellers use bicycle and for even longer distances, people use public transport. When people use public transport, the *number of transfers* also matter, as shown in Krauss et al. (2022). Glavić et al. (2021) mentioned that the e-scooter is mostly used for *leisure* purpose followed by *work* and *school*. Also, respondents mentioned that they would use the e-scooter, because of its *cost,* and *travel time* savings. In Molin and Timmermans (2010), travelling in the dark or during daytime also had influence on the mode choice, which is related to safety.

Identified trip determinants: travel time, travel distance, travel cost, trip purpose (leisure, work, business, education), number of transfers, time of day.

Mode characteristics

In Glavić et al. (2021), 79% of the respondents mentioned that they would feel *safe* when the infrastructure they use would be shared with pedestrians. When sharing infrastructure with cyclist, 96% would feel *safe* and much less, 50% would feel *safe* when the infrastructure would be shared with motorized vehicles. Also, respondents mentioned that they would use the e-scooter because of its *convenience* and *congestion avoidance*, and of its *environmental* friendliness. For the choice

experiment, it is assumed that people own a e-scooter. This implicitly also assumes that people have bought the e-scooter. The **purchase** factor of buying a e-scooter could also be a barrier on using the e-scooter and thus the choice of choosing the e-scooter for access/egress could be influenced. van Kuijk et al. (2022), indicated that the e-scooter might be attractive for public transport users if it is low-priced. When barriers such as **economic** (electronic payments), **technological** (app registration) and **information** (formal registration) are removed, the private e-scooter becomes more used among socioeconomically disadvantaged groups (Roig-Costa et al., 2024).

Identified mode determinants: comfort, safety, environment, purchase cost, accessibility barriers (economic, technological, information).

Build environment characteristics
Considering build-environment characteristics, people who live **close** to a transit station, but also in an area with high socioeconomic activities, have a higher preference for walking for access and egress (Mo et al., 2018). Arias-Molinares et al. (2021) showed that people who use shared services, live **close** to the urban area, in which most of the micromobility services are located. In Kim et al. (2007), **availability** of bus services between home and a public transport station was discussed and the result showed an increased in the probability of using a bus for this trip. Aguilera-García et al. (2024), indicated that people who live outside the centre of the city of Madrid, are less likely to own a e-scooter, because of low **population density** and less shared transportation options are available there. The **frequency** of public transport where people **live** and **work**, makes using the private e-scooter more attractive than the shared e-bike (Roig-Costa et al., 2024). In a city with a high level of build-environmental factors such as **public transport density** and **intersection density**, an decrease in e-scooter ridership was the result (Lu, Zhang, et al., 2024). On the other hand, when the **proximity** to the central business district (CBD) is low and there is a high **bikeway density**, an increase in e-scooter ridership was the result.

Identified build-environment determinants: availability and frequency of public transport, density (activities, population, public transport, intersection, bikeway), proximity to CBD.

Socio-psychological characteristics
Roig-Costa et al. (2024) did research into user characteristics of e-scooter and e-bike users. The results show that the users of private e-scooters used the e-scooter over the shared e-bike due to the **enjoyment** and **thrill seeking**. Also in Kopplin et al. (2021), the respondents used the e-scooter because of **enjoyment**, **saving time** on searching for parking, **saving money** on public transport tickets and when less access to a vehicle, the e-scooter offers mobility. When **environment consciousness** increases, people are likely to adopt the private e-scooter more (Aguilera-García et al., 2024), however in Roig-Costa et al. (2024), environment consciousness, was not a factor for a large part of the respondents. In Kopplin et al. (2021), the **environment** concerns was absent among e-scooter owners when using a e-scooter, but for non-owners this aspect was present when using the e-scooter. In the paper of Carroll (2022), several positive e-scooter experiences was mentioned namely, **convenience**, **fun**, easier to get around than PT, comfortable, quicker than walking and good for the environment. Also, several negative experiences were mentioned namely **unsafe**, slow and **inconvenient**. De Witte et al. (2013) mentioned several socio-psychological factors can have influence on mode choice, such as a positive or negative **experience** in the past, **familiarity** of the transport mean, individual's **lifestyle**, **habits** and **perceptions**. Oeschger et al. (2023) showed that when people had previous **experience** with shared services, this had influence on mode choice for the first -and last mile. These people are more likely to choose private and shared e-scooters and bicycles. Concerning **safety**, owners of private e-scooters drive safer than users of shared e-scooters, since they are not fully aware of the rules and also due to their riding skills (Mehranfar & Jones, 2024). In Brisbane Australia, the private e-scooter

ownership has increased, and the shared e-scooter rides has decreased, indicating an increase in **safety** (Haworth et al., 2021).

Identified socio-psychological determinants: experience, environment-consciousness, emotion (enjoyment, thrill seeking), comfort, convenience, safety.

External factors
In the research of Hardt and Bogenberger (2019), the constraints mentioned on using the e-scooter were **weather** conditions, **luggage** restrictions and **safety**. **Parking** this vehicle is a major benefit, besides **handling** this vehicle. But when costs are involved to **park** the private e-scooter safely, this led to a disutility of the private e-scooter mode choice (Oostendorp & Hardinghaus, 2023). For micromobility mode choice especially shared e-scooter and e-bikes, **precipitation** has a negative influence , whereas precipitation has a positive influence on public transport and car mode choice (Reck et al., 2022). Lu, Zhang, et al. (2024), showed that higher temperatures lead to increase in e-scooter ridership during weekdays, but when temperatures higher than 26 degrees Celsius, e-scooter ridership decreases during weekends.

Identified external determinants: weather (precipitation, temperature), restrictions (luggage), parking availability.

Unique factors
Lu, Kimpton, et al. (2024) did research into determinants of first/last-mile mode choice including conventional, exogenous and unique factors. The unique were explored for emerging modes such as the autonomous vehicle. In some way the e-scooter can also be seen as an emerging mode in the Netherlands, since the e-scooter has been introduced very recently. The e-scooter has distinct features such as (Kazemzadeh & Sprei, 2022):
- Speed and acceleration different to e-bikes and cars
- Driving on the e-scooter by standing
- Electrically assisted. The e-scooter can be turned on by kicking.

Furthermore, the e-scooter is **foldable** and can be **carried** in the public transport vehicle as mentioned multiple times earlier. Literature on how the unique factors of the private e-scooter has influence on the mode choice for the private e-scooter could not be found, which is an interesting determinant to include for the mode choice experiment. For this research the unique factors have not been considered. Only the option to take the e-scooter into the train has been considered.

Identified unique determinants: boarding option

3.5 Conceptual model

In this section the conceptual model has been build based on knowledge of the previous sections 3.2, 3.3 and 3.4. In the conceptual model, the links between the determinants are established (Utrecht, n.d.). The conceptual model serves as a tool, on which information to collect and how to structure the survey. The conceptual model should include the following information, the determinants group, the determinants in the group and finally the relationship between the determinant's groups and determinants.

The identified determinants based on section 3.4, that influences mode choice for the private e-scooter/micro vehicles are shown in table 6. In section 3.3, literature was also reviewed on how other research conducted their research with a focus on the stated preference methodology including

attributes and the alternatives involved. In that section the result was that a survey is mostly divided into three sections collecting information of the user, the user's trip characteristics and mode choices that the user makes. In section 3.4 the determinants belonging to these three sections have been discussed. Both sections have been connected and is shown in figure 7.

Table 6 Identified determinants

Determinants group	Determinants
User	age, income, education, gender, ownership, employment status (full-time).
Trip	travel time, travel distance, travel cost, number of transfers, time of day, trip purpose (leisure, work, business, education).
Mode	comfort, safety, environment, purchase cost, accessibility barriers (economic, technological, information).
Build environment	availability and frequency of public transport, density (activities, population, public transport, intersection, bikeway), proximity to CBD.
Socio Psychological	experience, environment-consciousness, emotion (enjoyment, thrill seeking), comfort, convenience, safety.
External	weather (precipitation, temperature), restrictions (luggage), parking availability
Unique	Boarding possibility (carrying)

In figure 7, the conceptual model has been shown in which the seven determinants' groups have been incorporated. The three main sections in the conceptual model are socio-economic characteristics, trip characteristics and alternative characteristics. This framework has been used on which the survey has been built in the next section and from which the main research question can be answered.
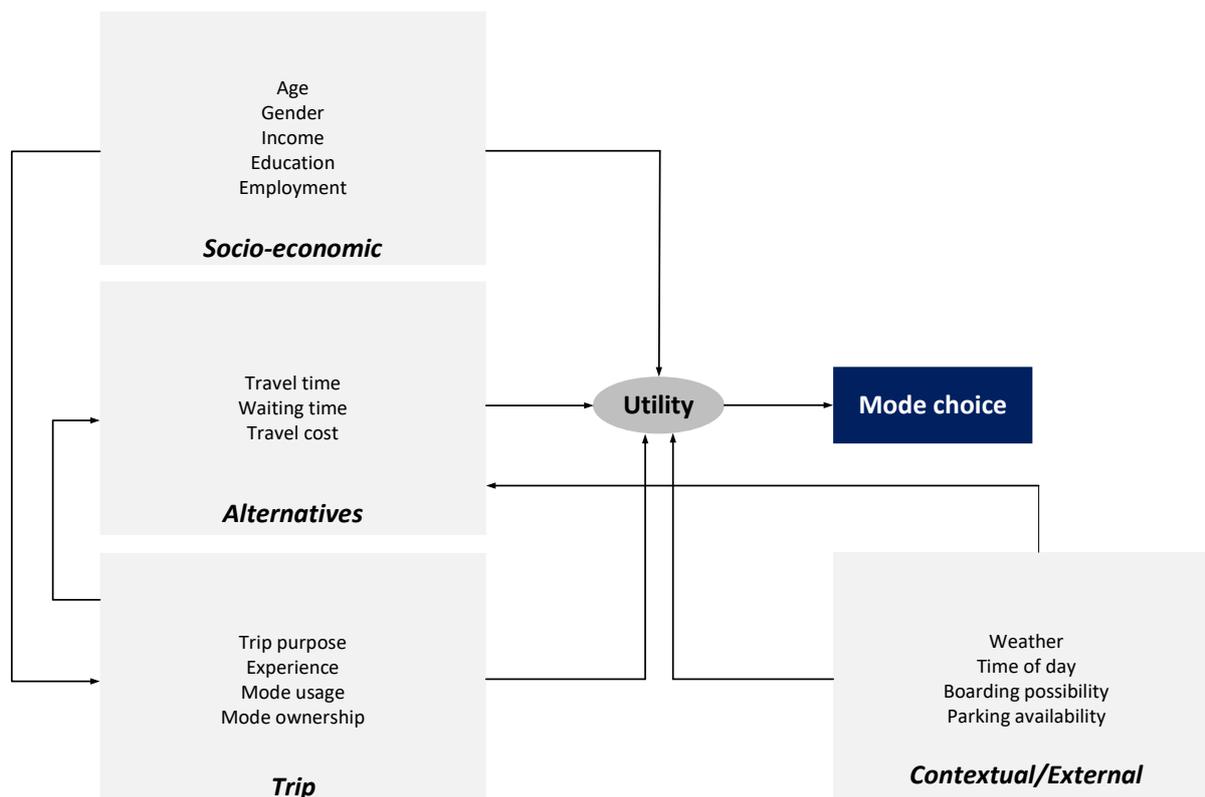
Figure 7 Conceptual model

3.6 Conclusion

In the previous sections, literature reviews on the topic of travel behaviour considering mode choice for access/egress trips and the determinants of these mode choices have been carried out with a focus on the private e-scooter. Few papers could be found on private e-scooters (Christoforou et al., 2021; Hardt & Bogenberger, 2019; Laa & Leth, 2020; Le Boennec & Salladarré, 2023; Moinse et al., 2024; Oeschger et al., 2023; Reck et al., 2022). Most of the papers on private e-scooters used descriptive analysis based on a questionnaire or used revealed preference data and build choice models to fit these data. Oeschger et al. (2023), exploited a choice experiment to capture the preference for private e-scooter. The private e-scooter was included only for the first mile, missing out on the potential mode shift of using the same private e-scooter for the last mile, whereas several papers have mentioned that the private e-scooter can be taken into the public transport vehicle (Laa & Leth, 2020; Le Boennec & Salladarré, 2023; Oeschger et al., 2020). The missing connection is the potential mode shift due to using the private e-scooter for both the first mile and last-mile, while they take the private e-scooter into the public transport vehicle.

Also when looking at the potential of the private e-scooter replacing unimodal modes such as car, literature shows that the private e-scooter replaces car trips (Christoforou et al., 2021; Glavić et al., 2021; Oostendorp & Hardinghaus, 2023; Reck et al., 2022). But the literature is still unclear on the potential mode shift from car to the private e-scooter in combination with train or vice versa, especially given that the car has the highest share considering full trips as mentioned in KiM (2023).

Another important aspect that the literature is scarce on, is the user profile of private e-scooter owners and their trip characteristics in the Netherlands.

To summarize, the following two research gaps have been identified, which have been filled in this research:

1) **The potential mode shift that the private e-scooter might cause for both multimodal and unimodal trips. The potential mode shift on unimodal trips is also a gap that was identified, but in this research only multi-modal trips have been considered.**

2) **The determinants (user, trip and attribute) that might cause this potential mode shift.**

4 Stated choice experiment design and survey

The goal of this research is to determine the potential modal shift and the factors influencing the mode choice for multi-modal trips (figure 8) when train travellers own an e-scooter. These can be captured through a survey in which a part is dedicated to a stated choice experiment to capture people their preference for different situations for access and egress trips. In this chapter the design of the stated choice experiment has been discussed.
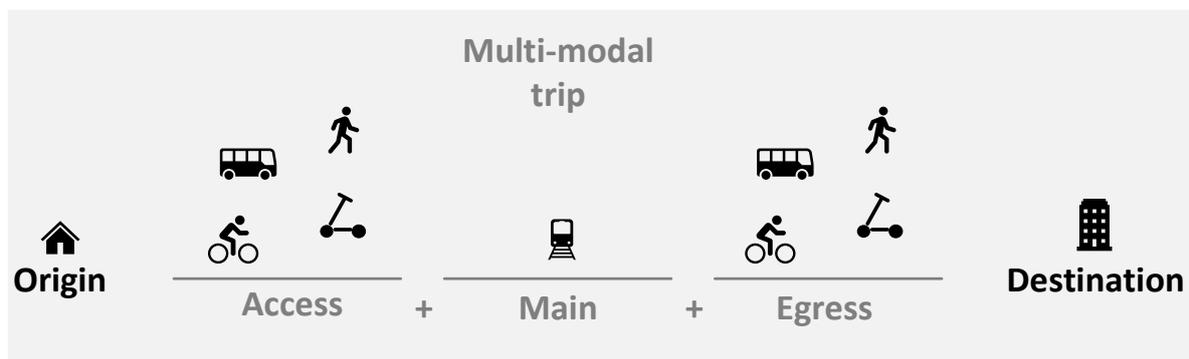
Figure 8 Multi-modal trip

Designing a stated choice experiment usually involves three steps (ChoiceMetrics, 2024):
1) Model specification including the parameters to be estimated.
2) Experimental design. During this step the choice situations are generated that the respondent will face.
3) Construction of the survey. During this step the survey is designed including the different sections to capture the user information, their trip information and the choice experiment.

The framework that was defined in the previous chapter served as how the eventual survey should be structured. In the coming sections the survey has been discussed including the model specification, the choice experiment design and finally the whole survey including the several sections of the survey. In figure 8, the multi-modal trip is shown with the several mode alternatives that has been considered in this study.

4.1 Model specification

During this section, the model has been specified, not the mathematical model, but a conceptualization of the actual model. Based on the literature, several assumptions have been made to simplify the model. After that, the alternatives have been discussed that have been included in the experimental design and finally the attributes that have been considered for the experimental design have been discussed.

4.1.1 Context

During the literature review, several factors were mentioned that influenced the mode choice for the private e-scooter as well for other modes. These factors were also included in the framework shown in figure 7. To simplify the choice experiment to not overwhelm the respondent with many factors, several assumptions have been made and discussed below. Many variables have initially been varied, but after the pilot study, several variables have been fixed. In this section the context before the pilot study has been discussed.

Weather: as was seen in literature, the weather is a determinant for the choice for the e-scooter (Hardt & Bogenberger, 2019; Molin & Timmermans, 2010; Reck et al., 2022; Torabi et al., 2022). The weather has initially been varied in this study.

Train boarding capacity: several e-scooter models exist, foldable or not, seated or not. For this research the foldable e-scooter is considered such that it can be taken into the train as was mentioned several times in literature (Le Boennec & Salladarré, 2023; Oeschger et al., 2020). In this study the train boarding capacity is related to how the e-scooter is handled in the train, meaning that when someone can store the e-scooter, this is an indication that there is capacity aboard the train, but when someone should hold the e-scooter, this is an indication of less capacity/a crowded train. So, the boarding capacity has been varied.

Distance: In literature it was mentioned that based on the distance, the mode choice varies. This study can be done for various distances. Since, several research have shown that the e-scooter substitutes walking for short distances such as in Reck et al. (2022), the distance for both access and egress is set at 2 km.

Availability: it is assumed that every respondent owns an e-scooter and thus is available to every respondent.

Luggage: in the literature review, luggage was also a determinant for the choice of the e-scooter. For the choice experiment it is assumed that the respondent carries a backpack which is manageable to carry when driving an e-scooter or bike.

Daytime and purpose: In literature was shown that trip purpose such as leisure, business or education is a determinant for the mode choice of the e-scooter (Glavić et al., 2021; Hardt & Bogenberger, 2019). Considering time of the day such as night or day, this has also influence on the mode choice related to safety as shown in Molin and Timmermans (2010). For the mode choice of the e-scooter this might have an influence. Both time of day and purpose are varied in this research.

Safety: the literature on e-scooter safety is enormous, as the type of infrastructure, policy and measures to improve safety has influence on the safety of persons. In this research it is assumed that people who own a private e-scooter know how to drive and are aware of the rules, keeping them themselves safe as was indicated in Mehranfar and Jones (2024). So the safety associated variables are kept fixed.

4.1.2 Alternatives

Several modes are available for access and egress trips, but to make the choice experiment manageable for the respondent, the modes as indicated in table 7 are considered including the private e-scooter.

On the access side, bike trips account for 40%, followed by walking (30%) and btm (20%), according to KiM (2023). On the egress side, walking is dominant (60%), followed by btm (22%) and bike (12%). For the choice experiment, both at the access and egress side, walk, btm, bike and the private e-scooter have been presented as alternatives as indicated in table 7. In table 7, the train has been shown as the main mode. The train has not been taken as a separate alternative but rather serve as the main mode in combination with the other modes for access and egress trips. Other modes such as the shared e-scooter is left out, since the shared e-scooter shows a lot of resemblance to the private e-scooter, other than the fact that a fee must be paid to use the shared service, and the private e-scooter can be used without paying. By including costs for the private e-scooter during the experiment, the private e-scooter can be analysed as private or as shared, but to make the experiment realistic as possible, no costs has been included, since in the Netherlands there is no shared e-scooter service currently.

Table 7 Alternatives considered for access and egress trips

Mode	Access	Main	Egress
Bike	X		X
Bus, tram, metro (BTM)	X		X
Train		X	
Walking	X		X
Private e-scooter	X		X

4.1.3 Attributes and context variables

During the literature review several attributes were mentioned that can influence the mode choice. Every alternative has attributes such as travel time and travel cost (ChoiceMetrics, 2024). Based on the literature review, the attributes in tables 8a, 8b and 8c have been taken into account for the several alternatives.

Table 8a Access attributes

Attribute	Private e-scooter	Bike	BTM	Walking
Walking time to BTM stop			X	
In-vehicle time	X	X	X	X
Waiting time train			X	
Bike parking search time		X		
Comfort in train	X			
Travel cost			X	

Table 8b Egress attributes

Attribute	Private e-scooter	Bike	BTM	Walking
Waiting time for BTM			X	
In-vehicle time	X	X	X	X
Walking time to destination			X	
Parking search time	X	X		
Travel cost			X	

Attribute	Access	Egress
Weather	X	X
Time of day	X	X
Trip purpose	X	X

4.2 Experimental design

After the first phase in which the context, alternatives and attributes have been discussed, the experimental design can be generated. During the experimental design the choice situations that the respondent will face, are generated (ChoiceMetrics, 2024). The experimental design involves several decisions considering the type of alternative, the attribute levels, the design type and at last the number of choices (ChoiceMetrics, 2024). These are discussed in this section.

4.2.1 Type of alternatives

For the type of alternatives, there are two ways to define these, labelled and unlabelled (ChoiceMetrics, 2024). When the alternatives have parameters that are specific to the alternative, then these are labelled for example, bus, train and cycling. When the alternatives have generic/common parameters, the alternatives are unlabelled for example route A and route B. In this research the alternatives for the access and egress trips are labelled, since there are modes with their specific attributes.

4.2.2 Attribute levels

During this part of the experimental design, several decisions should be made, whether the attributes are balanced, the number of attribute levels and the range of the attribute level. Furthermore, the source to find the attribute values has been discussed in this section as well.

Attribute level balance
Attribute level balance means that the attribute level appears an equal number of times at each attribute (ChoiceMetrics, 2024). If attribute level balance is satisfied, the parameters can be estimated at the whole range of levels.

Number of attribute levels
The number of attribute levels can have influence on the number of choice tasks. The more levels used, but also the number of levels per attribute can have influence on the number of choice tasks (ChoiceMetrics, 2024). Therefore, the number of attribute levels should be carefully selected in such a way that the number of choice situations can be minimized. In Bliemer and Rose (2024), the attribute levels can be qualitative, meaning no numbers or can be quantitative, with numbers. For this research the levels are quantitative, although some attributes are coded as dummy variables, having a qualitative meaning such as the attribute time of day coded as 0,1,2, meaning that 0 is peak, 1 is off-peak and 2 is weekend. For this research, most of the attributes have three levels, but there are a few attributes with two levels.

Range of attribute level
The range in the attribute level for example 1 km – 6 km, can have influence on the reliability of the estimated parameters. Attributes with wide range, lead to smaller standard errors compared to attributes with narrow ranges (Bliemer & Rose, 2024). Bliemer and Rose (2024) recommends using

realistic attribute levels, rounded attribute values, and equidistant attribute levels. The attribute values have been determined as realistically as possible, but the gap between the levels have been kept wide as possible.

Attribute levels
For travel times of BTM and bicycle, google maps has been used. Considering travel cost of BTM, the www.9292.nl website has been used. Using these different sources and the recommendations described for attribute level balance, number of attribute levels and range of attribute levels, the values shown in table 9 are the result.

The attribute values in table 9, are based on a straight line of 2 km from the train station to a random location in different cities for access and egress trips since in Jonkeren et al. (2018), the average biking distance from home to a BTM or Train station is around 2.4 km. For BTM, the access part, has been assumed that people travel in such a way that they minimize their waiting time at the BTM stop, but they must walk to the BTM stop, so only walking time to BTM stops has been considered. They must also wait for train when they arrive at the train station. On the egress part, the waiting time for BTM is taken into consideration as there is waiting time between the arrival of the train and the departure of the BTM. For the private e-scooter however, the travel times cannot be determined using google maps. It is assumed that private e-scooter is somewhat faster (1 min) than the bicycle (Oeschger et al., 2023). Furthermore, the expected comfort level of the private e-scooter is taken into consideration when in the train which consists of two possible values:
1) "Stored" meaning that the private e-scooter is folded and stored under the seat.
2) "Holding" means that the train is crowded, and the person should hold the e-scooter, because less space to store or the person wants to keep the e-scooter close to him or herself.

The attribute levels which are numerical have been determined based on distances of 2 km on both the access and egress side. Several locations have been selected on Google Maps and from there, the variations in the travel times and travel costs have been determined. Based on the variations, the levels were determined. Train trips of around an hour have been considered. For reference, train travelling from Rotterdam Central to Amsterdam Central takes an hour and 14 minutes. One of the locations selected is from Rotterdam Central to a location 2 km apart for the access part and then on the egress part is a location 2 km apart from Amsterdam Central. In such a way other train stations with train trips around an hour have been selected and from there the values have been collected. After the collection, the variations in the values have been observed and the attribute levels have been determined. The result of this collection is shown in table 9.

The variable bike parking search time for access and egress is an estimation. The same holds for the private e-scooter parking search time. These could not be found in literature and can also not be retrieved from Google Maps or from another article. The weather, time of day and trip purpose context variables with their levels have been taken from Molin and Timmermans (2010).

Table 9 Attribute levels

Attribute	Attribute level
Private e-scooter	
1 Access in-vehicle time	4, 8, 12
2 Comfort on the train	Stored, Holding
<u>3 Egress in-vehicle time</u>	<u>4, 8, 12</u>
<u>4 PE space search time at destination</u>	<u>1, 3, 5</u>
Bike	
5 Access in-vehicle time	4, 8, 12
6 Access bike parking search time	1, 3, 5
<u>7 Egress in-vehicle time</u>	<u>4, 8, 12</u>
<u>8 Egress bike parking search time</u>	<u>1, 3, 5</u>
BTM	
9 Access walking time BTM	2, 4, 6
10 Access In-vehicle time	3, 6, 9
11 Waiting time train	3, 6, 9
12 Access Travel cost access	1, 2, 3
<u>13 Egress waiting time for BTM</u>	<u>3, 6, 9</u>
<u>14 Egress In-vehicle time</u>	<u>3, 6, 9</u>
<u>15 Walking time to destination</u>	<u>2, 4, 6</u>
<u>16 Egress Travel cost</u>	<u>1, 2, 3</u>
Walking	
17 Access walking time	12, 18, 24
<u>18 Egress walking time</u>	<u>12, 18, 24</u>

Underlined attributes are egress variables. The not underlined attributes are access variables. The context variables hold for both access and egress.

4.2.3 Design type and prior values

In the previous sections, the context, the alternatives and the respective attributes with their levels have been specified. In this section the type of experimental design has been discussed.
Several design type exists (ChoiceMetrics, 2024):
- Full factorial design: all possible choice situations are included, which means that the number of situations that the respondent faces is too large
- Fractional factorial design: a subset of the full factorial design is chosen in a structured way
  - Orthogonal design: through this design the correlations between attributes are minimized
  - Efficient design: not only is the correlation minimized but also the standard errors are minimized of the estimated parameters. This design, however, needs prior estimates which need to be accurate to maximize the information shown to the respondent.
  - Bayesian efficient design: this design is similar to the efficient design, but instead of fixed prior parameters, the priors are now randomly assigned.

For this research the efficient design has been used. The efficiency of the design can be measured by measuring how much the efficient design error is. The most widely used measure is the D-error. The

lowest value for the D-error is an optimal design, but this is difficult to achieve in practice (ChoiceMetrics, 2024). Instead an acceptable low D-error is accepted, calling the design an D-efficient design (ChoiceMetrics, 2024).

As was mentioned, priors are necessary for an efficient design. These priors can be found in literature such as in Arentze and Molin (2013), who has a similar design as to this research. In table 10, the priors are shown including the literature from which the priors have been retrieved. Many prior values could not be found such as bike parking search time and private e-scooter parking search time and in-vehicle time, but these have also been taken from other literature which have been assumed to be the same.

For the private e-scooter in-vehicle time (access and egress), ASC (access and egress), the shared e-scooter travel time parameter from van Kuijk et al. (2022) has been assumed, considering the similarities of the shared and private e-scooter. For the bike parking search time the value was around -0.1 as observed in Geržinič, Cats, et al. (2024); Geržinič, van Hagen, et al. (2024); Geržinič et al. (2023). This value was also assumed to be similar for the private e-scooter search time. The parameter of "e-scooter comfort in train" could not be found in literature. This parameter is related to the crowdedness in the train. When there are no seats available because of a high level of crowdedness, the person with an e-scooter should hold the e-scooter and vice versa. The value for crowdedness in trains in the Netherlands was around -1 (Shelat et al., 2022; Singh et al., 2023; Yap et al., 2020). However, for all the values in table 10, a bayesian prior has been defined including a standard variation. The standard deviation is shown between brackets and is based on the observed variation in the several mentioned literatures.

Table 10a Prior values Access

Attribute	Private e-scooter	Bike	BTM	Walking
ASC	-0.5*** (0.7)	-0.438*	-0.888*	0 (reference)
Walking time to BTM stop			-0.11*	
Walking time for whole access trip				-0.110*
In-vehicle time	-0.03*** (0.07)	-0.095*	-0.084*	
Waiting time train			-0.073*	
Bike parking search time		-0.1**		
E-scooter comfort in train	-1.0**** (1.0)			
Travel cost			-0.207*	

* Arentze and Molin (2013)
** Geržinič, Cats, et al. (2024); Geržinič, van Hagen, et al. (2024); Geržinič et al. (2023)
*** van Kuijk et al. (2022)
**** Shelat et al. (2022); Singh et al. (2023); Yap et al. (2020)

Table 10b Prior values Egress

Attribute	Private e-scooter	Bike	BTM	Walking
ASC	-0.5*** (0.7)	0.055**	-0.165*	0 (reference)
Waiting time for BTM			-0.112*	
Walking time for whole access trip				-0.101*
In-vehicle time	-0.03*** (0.07)	-0.130*	-0.069*	
Walking time to destination			-0.101*	
Bike parking search time		-0.1**		
Private e-scooter parking search time	-0.1** (0.15)			
Travel cost			-0.207*	

* Arentze and Molin (2013)
** Geržinič, Cats, et al. (2024); Geržinič, van Hagen, et al. (2024); Geržinič et al. (2023)
*** van Kuijk et al. (2022)
**** Shelat et al. (2022); Singh et al. (2023); Yap et al. (2020)

4.2.4 Number of scenarios and experimental design

The experimental design has been generated with the software Ngene. Two experimental designs have been generated for the access and egress sides. For each access and egress choice tasks, 12 rows were defined to generate 12 choice tasks. The Ngene code that was used to generate the experimental design is shown in appendix A.1 and A.2. The experimental designs are shown in tables A.3 and A.4.

4.3 Survey

In the previous section, section 4.2, the experimental design has been generated. The experimental design has been used to present the respondents with several choice tasks. In this section the survey has been discussed. The survey is shown in appendix A.5. For convenience only two scenarios have been shown in appendix A.5.

4.3.1 Survey outline

The survey begins with an explanation of the survey, which parts the survey contains and the goal of the survey and other information. In each part of the survey, an introduction has been provided. For the choice experiment section, an elaborate explanation of how each scenario is structured. The survey consists of three parts, user characteristics, trip characteristics and the stated choice experiment part.

User characteristics
In this section, questions are asked on the respondents their personal information, see table 11.

Table 11 User characteristics

User characteristic	Possible answers to choose from
Age	Younger than 18
	Between 18 and 35
	Older than 35
Gender	Male
	Female
	Non-binary
	Prefer not to say
Education	Primary school
	High school
	Undergraduate
	Graduate
	PhD or higher
	Prefer not to say
Average monthly income	2500 and lower
	Between 2500 and 4500
	Higher than 4500
	Prefer not to say
Occupation	Part-time job
	Full-time job
	Jobseeker
	Student
	Volunteer
	Retired
	Unable to work
	Prefer not to say

Trip characteristics

In this section, questions are asked to the respondents concerning their current travel behaviour. The variables included are train travel frequency, travel purpose, current access and egress mode choice, e-scooter ownership, e-scooter experience, driving license ownership and LEV's ownership, see table 12.

Table 12 Trip characteristics

Trip characteristic	Possible answers to choose from
Train travel frequency	0–1
	2–4
	5--8
Travel purpose	Work
	School
	Leisure
	Other
Current access mode	Walking
	BTM (bus, tram, metro)
	Bike
	Shared modes (e-moped, bike, e-bike, e-car)
	Light-electric vehicles, LEV (e-bike, e-scooter, e-moped)
	Car as a driver
	Car as a passenger

	Other
Current egress mode	Walking
	BTM (bus, tram, metro)
	Bike
	Shared modes (e-moped, bike, e-bike, e-car)
	Light-electric vehicles, LEV (e-bike, e-scooter, e-moped)
	Car as a passenger
	Other
E-scooter ownership	Yes
	No and I have no intention to buy one
	No, but I am considering to buy one
E-scooter driving experience	Yes
	No
Driving license ownership	No
	Yes and I own a car
	Yes, but I do not own a car
Micro-vehicle ownership	Yes
	No

Stated choice experiment

In this section, the choice experiment has been presented, which involves 12 scenarios', including the access and egress alternatives. Each scenario is composed of access, egress and a whole trip part.

In this research the assumption is that the private e-scooter can be used for both the access and the egress trip. During the scenario's, the respondents receive a question first on access, then on egress and finally on the whole trip. This means that respondents can select an access and an egress mode separately. To maintain the assumption of the e-scooter being used for both the access and egress trip, a three-step approach has been used and shown in figure 9. The reason for using a three-step approach is that otherwise when someone selects the private e-scooter for access and another mode for egress, then the assumption is violated. So, to solve this, during access, a respondent can select between Bike, BTM and Walking. During egress, a respondent can select between Bike, BTM and Walking. Then in the final part of the scenario, the respondent can select between private e-scooter for the whole trip or their current choices on access and egress combined.
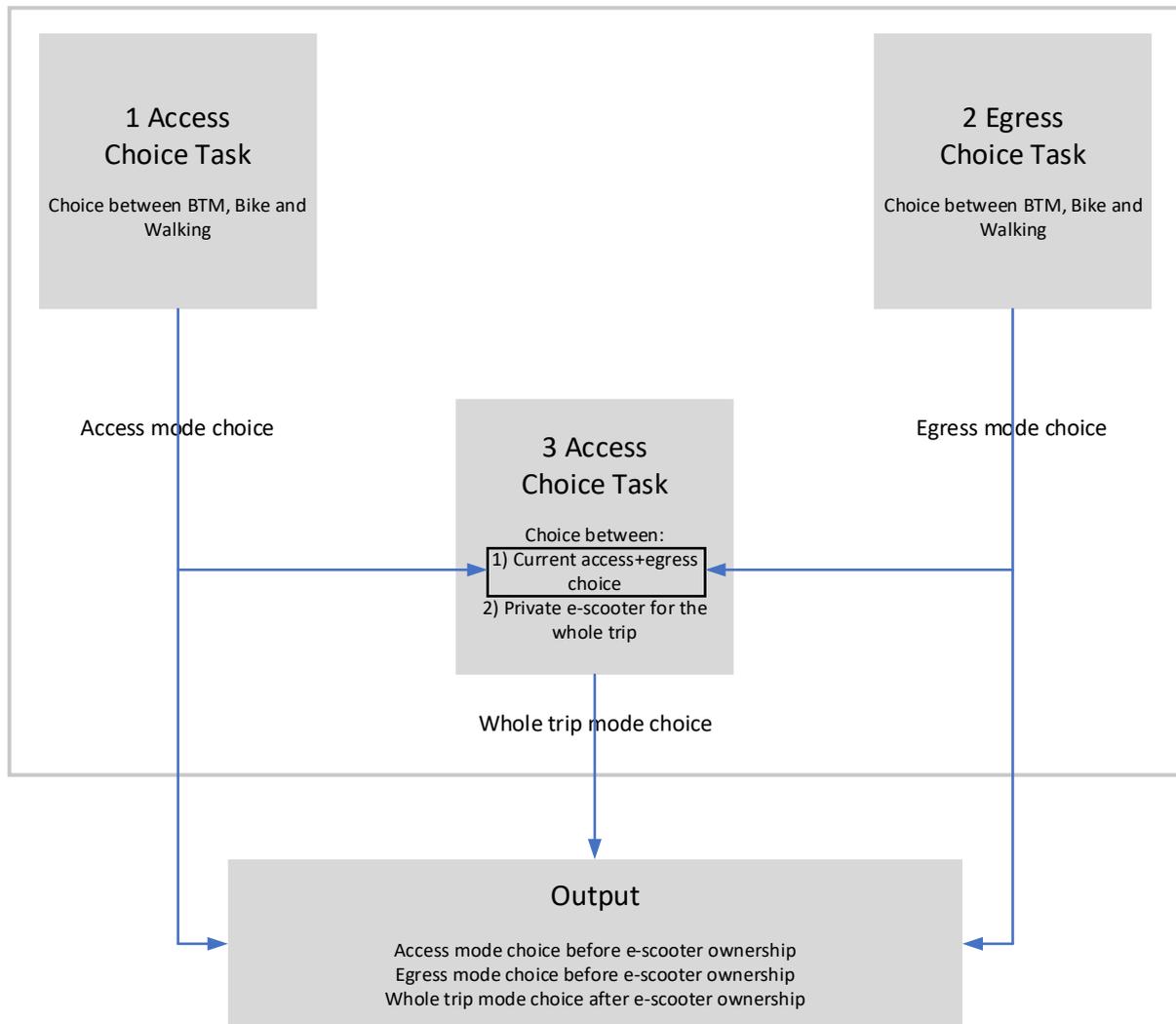
Figure 9 Three step mode choice approach

4.3.2 Survey distribution

The survey has been implemented in Qualtrics. By attaching the right textual values to the experimental design values, the survey was implemented in Qualtrics. The choice cards as seen in 4.3.4 have been visually designed in Excel and after that implemented in Qualtrics. The pilot survey was distributed to especially Whatsapp contacts. The final survey distribution was done on various platforms such as Facebook, Surveycircle, Instagram, Linkedin, Whatsapp contacts and Whatsapp groups. Also, through physically asking people to take part in the Survey, were one of the methods for the survey distribution. Approximately one and a half month was taken to distribute the survey and collect responses.

4.3.3 Pilot and points of improvement

Before the actual survey was carried out, a pilot survey was carried out and conversations on the survey were carried out as well. There were several points for improvements that were implemented for the final survey as shown in appendix A.5. The points of improvement were:
-    The context that initially was varied, was forgotten by respondents. For the final survey the context was left out. Instead, a fixed context was shown (figure 10).

Figure 10 Fixed context

- There was also difficulty in English terms such as access and egress. For the final survey the whole survey was done in Dutch to make understanding of the survey and especially the choice experiment easier. The English-speaking audience was left out after it was clear that the pilot survey was mostly answered by Dutch speaking people and there was difficulty in understanding the content of the choice experiment.
- The meaning of the numbers shown at the choice tasks. These numbers are varied levels and mean that they are the corresponding values to the attributes such as travel time and travel cost. In the final survey the numbers were explained better.
- The guide of the choice experiment was unclear. This was made clearer, by showing an image of a whole trip including access, egress and train trip (figure 11). Based on this, the scenarios are designed. So, the respondent first receives a question on access, then on egress and finally on the whole trip.
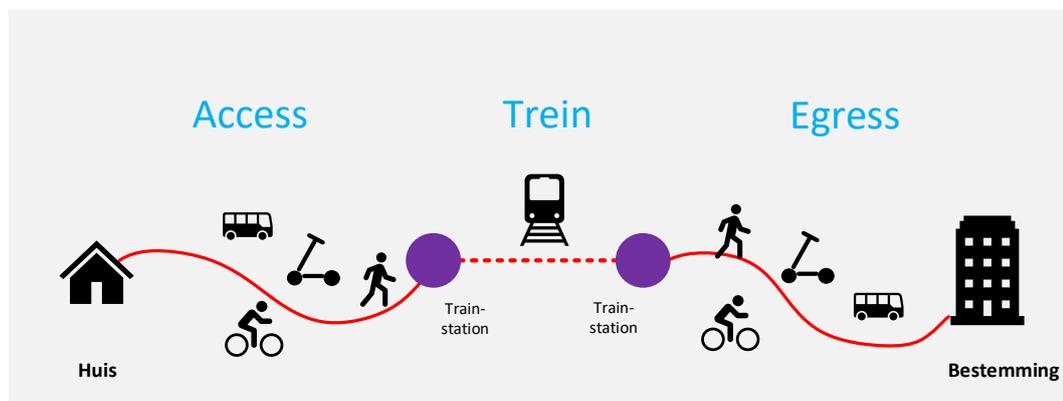

Figure 11 A trip from home (huis) to destination (bestemming).

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- For convenience also a fixed distance was added for the context such that the respondent can have an indication of the access and egress trip length. Furthermore, also other fixed variables as train trip length and day of travelling were added.
- There was also confusion on the attribute train waiting time. This was initially added only for BTM and was left out for the alternative bike and walking. This is almost not common to have zero waiting time for trains. To make it realistic, a fixed train waiting time was added for bike and walking of 3 minutes.

4.3.4 Choice task

The eventual choice task is based on the three steps approach of figure 9. This three-step approach has two main benefits:
1) This ensures that the mode choice alternatives for access as well as egress are representative. When a combination of access and egress mode choice alternatives would be taken, then the number of alternatives would increase and then some alternatives had to be removed to make it manageable for the respondent. The access and egress choice task are now separate which is more manageable for the respondent.
2) This also ensures that the mode shift can be observed, due to the third question in which the answers of the access and egress choice task come together and the e-scooter is offered as an alternative.

In figure 12 an example of a choice task is shown including the three questions respective access, egress and whole trip.

Scenario 1

Vraag 1: Welke vervoerswijze zou u kiezen om te reizen vanaf uw huis naar het treinstation (*access*)?

	BTM	Fiets	Lopen
Looptijd naar een BTM halte (minuten)	6		
Reistijd (minuten)	3	12	24
Wachttijd voor de trein (minuten)	3	3	3
Parkeerplek zoektijd (minuten)		1	
Reiskosten (euro's)	1		

◉ BTM

○ Fiets

○ Lopen

Vraag 2: welke vervoerswijze zou u kiezen om te reizen vanaf het treinstation naar uw bestemming (*egress*)?

		BTM	Fiets	Lopen
⏳	Wachttijd voor de BTM (minuten)	9		
🕐	Reistijd (min)	3	12	24
🚶	Looptijd naar eindbestemming	6		
🔍	Parkeerplek zoektijd (minuten)		1	
€	Reiskosten (euro's)	1		

○ BTM

◉ Fiets

○ Lopen

Vraag 3: bij deze vraag kijken we naar de gehele reis dus access en egress en trein ertussen. Stel dat u een e-step bezit. Zou u deze e-step gebruiken voor de gehele reis of zou u nog steeds de vervoerswijze kiezen die u gekozen hebt bij de vragen 1 en 2 hierboven?

		BTM	Privé e-step
🚶	Looptijd naar een BTM halte (minuten)	6	
🕐	Reistijd (minuten)	3	8
⏳	Wachtijd voor de trein (minuten)	3	3
🔍	Parkeerplek zoektijd (minuten)		
€	Reiskosten (euro's)	1	
🛡	Comfort in de trein met de e-step		Comfortabele treinrit omdat de e-scooter geborgen is.

+ +

		Fiets	Privé e-step
⏳	Wachttijd voor de BTM (minuten)		
🕐	Reistijd (min)	12	4
🚶	Looptijd naar eindbestemming		
🔍	Parkeerplek zoektijd (minuten)	1	5
€	Reiskosten (euro's)		

◉ Ik zou de e-step kiezen voor de gehele reis

○ Ik zou dezelfde vervoerswijze kiezen zoals ik gekozen heb bij de vragen 1 (BTM) en 2 (fiets)

Figure 12 Access, egress and whole trip choice task

4.4 Conclusion

Designing the stated preference experiment for this research was a challenging task. The constraint of using the private e-scooter for both the access and the egress stage and not separately was a constraint that had to be implemented. This caused a challenge in how to design the stated choice experiment mathematically and thinking about the process of how a respondent would address such an experiment. This kind of design has not been seen previously in literature. The approach proposed in this section is a first step in designing a more robust access-egress stated choice experiment design.

The design involved a three-step approach including access, egress and a whole trip section. The whole trip section was necessary to eventually implement the constraint. The design proposed here offers a flexible way of offering more alternatives to respondents, without leaving out core alternatives. The attributes used were chosen according to literature and chosen carefully as realistically as possible, that are currently present in The Netherlands.

There was however a design dilemma. On the one hand the choice was to show less scenarios to the respondents, but this deign would need many respondents to fill in the survey. On the other hand, the choice was to show more scenarios to the respondents, but this design would lead to respondents not answering all the questions or just filling in random answers. Since the timespan for this research is limited, it was opted to choose for the design with less scenarios. It is important to mention that each scenario consisted of three parts, access, egress and a whole trip part. So eventually the survey was large and complex for a respondent to answer. In the future it is recommended to use such a design by opting for a design in which less scenarios are shown but find many respondents to answer the questions in the scenarios.

5 Descriptive statistics

During this section the answers obtained from the survey are analysed, including the respondents their information, their trip information and the answers obtained from the stated choice experiment (SCE). The survey has been sent to people on several platforms. The data collection was from the 28th of April till the 28th of May of 2025. A total of 145 responses were collected, of which 118 were eligible for analysis. Every respondent answered 12 scenarios. Each scenario had three questions. The first question was on access, the second on egress and the final question on the whole trip. The software used to analyse the obtained data from Qualtrics, was through the programming language Python in Jupiter Notebook.

5.1 Sample statistics

In this section, the statistics regarding the first part (respondent characteristics) and the second part (trip characteristics) are discussed.

5.1.1 Respondent characteristics

During the first part of the survey, questions were asked regarding people their personal information. The survey was mainly sent to young people in the range between 18 and 35 years old, since the expectation beforehand was that the e-scooter was appealing to especially young people. According to literature, the private e-scooters are mainly used by young people (Christoforou et al., 2021; Glavić et al., 2021; Oeschger et al., 2023). Considering gender, more females took part in the survey. Also here, the survey was sent to familiar people. When looking at the education distribution, the respondents are highly educated. This is in line with literature (Christoforou et al., 2021). Since the survey has been sent to mostly young people and students, the expectation beforehand was that they had a low income, indicated as 2500 and lower in table 13. Most of the people are students and the other half have a full-time job. So, the data obtained is not very diversified, since the survey was distributed to mostly young people. Among the young people, differences could however be seen when looking at the income, education and occupation.

Table 13 Descriptive statistics of respondents

User characteristic	Category	N	Sample
Age	Younger than 18	0	0 %
	Between 18 and 35	112	95 %
	Older than 35	6	5 %
Gender	Male	48	41 %
	Female	70	59 %
	Non-binary	0	0 %
	Prefer not to say	0	0 %
Education	Primary school	0	0 %
	High school	19	16 %
	Undergraduate	58	49 %
	Graduate	37	31 %
	PhD or higher	1	1 %
	Prefer not to say	3	3 %

Average monthly income	2500 and lower	53	45 %
	Between 2500 and 4500	31	26 %
	Higher than 4500	9	8 %
	Prefer not to say	25	21 %
Occupation	Part-time job	16	13 %
	Full-time job	48	41 %
	Jobseeker	1	1 %
	Student	52	44 %
	Volunteer	0	0 %
	Retired	0	0 %
	Unable to work	0	0 %
	Prefer not to say	1	1 %

5.1.2 Trip characteristics of respondents

During the second part of the survey, questions were asked regarding the travel characteristics of the respondents. Every trip characteristic in table 14 shows diversified characteristics. For young people, mostly students, the train travel frequency between 2-4 days per week is high as characterized by 45% of the sample. The purposes for which people used the train were work, school and leisure and all three trip purposes were each done by approximately 30% of the respondents.

Considering current access modes, BTM (36 %) is mostly used, followed by bike (20 %) and walking (26 %). This was also the conclusion from KiM (2023) . Interestingly also 11 % of the respondents used the car for egress. From the data it is not clear whether the respondent used the car for access, or the respondent used the car for the whole trip access plus egress. On the egress side, BTM (47 %) and walking (41 %) dominate, which are also in line with KiM (2023). Bikes have a very low usage at the egress side, likely due to not owning a bike at the egress side.

Many of the respondents (83 %) does not own an e-scooter and are not intending to buy one, however 16 % would like to buy an e-scooter. Interestingly, more than half of the respondents, 55 % have experience with driving an e-scooter. This could be a shared e-scooter that the respondents have driven on. When looking at the driving license ownership, around 39% own a driving license, but no car and around 41% own a driving license and a car. Approximately 20% of the respondents do not possess a driving license and this group is likely to travel by train. 65% of the respondents own a micro-vehicle (bike, e-bike etc.). These vehicles could be a competitor to the private e-scooter.

Table 14 Descriptives of respondents their trip

Trip characteristic	Possible answers to choose from	N	Sample
Train travel frequency	0–1	49	42 %
	2–4	52	45 %
	5--7	15	13 %
Travel purpose	Work	35	30 %
	School	32	28 %
	Leisure	37	32 %
	Other	12	10 %
Current access mode	Walking	31	26 %
	BTM (bus, tram, metro)	41	36 %
	Bike	23	20 %

	Shared modes (e-moped, bike, e-bike, e-car)	3	3 %
	Light-electric vehicles, LEV (e-bike, e-scooter, e-moped)	0	0 %
	Car as a driver	13	11 %
	Car as a passenger	4	3 %
	Other	1	1 %
Current egress mode	Walking	46	41 %
	BTM (bus, tram, metro)	55	47 %
	Bike	4	3 %
	Shared modes (e-moped, bike, e-bike, e-car)	2	2 %
	Light-electric vehicles, LEV (e-bike, e-scooter, e-moped)	0	0 %
	Car as a passenger	5	4 %
	Other	4	3 %
E-scooter ownership	Yes	1	1 %
	No and I have no intention to buy one	97	83 %
	No, but I am considering to buy one	18	16 %
E-scooter driving experience	Yes	64	55 %
	No	52	45 %
Driving license ownership	No	23	20 %
	Yes and I own a car	48	41 %
	Yes, but I do not own a car	45	39 %
Micro-vehicle ownership	Yes	75	65 %
	No	41	35 %

5.2 Potential mode shift based

As was said earlier, each respondent received 12 scenarios. Each scenario had three questions, access, egress and a whole trip question. The access and egress questions had the alternatives bike, BTM and walking, but during the whole trip question, two alternatives were shown. The first alternative consisted of the answers chosen of the access and egress question combined, and the second alternative was the private e-scooter that can be used for the whole trip (access + egress). The choice scenario can be seen as a trip, so every respondent was faced with 12 different trip situations. Due to this three-step approach, the mode shift could be determined. When combining the access and egress alternatives, 9 combinations were obtained. In table 15a below, the 9 combinations (chains) are shown. A chain is an access mode plus train and egress mode. When analysing the stated choice experiment answers on the choice scenarios, the change in mode shift from the nine combinations to the private e-scooter was on average 4% based on the total number of trips (N). Especially the combination where bike is the access mode and egress mode, show large shifts to the PE of around 13%, which could indicate that the private e-scooter is indeed a competitor to the bike. When observing the change in modal shift by chain there is a high shift from walking, implying that long walking times are less preferred. There is one combination BTM-Bike, that in 45 % of the trips, people who initially answered BTM – Bike, are more likely to replace this chain by the PE – PE combination.

When observing access and egress mode choices separately, there are some interesting results. Since the private e-scooter is used for both access and egress, the choice frequency of the private e-scooter should be the same for both access and egress. This is the case as can be seen in table 15b. For both access and egress, the private e-scooter is dominant. In 37 % of the trips people are likely to choose the private e-scooter for access and 37 % for egress. This percentage can be considered as a 37% probability that the private e-scooter will be chosen for the access and egress trip. This was not as expected prior to the experiment. The expectation was that the private e-scooter would be chosen much less compared to the other modes. This could be due to the sample size being mostly young people and that this is a hypothetical study in which people had to imagine that they own an e-scooter. As can be seen in table 15b, is that bike is still popular for both access and egress, of around 30 % of the trips are likely to be carried out by bike.

Table 15a Mode shift when considering the whole chain

	Chain	N (trips)	Stayed with current mode	Shifted	Shifted to PE-PE by chain (%)	Shifted to PE-PE by total N (%)
1	BTM-BTM	193	132	61	32%	6%
2	BTM-BIKE	119	66	53	45%	5%
3	BTM-WALKING	56	40	16	29%	2%
4	BIKE-BTM	65	42	23	35%	2%
5	BIKE-BIKE	344	209	135	39%	13%
6	BIKE-WALKING	77	46	31	40%	3%
7	WALKING-BTM	32	20	12	38%	1%
8	WALKING-BIKE	78	45	33	42%	3%
9	WALKING-WALKING	93	70	23	25%	2%

Table 15b Access and egress mode selected

Mode	Access		Egress	
	N	(%)	N	(%)
BTM	238	22%	194	18%
Bike	297	28%	320	30%
Walking	135	13%	156	15%
Private e-scooter	387	37%	387	37%

5.3 Conclusion

Including separate choice experiments for the access and egress trips, proved to be beneficial in terms of obtaining the mode shift. The results showed that especially people who use the bike for access and bike for access, mainly by students, are willing to switch to the private e-scooters, in 13% of trips. When looking at the potential mode split when people would own the private e-scooter, in approximately 37% of the trips, people would likely use it for both access and egress. So, the potential is huge when people would own a private e-scooter in the Netherlands for access and egress trips. To mention is, that this is especially the case for train travellers between 18 and 35 years and are students and highly educated.

For this research, it is important to mention that the sample size is biased, since predominantly students, young highly educated people between the age of 18 and 35 have taken part in the choice experiment. This is however in line with literature, where especially young highly educated males use the private e-scooter (Arias-Molinares et al., 2021; Christoforou et al., 2021; Reck et al., 2022). Also, the gender split is not in line with what is observed in literature. In literature mostly male use the private e-scooter. Since there is bias, the respondent characteristics has not been taken into consideration for the modelling part in the next section. For a follow-up research a larger diversified sample is recommended.

6 Discrete choice modelling

In this chapter the data that was obtained from the survey has been analysed through discrete choice modelling. In this section the model that has been applied to analyse the data has been discussed as well.

6.1 Choice for discrete choice model

As mentioned earlier, the complete trip consists of an access and an egress part. To focus on the factors causing the mode shift, these have been added to the analysis of the access trip only. The data obtained for the egress trip is of less quality and the sample size was too small to achieve statistical significance for many attributes. Since access and egress are connected, focusing on the access trip would give the necessary information on the factors influencing the mode choice to shift to the private e-scooter. Adding interactions with the actual access and egress mode choice as mentioned in the descriptive analysis will provide the information of travellers, who would like to shift to the private e-scooter. For completeness, the egress analysis has also been provided in section 6.4.

The data that was obtained is of a panel structure. A panel structure means that one respondent has faced several questions and thus gave several answers. During the stated preference experiment, the respondent faced 12 scenarios. Each scenario had three questions, an access, an egress and a whole trip question. The respondent had to answer 36 questions. The huge number of questions could be also a reason why the egress data is of bad quality.

There are several choice models that can be used to analyse the stated preference data such as the multinomial model (MNL), the mixed logit model (ML) and the nested logit model. These have been discussed in section 2.3. The MNL model has the IIA (Independence from Irrelevant Alternatives) property, meaning that the probabilities of choosing any two alternatives is not dependent on the availability of another alternative (McFadden et al., 1977). The drawback of the MNL is that it firstly cannot deal with preference heterogeneity (differences) of alternatives. Secondly, the MNL model cannot deal with respondents that answer multiple choice questions (panel structure) and thirdly the MNL model assumes constant error variance for all alternatives in the model (Bliemer & Rose, 2010). The mixed logit model with panel structure can better deal with correlation among choice situations that the respondent face, with preference heterogeneity and every alternative has a non-constant variance error term (Bliemer & Rose, 2010). The LCCA model has not been discussed since the respondents are mostly students and have a high education. Segregating the already dominant student set, might not give the information necessary to explain the factors that cause modal shift. The model that has been used for analysing the data is initially ML-panel structure base model and afterwards the ML-panel base structure model is further elaborated by adding the trip characteristics variables.

6.2 Base access ML model

For the base ML model, the alternative specific coefficients (beta's) and their respective attributes were added in the model including an alternative specific constant (ASC). This constant captures the utility for an alternative when all other factors are zero. There is also an error in every utility function. Every alternative has a different error term, which is in line with what the ML model is capable of. The error term is to capture the unobserved factors other than the attributes considered during the stated choice experiment. For every coefficient an additional standard deviation was added with a normal distribution, which is the feature to capture heterogeneity in the ML model, that the MNL model

cannot capture. The attributes that were used for the stated choice experiment are the observed factors and were carefully chosen according to the literature review in chapter 3 and the eventual conceptual model defined in section 3.5. These attributes can be estimated. But there are many other attributes that could be captured but have been left out to avoid the model becoming too complex. The essence lies in capturing the purpose of the research as defined in section 1, which is the mode shift and the factors that cause the mode shift. The model was defined as realistically as possible, including attributes that are recognizable in the Netherlands. These attributes have been discussed earlier during the stated choice experiment. Below the model has been defined and the description is in table 16. The model is in the form of utility functions of the different alternatives. Each alternative has specific attributes belonging to the alternatives and each alternative has a coefficient, which explains how important the attribute is to the alternative. Note that the additional standard variance is not shown here in the utility function, for clarity purposes. The compact form of the ML model was discussed earlier in section 2.3. For the private e-scooter the willingness to pay (WTP) cannot be calculated since there are no costs involved. Including cost for the private e-scooter would confuse respondents, since the private e-scooter is shown as an alternative in the choice experiment and not as a shared e-scooter. However, including cost, would allow simulating price sensitivity of respondents and shared modes could be analysed. The shared modes are out of scope of this research. The focus is on the private e-scooter.

Model definition

$$V_{a\_btm} = ASC_{a\_btm} + \beta_{a\_btm\_wktb} * a\_btm\_wktb + \beta_{a\_btm\_tt} * a\_btm\_tt + \beta_{a\_btm\_wat} * a\_btm\_wat + \beta_{a\_btm\_c} * a\_btm\_c + \varepsilon_{a,btm}$$

$$V_{a\_bike} = ASC_{a\_bike} + \beta_{a\_bike\_tt} * a\_bike\_tt + \beta_{a\_bike\_pst} * a\_bike\_pst + \varepsilon_{a,bike}$$

$$V_{a\_pe} = ASC_{a\_pe} + \beta_{a\_pe\_tt} * a\_pe\_tt + \beta_{com\_pe} * com\_pe + \varepsilon_{a,pe}$$

$$V_{a\_walking} = ASC_{a\_walking} + \beta_{a\_walk\_tt} * a\_walk\_tt + \varepsilon_{a,walking}$$

Model description

Table 16 Base ML model description

Term	Description
V_{a_btm}	Utility of access BTM
V_{a_bike}	Utility of access Bike
V_{a_pe}	Utility of access private e-scooter
$ASC_{a,btm}$	Alternative specific constant for access BTM
$ASC_{a,bike}$	Alternative specific constant for access bike
$ASC_{a,pe}$	Alternative specific constant for access PE
$ASC_{a,walking}$	Alternative specific constant for access walking
$\beta_{a\_btm\_wktb}$	Access walking time to BTM stop coefficient
$\beta_{a\_btm\_tt}$	Access BTM in-vehicle time coefficient
$\beta_{a\_btm\_wat}$	Access waiting time for train coefficient
$\beta_{a\_btm\_c}$	Access BTM travel cost coefficient
$\varepsilon_{a,btm}$	Error term for access BTM
$\beta_{a\_bike\_tt}$	Access bike travel time coefficient
$\beta_{a\_bike\_pst}$	Access bike parking search time coefficient

$\varepsilon_{a,bike}$	Error term for access bike
$\beta_{a\_pe\_tt}$	Access private e-scooter travel time coefficient
$\beta_{com\_pe\_1}$	Comfort of the private e-scooter on the train when it is stored coefficient
$\varepsilon_{a,pe}$	Error term for access private e-scooter
$\beta_{a\_walk\_tt}$	Access walking travel time coefficient
$\varepsilon_{a,walking}$	Error term for access walking

Model results

Table 17 Base ML model results

Alternative attributes	Estimate	p-value
$ASC_{a,bike}$	-2.09***	0.00
$ASC_{a,btm}$	-1.59*	0.07
$ASC_{a,pe}$	-3.36***	0.00
$\beta_{a\_bike\_pst}$	-0.36***	0.00
$\beta_{a\_bike\_tt}$	-0.25***	0.00
$\beta_{a\_btm\_c}$	-0.33**	0.04
$\beta_{a\_btm\_tt}$	-0.15***	0.00
$\beta_{a\_btm\_wat}$	-0.21***	0.01
$\beta_{a\_btm\_wktb}$	-0.40***	0.00
$\beta_{a\_pe\_tt}$	-0.18***	0.00
$\beta_{a\_walk\_tt}$	-0.40***	0.00
$\beta_{com\_pe\_1}$	0.25	0.33

***Significant at 99% confidence level,
**Significant at 95% confidence level,
*Significant at 90% confidence level

In table 17 above, the results of the access base ML model are shown including the p-value, which is an indication of the statistical significance (Abdullah et al., 2025). The statistical significance is indicated in stars, which have different confidence intervals. The confidence intervals indicate that the true value of the population coefficient will likely lie between the intervals. This means that when a coefficient is significant at a 99% confidence interval, that this coefficient has 99% probability that it is likely true for the entire population and 1% probability that it might be wrong. Most used confidence levels are 90%, 95% and 99%. Also note that the additional standard deviation term is not shown here, but in the appendix B.3.

All the coefficients are statistically significant except the comfort in the train when the private e-scooter is stored. This could mean that there are other variables that are left out of this model, which correlate with this variable. The solution could be to interact this attribute (com_pe_1) with other attributes or include the other attributes without interaction. The base of the comfort level is when someone should hold the e-scooter. The positive sign of the comfort level when the private e-scooter is stored seems to be valid, since it is expected that when there is discomfort, this leads to a negative contribution of the utility and this on its turn could lead to less probability of someone choosing the private e-scooter. The comfort level attribute is not statistically significant, which can also be caused by a limited sample size.

When comparing the two private modes, bike and the private e-scooter, people would seem to attach more disutility due to travel time when choosing the bike compared to the e-scooter. This could be related to the speed of the mode. When designing the stated choice experiment, the travel times of the private e-scooter were defined as a minute faster than the conventional bike. So, each minute increase in travel time leads to a decrease of utility of the bike by 0.25 utils. BTM is even faster than the private e-scooter which makes BTM more attractive in terms of travel time. Walking is the least preferred in terms of travel time as can be seen by the relatively high contribution of the coefficient on utility. Both btm_wktb (walking time to a BTM stop) and walk_tt (walking time) have similar coefficient of -0.40. In short, all the variables when increased show a negative contribution to utility. Only the comfort level shows a positive sign, but this is not significant, still it shows a value that could be expected.

When comparing the ASCs of the alternatives, the PE shows the highest value. When computing probabilities by assuming that all other factors are zero, except the ASC, then the PE has the lowest probability of being chosen, despite the high frequency of been chosen during the choice experiment. But in reality, this is not possible since there is variety (heterogeneity) in tastes concerning the attributes and everyone values (weights) the attributes differently. In section 4.2.3, when defining the prior values, the values of bike parking search time and private e-scooter in-vehicle time could not be retrieved from other sources and so the estimates in this research can be used in another research since these are statistically significant.

6.3 ML access model with explanatory attributes

To see the influence of the trip variables, these were not interacted with other attributes but were instead added as a separate variable to see the effect of the trip attributes on the mode choice. The added trip attributes are shown in table 18 and the variables are coded as dummy variables. For the trip purpose as an example, there are three levels including a base level. The base level has been left out during model estimation. This is necessary as this might cause multicollinearity among the dummy variables, which is the well-known dummy variable trap (Stock & Watson, 2019). For interpretation purposes, setting one level of the category as base is also preferable. For the current access mode and egress mode, not all the modes as were presented to the respondent during the trip characteristics survey questions, are included for the analysis, only Bike, BTM and Walking, since these were chosen much more compared to the others. On top of the utility functions of the base ML model, the terms as shown in table 18 were added.

Every level was added separately with an own coefficient. For example, current access mode with level 3 (walking), was added as $\beta_{access\_pe\_cam3} * cam3$. This was done for every variable and level. Note that the trip attributes are added as dummy variables, not as a linear variable. When opting for a linear variable, this means that the change in utility is the same between every level, but this is not correct. For example, trip purpose has three levels, 0 for work, 1 for leisure and 2 for education. When coded linearly, the interpretation would be that when going from 0 (work) to 1 (leisure), that has the same increase in utility as when going from 1 (leisure) to 2 (education). To avoid this, dummy variables are added, which represent a category on its own compared to the base. These explanatory variables were added only in the utility function of the private e-scooter, since the focus is on the private e-scooter and the equation is shown below.

Finding the optimal model for the data obtained was an iterative procedure, including several attributes into the model. Running the model, was computer intensive. For the ML model with explanatory attributes, the model was running for approximately four hours. An MNL model is much faster, but the MNL is not suitable for the data collected, since the data is of a panel structure.

Model definition

$$V_{a\_pe} = ASC_{a\_pe} + \beta_{a\_pe\_tt} * a_{pe\_tt} + \beta_{com\_pe} * com\_pe + \beta_{access\_pe\_cam0} * cam0$$
$$+ \beta_{access\_pe\_cam1} * cam1 + \beta_{access\_pe\_cam2} * cam2 + \beta_{access\_pe\_cem0}$$
$$* cem0 + \beta_{access\_pe\_cem1} * cem1 + \beta_{pe\_ee0} * cee0 + \beta_{pe\_cee1} * cee1$$
$$+ \beta_{pe\_d0} * d0 + \beta_{pe\_d1} * d1 + \beta_{pe\_d2} * d2 + \beta_{pe\_tf0} * tf0 + \beta_{pe\_tf1} * tf1$$
$$+ \beta_{pe\_tf2} * tf2 + \varepsilon_{a,pe}$$

Model description

Table 18 Explanatory attributes

Trip attributes	Coefficient	Levels
Current access mode (cam)	$\beta_{access\_pe\_cam\#}$	3 Walking (base)
		0 bike (base)
		1 BTM
Current egress mode (cem)	$\beta_{egress\_pe\_cem\#}$	0 Walking (base)
		1 BTM
E-scooter driving experience (ee)	$\beta_{pe\_ee\#}$	0 Yes (base)
		1 No
Travel purpose (tp)	$\beta_{pe\_tp\#}$	0 Work (base)
		1 Leisure
		2 Education
Driving license (d)	$\beta_{pe\_d\#}$	1 No (base)
		0 Yes, but no car
		2 Yes and I also own a car
Train frequency (tf)	$\beta_{pe\_tf\#}$	2 0 − 1 (base)
		0 2 − 4
		1 5 - 7

Model result

Table 19 Result of ML model with explanatory attributes

	Estimate	p-value
ASC		
$ASC_{a,bike}$	**-2.01*****	*0.00*
$ASC_{a,btm}$	*-1.36*	*0.14*
$ASC_{a,pe}$	**-5.22*****	*0.00*
Alternative attributes		
$\beta_{a\_bike\_pst}$	**-0.364*****	*0.00*
$\beta_{a\_bike\_tt}$	**-0.29*****	*0.00*
$\beta_{a\_btm\_c}$	**-0.40****	*0.02*
$\beta_{a\_btm\_tt}$	**-0.15*****	*0.00*
$\beta_{a\_btm\_wat}$	**-0.18****	*0.02*
$\beta_{a\_btm\_wktb}$	**-0.42*****	*0.00*
$\beta_{a\_pe\_tt}$	**-0.16*****	*0.00*
β_{com_pe}	*0.33*	*0.22*
$\beta_{a\_walk\_tt}$	**-0.41*****	*0.00*

Explanatory variables		
$\beta_{access\_pe\_cam3}$	0 (base)	
$\beta_{access\_pe\_cam0}$	-0.39	0.64
$\beta_{access\_pe\_cam1}$	**-1.77*****	0.00
$\beta_{egress\_pe\_cem0}$	0 (base)	
$\beta_{egress\_pe\_cem1}$	0.26	0.65
β_{pe_d1}	0 (base)	
β_{pe_d0}	0.74	0.24
β_{pe_d2}	**1.32****	0.04
β_{pe_ee1}	0 (base)	
β_{pe_ee0}	**1.58*****	0.01
β_{pe_tf2}	0 (base)	
β_{pe_tf0}	**1.03***	0.07
β_{pe_tf1}	0.59	0.58

*** Significant at 99% confidence level,

** Significant at 95% confidence level,

* Significant at 90% confidence level

Figure 13 Coefficient plot including standard error

In the results above in table 19 and figure 13, few coefficients are statistically insignificant such as the ASC of BTM and the comfort level of the private scooter. In figure 13, the coefficient with low standard errors has the highest level of significance. The further away from zero, the more this coefficient contributes to the probability of choosing (when positive) or not choosing (negative) an alternative. The standard errors refer to the accuracy that the sample mean of this study, deviates from the actual mean of the population. Note that there was also a random variable added which is not shown in table 19, but in the appendix B.4, capturing heterogeneity among the respondents.

Although the comfort level is statistically insignificant for the private e-scooter, the expectation is still that when the private e-scooter can be stored in the train, people are more likely to use the private e-scooter for both the access and egress part. Also, when looking at the ASC's only, the private e-scooter will most likely be less chosen compared to the other alternatives. The attributes that have a positive influence on choosing the private e-scooter are the train frequency, e-scooter experience and driving license ownership.

Access and egress modes
The explanatory attributes are interpreted in terms of the base. When looking at the egress modes, cem0 is the current egress mode and this is the base as indicated in table 18, and cem1 is BTM. In table 19 the coefficient of cem1 is 0.26. Although insignificant, this means that compared to walking in the egress stage, people who travel by BTM are more likely to shift to the private e-scooter.

When looking at the access modes, cam3 is walking and is the base, cam0 is bike and cam1 is BTM. Cam1 is significant and has a value of -1.77. In contrast to cem1, people who travel by BTM at the access stage compared to walking, people would less likely shift to the private e-scooter. Cam0 is not significant, but it has a positive sign which could also be true that bike users are willing to shift to private e-scooters. This could be true since many bike users as was seen in table 15, would switch to the private e-scooter.

Driving license and car ownership
d1 is the base and represents people without a driving license. The d0 is for people who do have a driving license, but do not own a car. The d2 is for people who have a driving license and a car. The d2 is significant at 90% confidence level and contributes positively to utility, indicating that people who own a car would be willing to switch to the private e-scooter as a mode for access and egress in combination with train. The car is mostly used as a unimodal mode. To be precise, 70% of whole trips in the Netherlands are made by car (CBS, 2023). So as a first impression, the private e-scooter in combination with the train can be a competitor to the car when considering the whole trip from home to destination, but this competition should be defined in a follow-up research.

E-scooter experience
People who have previous experience driving an e-scooter including shared e-scooters, are more likely to switch to private e-scooters. This is in line with the results of Oeschger et al. (2023), who mentioned that people who had experience with shared e-scooters are more likely to choose the private e-scooter. In the Netherlands, shared e-scooters are not present, so the respondents who have experience with shared e-scooters, likely used the shared e-scooter outside the Netherlands.

Train frequency
Tf1, means that people who travel 5-7 days per week by train, tf2 means that people who travel 0-1 days per week by train and tf0 means that people who travel 2-4 days per week by train. The results show that people who travel 2-4 days per week would likely switch to the private e-scooter. This could likely be due to the convenience of travelling on access and egress. The private e-scooter might provide such convenience compared to cycling but also cost benefits compared to the BTM.

6.4 Base egress ML model

During this section, the egress trip has been analysed in the same manner as the access trip. The egress trip analysis is also of interest, since egress attributes can also have influence on a traveller his or her mode choice. There are few papers that have analysed both access and egress separately in the same study such as Azimi et al. (2021). The paper of Azimi et al. (2021) showed that both access and egress attributes such as land-use, trip-attributes and personal characteristics have influence on the mode choice. The difference however with Azimi et al. (2021) is that in this research the private e-scooter of the access is connected with the egress. Below are the utility functions of the four alternatives, btm, bike, walking and private e-scooter, including their alternative specific attributes, the alternative specific constants (ASC's) and the alternative specific error terms (ε's).

Model definition

$$V_{e\_btm} = ASC_{e\_btm} + \beta_{e\_btm\_wab} * e\_btm\_wab + \beta_{e\_btm\_tt} * e\_btm\_tt + \beta_{e\_btm\_wktd} * e\_btm\_wktd + \beta_{e\_btm\_c} * e\_btm\_c + \varepsilon_{e,btm}$$

$$V_{e\_bike} = ASC_{e\_bike} + \beta_{e\_bike\_tt} * e\_bike\_tt + \beta_{e\_bike\_pst} * e\_bike\_pst + \varepsilon_{e,bike}$$

$$V_{e\_pe} = ASC_{e\_pe} + \beta_{e\_pe\_tt} * e\_pe\_tt + \beta_{e\_pe\_pst} * e\_pe\_pst + \varepsilon_{e,pe}$$

$$V_{e\_walking} = ASC_{e\_walking} + \beta_{e\_walk\_tt} * e\_walk\_tt + \varepsilon_{e,walking}$$

Model description

Table 16 Base ML model description

Term	Description
V_{e_btm}	Utility of egress BTM
V_{e_bike}	Utility of egress Bike
V_{e_pe}	Utility of egress private e-scooter
$ASC_{e,btm}$	Alternative specific constant for egress BTM
$ASC_{e,bike}$	Alternative specific constant for egress bike
$ASC_{e,pe}$	Alternative specific constant for egress PE
$ASC_{e,walking}$	Alternative specific constant for egress walking
$\beta_{e\_btm\_wab}$	Egress waiting time for bus coefficient
$\beta_{e\_btm\_tt}$	Egress BTM in-vehicle time coefficient
$\beta_{e\_btm\_wktd}$	Egress walking time to destination coefficient
$\beta_{e\_btm\_c}$	Egress BTM travel cost coefficient
$\varepsilon_{e,btm}$	Error term for egress BTM
$\beta_{e\_bike\_tt}$	Egress bike travel time coefficient
$\beta_{e\_bike\_pst}$	Egress bike parking search time coefficient
$\varepsilon_{e,bike}$	Error term for egress bike
$\beta_{e\_pe\_tt}$	Egress private e-scooter travel time coefficient
$\beta_{e\_pe\_pst}$	Egress parking search time for the private e-scooter coefficient
$\varepsilon_{e,pe}$	Error term for egress private e-scooter
$\beta_{e\_walk\_tt}$	Egress walking travel time coefficient
$\varepsilon_{e,walking}$	Error term for egress walking

Model results

Table 17 Base ML model results

Alternative attributes	Estimate	p-value
$ASC_{e,bike}$	0.63	0.24
$ASC_{e,btm}$	**-2.63****	0.02
$ASC_{e,pe}$	-0.39	0.49
$ASC_{e,walking}$	*0 (base)*	-
$\beta_{e\_bike\_pst}$	-0.02	0.73
$\beta_{e\_bike\_tt}$	-0.02	0.50
$\beta_{e\_btm\_c}$	0.20	0.27
$\beta_{e\_btm\_tt}$	0.04	0.47
$\beta_{e\_btm\_wab}$	0.14**	0.01
$\beta_{e\_btm\_wktd}$	0.03	0.71
$\beta_{a\_pe\_tt}$	0.08***	0.01
$\beta_{e\_walk\_tt}$	**-0.06***	0.07
$\beta_{e\_pe\_pst}$	0.09	0.11

***Significant at 99% confidence level,
**Significant at 95% confidence level,
*Significant at 90% confidence level

As can be seen in table 17, the results are largely not valid, not significant. In appendix B.5, the additional standard deviation is shown. There are a few significant estimates, but these are not logical such as btm_wab of 0.14, which means that an increase in 1 minute of walking time to the bus leads to an increase in the utility of btm by 0.14 and thus a higher probability to be chosen. As observed in literature, walking time is always negative, meaning that an increase in walking time leads to decreased probability in choosing that mode.

The reason for the egress estimates being largely insignificant is due to several reasons:
1) The sample size was too small, to obtain statistically significant results.
2) Possible irrational answering of the egress survey question. During the survey, people might have answered the egress question without thinking carefully on which option is the best option according to the attribute values.
3) There is also a possibility that the egress attributes, correlate with other not considered attributes. These omitted variables could explain the not significant attributes and so when the omitted variables were included, the estimates might be correlate. To find the right set of attributes, needs careful selection of attributes during the experimental design.

When the estimates would make sense, then other explanatory variables could have been added to do a further analyses on influencing factors on the mode choice, as was done in Azimi et al. (2021) and in section 6.3 of this research. Since each person answered both access and egress questions and the focus is on the private e-scooter, including the personal characteristics for the access part is enough to see which personal characteristics influence the choice for the private e-scooter, since the private e-scooter is used for both the access and egress part.

6.5 Cross-sensitivity analysis

In section 6.2 and 6.3, the ML model was applied to make estimations for the observed attributes such as travel time for the access trip. In this section, a sensitivity analysis has been carried out to see the effect of changing attributes on the competition between modes, with the focus on the probability of choosing the private e-scooter. The attributes that are statistically significant in section 6.2, were considered to do the sensitivity analysis. Every alternative, bike, btm, walking and the private e-scooter, have the travel time attribute, so this has been considered for the sensitivity analysis. Eventually, the four utility functions with their statistically significant estimates are shown below. These utility functions have been used for the sensitivity analysis. The additional standard deviation from the ML model as shown in appendix B.5 has been discarded and so the eventual model becomes a MNL-model to ease the model for the purpose of the sensitivity analysis.

$$V_{a\_btm} = -1.59 - 0.40 * a\_btm\_wktb - 0.15 * a\_btm\_tt - 0.21 * a\_btm\_wat - 0.33 * a\_btm\_c + \varepsilon_{a,btm}$$

$$V_{a\_bike} = -2.09 - 0.25 * a\_bike\_tt - 0.36 * a\_bike\_pst + \varepsilon_{a,bike}$$

$$V_{a\_pe} = -3.36 - 0.18 * a\_pe\_tt + \varepsilon_{a,pe}$$

$$V_{a\_walking} = -0.40 * a\_walk\_tt + \varepsilon_{a,walking}$$

The probabilities have been computed based on the simplified MNL model shown in the equation below and discussed in section 2.3. The scale parameter μ is normalized to 1 and the error variance term is of extreme value 1 distribution or the Gumbel distribution, since the MNL has the IIA assumption and so the error term of the utility function can be neglected.

$$P(i|C_n) = \frac{e^{\mu V_{in}}}{\sum_{j \in C_n} e^{\mu V_{jn}}}$$

The focus is on the change of an attribute value of another alternative on the probability of the private e-scooter. Many attributes can be varied and used for the sensitivity analysis, but this would make the analysis very elaborate. The influence of the travel time has been the focus. The percentage change in usage of an alternative caused by an attribute change of another alternative is called cross-sensitivity in literature (Litman, 2004). The cross-sensitivity equation is shown below (Goolsbee et al., 2019). The cross-sensitivity is different than the travel time-sensitivity, which is the change in probability caused by a change in the travel time of the private e-scooter. In this research the interest is how the probability of choosing the private e-scooter changes with respect to a change of the travel time of another alternative, that is why the cross-sensitivity might provide more information.

$$E_{ij}^P = \frac{\% \Delta P_i}{\% \Delta tt_j} = \frac{\Delta P_i}{\Delta tt_j} * \frac{tt_j}{P_i} = \frac{P(t2) - P(t1)}{t2 - t1} * \frac{tt_1}{P1}$$

E_{ij}^P: cross-probability elasticity of alternative i caused by an attribute change in alternative j
ΔP_i: change in probability of alternative i
Δtt_j: change in travel-time of alternative j
tt_j: travel time of alternative j
P_j: probability of alternative i

The change in probability of alternative i is the change in probability at travel time x_2 minus the probability at travel time x_1. In this case, the focus is on private e-scooter (i) and alternative j has been varied by btm, bike and walking. By varying the travel time between 5 and 30 minutes with steps of 1 minute, the eventual probability change in choosing the private e-scooter with respect to a change in travel time of the other alternatives is shown in the figure below.
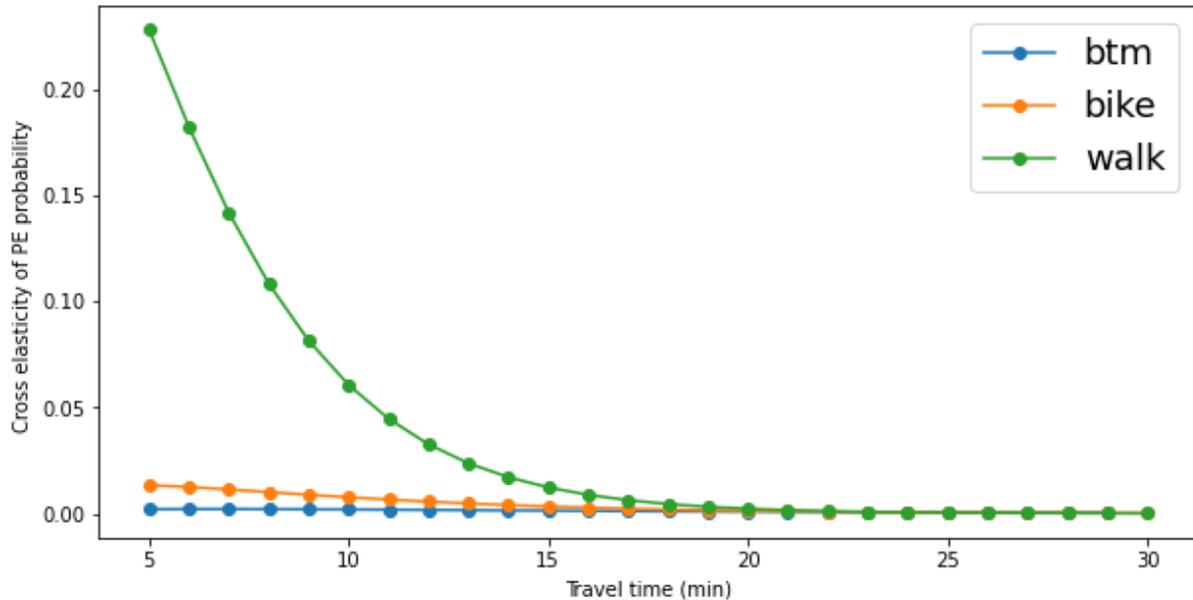

Figure 14a Cross-elasticity
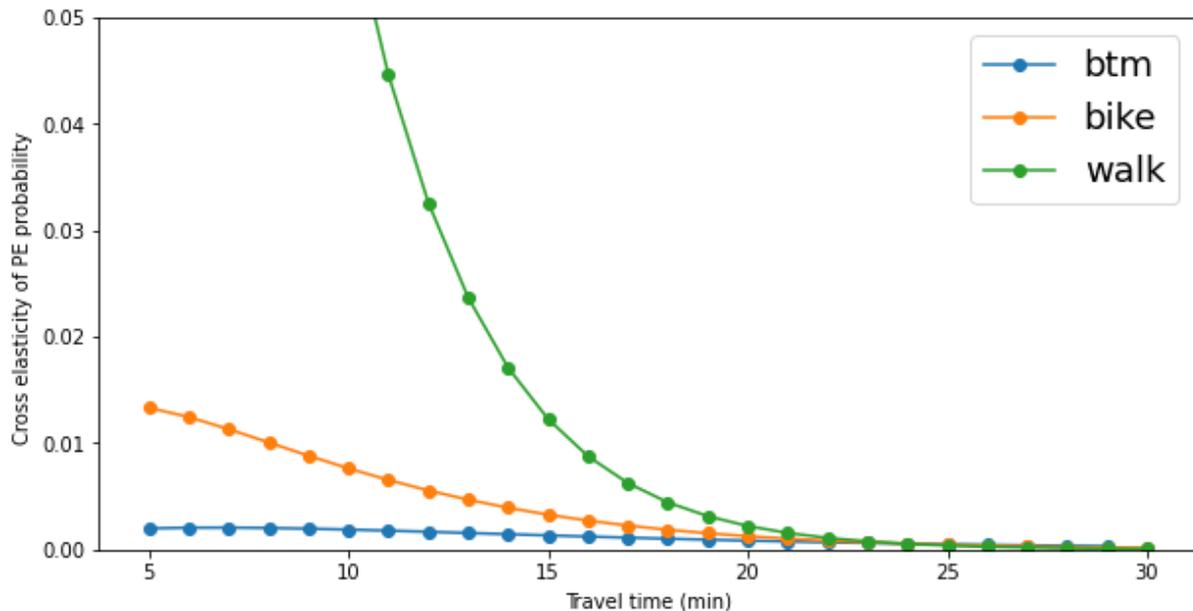
Figure 14b Cross-elasticity zoomed in

In table 20, three values have been shown. When the travel time of BTM and the private e-scooter is 5 min, the sensitivity is 0.0020, meaning that when the travel time of btm increases with 1%, the probability of choosing the private e-scooter increases with 0.0020 %. Based on figure 14 and table 20, the conclusion is that the change in travel time of walking has much more influence on the probability of choosing the private e-scooter compared to btm and bike. In all the three alternatives, the highest

changes in probability caused by changes in travel time is at the beginning when the travel times are relatively small, between 5-15 min. But as the travel time increases of all the alternatives, so does the change in probability of choosing the private e-scooter reduces. Changes in btm has almost no change in probability of choosing the private e-scooter. Bike on the other hand causes an increase of 0.0133 % in the probability of choosing the private e-scooter when the travel time of bike increases by 1% at 5 min. The highest change in probability of choosing the private e-scooter is 0.2281 % when the travel time is increased 1% at 5 min walking time.

Table 20 Cross-sensitivity at 5, 17 and 29 minutes.

Travel time	Btm	Bike	Walking
5 min	0.0020	0.0133	0.2281
17 min	0.0011	0.0023	0.0062
29 min	0.0003	0.0002	0.0001

The conclusion is that changes in short travel times, around 5 min, causes the highest changes in the probability of choosing the private e-scooter. The highest changes are due to walking followed by bike and btm.

6.6 Results discussion

To fit the data that was obtained through the stated preference survey, a mixed logit model was applied. Initially a base access model without trip attributes was estimated and afterwards a ML model with trip attributes. No interaction between variables were defined, since the influence of the trip attributes is of interest as also defined in the conceptual model in section 3.5. Analysing the access data was enough, since the private e-scooter, when chosen for the access trip, should also be used for the egress trip. So, including trip attributes into the discrete choice modelling on the access data, provided information on the attributes of the private e-scooter switchers. The data of the egress, however, provided the switch potential towards private e-scooters as defined in section 5.

For completeness, the discrete choice modelling of the egress trip was also done, but during the interpretation of the results, many coefficients were insignificant. This could be due to the sample size being limited or variables were not included in the choice experiment or irrational answers. Some variables could be correlated with variables that were not included in the experiment, but reality is complex and so does human decision making. When making choices, individuals consider several factors, and some factors might even correlate with other factors. This makes capturing reality, complex and so modelling. Including all the attributes and at the same time obtaining statistically significant estimates of all the coefficients, is time consuming and even financially intensive. During modelling in this section, the insignificant factors could not be explained in terms of the available included factors that were observed during the choice experiment. The results however obtained from the modelling adds to the already existing huge amount of access and egress knowledge in literature.

7 Conclusion

In this section the main points of this research have been discussed including answering the sub-questions and the main question. Furthermore, several limitations have been mentioned and topics for follow-up research based on the limitations in this research have been mentioned.

7.1 Main Points

In chapter 1, three sub-questions were mentioned and a main research question. These have been answered below.

Sub-research question 1

"what are travellers their behaviour concerning mode choice for access/egress trips when owning a private mode?"

During this sub-research question a comprehensive literature review was done to collect the available knowledge on current access and egress mode choice behaviour when someone owns an e-scooter. Micro-modes in combination with train has many advantages. Micro-modes such as bikes and e-scooters are mostly used for short distance trips and complement the train for long distance trips (Le Boennec & Salladarré, 2023). The private e-scooter can be taken into the train. Private-micromodes are very flexible in terms of availability and usage. There is no more waiting time, nor fixed routes and walking times (Cao et al., 2021). They can even be used in dense areas where it is not beneficial to use the car (Moinse et al., 2024). Users of private e-scooters shifted away from car trips and walking trips (Reck et al., 2022). In literature was mentioned that approximately 94% of e-scooter owners in France used their vehicle to reach the station (Moinse et al., 2024) and 80% even used it to take it onto the public transport in Vienna (Laa & Leth, 2020). When comparing shared and private modes, the shared modes can be used in specific areas and can be left anywhere in the operation zones in case of dockless services and in case of docked services, the vehicles should be parked at specific locations (van Kuijk et al., 2022). The private modes on the other hand can be used everywhere and can be brought into the train or btm and can be used on the other side, the egress part. There are a few private modes that are comfortable to be taken into the train such as private e-scooters, foldable bikes and the private bikes. The private e-scooter can be folded and brought into the train, but the normal bike can be brought into the train if there is capacity available (Oeschger et al., 2020). Especially on the access side bike is used and on the egress side especially shared modes, because less people own a bike at the egress side. From the literature review could be concluded that the private e-scooter has a huge potential for replacing other modes for access and egress modes.

Sub-research question 2

"Which factors are relevant for access and egress mode choice in which the private e-scooter is chosen?"

During this sub-question, also literature was used to identify the factors (attributes) that are of influence on the mode choice for access and egress modes, with the focus on the private e-scooter. Many factors were found, but the factors were categorized in the following groups:
1) User: users of e-scooters were mostly younger than 35 years, male, have a high income, have a high education and are full-time employed (Arias-Molinares et al., 2021; Christoforou et al., 2021; Reck et al., 2022).

2) Trip: considering trip characteristics, people use the e-scooter for mostly leisure followed by work and school purposes and the factors that e-scooter users care mostly are travel time savings followed by cost (Glavić et al., 2021; Hardt & Bogenberger, 2019).

3) Mode: e-scooter users, use this mode for its environmental friendliness and convenience, but owning such a vehicle has a price tag and this can act as an barrier for usage of this mode (Glavić et al., 2021; van Kuijk et al., 2022).

4) Build environment: where there is high public transport density, there is low e-scooter ridership and where the proximity to the city centre is high, the usage of e-scooter is high (Lu, Zhang, et al., 2024).

5) Socio-psychological: the private e-scooter is used due to its convenience, cost saving, environmental friendliness, previous experience and because it is environmental friendly (Aguilera-García et al., 2024; Carroll, 2022; Kopplin et al., 2021; Oeschger et al., 2023; Roig-Costa et al., 2024).

6) External: weather condition showed to have influence on micromobility modes such as bikes and e-scooters (Hardt & Bogenberger, 2019; Lu, Zhang, et al., 2024; Oostendorp & Hardinghaus, 2023; Reck et al., 2022).

7) Unique: less literature was found on the influence of distinct features of micro-modes including the e-scooter on mode choice, but the foldable feature of the e-scooter and to be taken into the train was mentioned many times in literature as such a distinct feature (Le Boennec & Salladarré, 2023).

The literature on access and egress mode choice studies is immense and to have a clear overview on what has already been done concerning mode choice determinants, can help other research in using this framework for their own research.

Sub-research question 3
"Which determinants contribute to a mode shift due to e-scooter ownership?"

In section 5, the design of the stated choice experiment was discussed for the whole trip including access and egress. Afterwards data was collected by distributing the survey and collecting the responses. The survey consisted of three parts, the user characteristic, trip characteristic and the stated choice experiment. The influence of alternative and trip characteristics was analysed for only the access trip. The egress trip was also analysed but with only the alternative determinants, since the data collected for the egress side was of insufficient quality. This approach still provided information on the influence of trip characteristics and alternative related characteristics on the mode choice for the private e-scooter.

A mixed logit model with alternatives and user attributes was included with no interaction effects, to see how each attribute solely contributes to the mode choice. Concerning trip attributes, people who travelled 2-4 times per week with train, possesses a driving license and a car and people who had precious experience with the e-scooter were more likely to replace their current access and egress modes with the private e-scooter. The comfort level of the private e-scooter in the train, has also a positive influence on choosing the private e-scooter, but this factor was statistically insignificant, due to probably a small sample size or omitted variables in the discrete choice model. In the next sub-section this limitation has been discussed. Concerning alternative attributes, there is not much difference in the travel time attributes of the private e-scooter, compared to BTM and bike. The travel time attribute of the private e-scooter could not be found in literature, and this is a novelty as well the bike parking search time attribute. These can be used in other research as prior values for their choice experiments. However, the travel time estimate is the lowest for the private e-scooter and this could indicate that people who choose the private e-scooter, would like to save on time. During the travel time cross-sensitivity analysis of choosing the private e-scooter, the observation is that the marginal

change in probability of choosing the PE is highest when the walking time increases followed by changes in travel time of the bike and the btm. The highest change in elasticity is between 5-10 min of travel time. This could indicate that for short distances the private e-scooter is a substitute to especially walking and bike.

Main research question

"What is the potential impact on the travel behaviour for multi-modal trips when train travellers own an e-scooter?"

The information of the previous three sub-questions has led to answering the main question. The main question was focused on the potential influence of the private e-scooter on access and egress modal shift. Since the 1st of July 2025 the private e-scooter is allowed in the Netherlands, only if the private e-scooter has passed the inspection test and has a license plate. This allows people to legally use their e-scooter (e-step) in the Netherlands and so train travellers who own an e-scooter can use this mode for their access and egress trip. During the analysis of the survey responses, the potential mode shift was determined due to e-scooter ownership. The important assumption during the choice experiment was that people had to assume that they own a e-scooter. Due to this the potential shift in mode could be determined. During the discrete choice modelling part, the access data and egress data were analysed. In section 5 the potential mode shift was determined. Each person who took part in the choice experiment had to answer 12 choice scenarios and each scenario included an access, egress and a whole trip question. A scenario can be seen as a trip in this research.

When looking at the whole chains in general, the biggest group of potential switchers to the private e-scooter, are the train travellers who travel by bike at the access and bike at the egress stage. To be exact, in 13% of all the trips, bike-bike travellers switched to the private e-scooter. The next group is the BTM-BTM travellers, these travellers are likely to switch to the private e-scooter in 6% of trips. Approximately 40% of people would switch to the private e-scooter, when an active mode was involved such as btm-bike, bike-bike, bike-walking and walking-bike. This could be due to the convenience that the private e-scooter can bring and the travel time savings.

When observing the access and egress trip separately, the results show that in 37% of the trips, people selected the private e-scooter for their access trip. This is an indication that the private e-scooter has a probability of 37% of being chosen for the access and egress trip. Earlier was mentioned that when the private e-scooter is selected for the access trip, the e-scooter is also used for the egress trip and so the private e-scooter is also used in 37% of the egress cases in the Netherlands. This is much lower than the mentioned 80% and 94% usage of the private e-scooter in Vienna and France (Laa & Leth, 2020; Moinse et al., 2024). E-scooter has lower weights concerning travel time, compared to bike and walking. This means that the private e--scoter based on the travel time components are more likely to be chosen. Also, other components such as bike search time, btm costs and waiting time who have a relatively high contribution to utility lead to less likeness of choosing btm and bike. In short, there are determinants who lead to higher likeliness of choosing an e-scooter, but there are also determinants that causes a mode to be chosen much lesser.

An important notion is that these results are specifically for the group of people who have are students, have a high education, are between 18-35 years and who have an income of lower than 2500 euro in the Netherlands. The determinants that cause this modal shift were mentioned earlier and are people who travel 2-4 times per week by train, people who own a driving license and a car, have e-scooter experience and people who are very sensitive to travel time changes.

7.2 Strength, limitations of this research and further research

During this research several limitations were encountered and have been discussed in this section. Also, what this research has contributed has also been discussed.

7.2.1 Contribution of this research

The contribution of this research was to establish the potential mode shift due to e-scooter ownership in the Netherlands and the factors that causes this mode shift. This has been done by exploiting a stated choice experiment. By presenting a stated choice experiment thee step approach to see which mode choice determinants, from the seven categories in section 3.4, influences the mode choice for a whole trip chain, more information could be gathered in a more efficient way. Also, with this approach the mode shift can be determined. So, it is a multifunctional approach, which was not previously designed to capture determinants causing the mode shift due to a mode that can be used for both the access and egress stage. Previously, several research have tried to do similar research, but those research focused on only the access or egress. By looking at the whole chain, the trip could be analysed in more detail. In this research a relatively large, stated choice experiment was exploited. The results of this research can help follow-up research in capturing a person their whole trip from origin to destination in a more efficient way and by also using prior values of this research that were not previously estimated before.

People who are curious about the private e-scooter can also see that many people are likely to choose the private e-scooter in some situations and who these people are. Also, the benefits in terms of travel time and costs can be appealing to train travellers when planning their trip from origin to destination including their access and egress trips.

In short, the following points are strong points of this research:
- The proposed three step stated choice experiment approach to include a mode that can be used for both the access and egress:
    - Alternatives can be added that do not correlate between access and egress
    - Alternatives can be added that are correlated, such as the e-scooter that can be used for both the access and egress.
    - Mode shift can be determined.
    - This approach does not overwhelm the respondent with large questions and many alternatives
    - Analysing the data of access and egress through discrete choice modelling of this approach, proves to provide necessary information of the mode shift caused by owning an e-scooter.
- An elaborate literature review with an overview of the seven categories, that causes a mode shift due to owning a private e-scooter.
- Prior values that were not defined previously such as bike parking search time and private e-scooter travel time.

7.2.2 Limitations and further research

During this research, several limitations and difficulties occurred. Designing the stated preference experiment with the constraint of when the private e-scooter is used for the access trip, it should also be used for the egress stage, proved to be very challenging. During this research, two experiments

were designed, an access and an egress experiment. Every respondent answered 12 scenarios. Each scenario involved three questions, access, egress and a whole trip question. For access and egress, the respondents could choose between BTM, Bike and walking. At the whole trip section, the respondents could select between the combination of their access and egress answers and between private e-scooter for the whole trip. In this way the constraint could be implemented. This design proved to be very time-consuming for respondents, making answering the questions somewhat less rational. This was also to be seen when the egress data was analysed in which most of the attributes were insignificant. An alternative design could have been to have less scenarios, but this would need much more respondents.

This design is a first step towards a more robust design. This design also allowed flexibility in having many more alternatives and the mode shift could be estimated towards private e-scooters. Another design could have been to define several pre-defined combinations of access and egress alternatives, but this design would not be representative in terms of real-world combinations, and the number of attributes should be less, otherwise the respondent would be overwhelmed with attributes. In much research only the access or the egress stage is considered, by making assumptions on the egress stage. This is possible by saying that when the private e-scooter is used for the access stage, the e-scooter will be used for the egress stage, but this design omits important attributes at the egress stage for mode choice decision making of a person. The design proposed in this research can be further optimized, by considering sample size, correlation between the designs, attributes and their levels and the time span of the research. When looking at the perspective of the respondents, the number of questions is important, the number of attributes and the understandability of the design.

In short, the design of this type of problem with the constraint of using a mode for both the access and egress stage still needs more research and testing. Especially for modes that are taken onto the train such as private (e-)bike, foldable bike and private e-scooter. When people travel from their origin to a destination, people consider their whole trip.

After some time, a follow-research can be conducted by obtaining revealed preference data to see the actual mode shift impact caused by the private e-scooter and the factors that led to this mode shift for access and egress trips, since the private e-scooter is allowed in the Netherlands from the 1st of July 2025.

In short, the following points are weak points of this research:
- The egress data was of less quality. The design should be improved on especially the approach towards collecting responses for the egress part. The important assumption should be implemented that the private e-scooter is used for both the access and egress stage when chosen.
- A better way of reducing the number of scenario's should be determined, such that the data quality can be improved.
- As said earlier human decision making is complex. This holds that choosing the determinants for the experiment is also crucial. For this research realistic determinants were chosen. To obtain more information on the mode choice, it is recommended to also include other determinants that are not currently in place in the Netherlands. In this way also future policies can be defined.

7.3 Policy recommendations

The result has shown that there is a huge mode shift potential due to e-scooter ownership in the Netherlands. The recent law of allowing e-scooters on the road, with a license plate, might fulfil this potential. As mentioned earlier, the e-scooter due to its convenience and its usage for mostly short distances, might be in demand for access and egress trips for especially the group of people who are between 18-35 years old, are students, highly educated, have an income lower than 2500 euro and use the train 2-4 times a week. The e-scooter can be an option to travel more efficiently on access and egress, avoiding waiting times, faster travel times and less physical effort. Also, in literature was mentioned that the e-scooter can complement the train for longer distances and this research showed that the e-scooter can be a competitor to the bike. Also, the e-scooter can be brought into the train. This might affect the comfort in the train of people who do not bring an e-scooter into the train. More e-scooters on the street might increase crowdedness on the bike lanes and even causing incidents. These are a few drawbacks when the mode shift potential of the e-scooter as analysed in this research might be fulfilled. A recommendation regarding owning a private e-scooter is that there is huge mode switch potential for the group that was mentioned before. The private e-scooter can provide efficient access and egress travelling in terms of travel costs, travel time and comfort. Is this can enhance travelling for this group of people, then decision makers should certainly take this potential into account without ignoring the influence on other group of travellers for access and egress trips.

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Appendix

Appendix A Choice experiment design

A.1 Access Ngene code

design
;alts = PE, BTM, BIKE, WALKING
;rows = 12
;eff = (mnl, d, mean)

;model:

? PE = Private e-scooter, BTM = Bus, Tram, metro, BIKE = Bicycle, WALKING = walking

? for WALKING, the asc is removed, because this is the reference alternative

U(PE) = asc1[(n,-0.5,0.7)]
    + a1[(n,-0.03,0.07)] * access_PE_TT[4,8,12] ? TT = travel time
    + a2[(n,-1,1)].dummy[0]* com_PE[1,0] ? com = comfort in train, 1 = stored 0 = holding
/

U(BTM)= asc2[-0.888]
    + b1[-0.11] * access_BTM_WKTB[2,4,6] ? WTB = Walking time BTM
    + b2[-0.084] * access_BTM_TT[3,6,9]
    + b3[-0.073] * access_BTM_WAT[3,6,9] ? WAT = waiting time train
    + b4[-0.207] * access_BTM_TC[1,2,3] ? TC = travel cost
/

U(BIKE)= asc3[-0.438]
    + c1[-0.095] * access_BIKE_TT[4,8,12]
    + c2[-0.1] * access_BIKE_PST[1,3,5]
/

U(WALKING)= d1[-0.110] * access_W_TT[12,18,24]

$

A.2 Egress Ngene code

```
design
;alts = PE, BTM, BIKE, WALKING
;rows = 12
;eff = (mnl, d, mean)

;model:

? PE = Private e-scooter, BTM = Bus, Tram, metro, BIKE = Bicycle, WALKING = walking

? for WALKING, the asc is removed, because this is the reference alternative

U (PE) = asc1[(n,-0.5, 0.7)]
        + a1[(n,-0.03,0.07)] * egress_PE_TT[4,8,12]
        + a2[(n,-0.1,0.15)] * egress_PE_PST[1,3,5]
/

U(BTM)= asc2[-0.165]
        + b1[-0.112] * egress_BTM_WTB[3,6,9] ? WTB = waiting time BTM
        + b2[-0.069] * egress_BTM_TT[3,6,9]
        + b3[-0.101] * egress_BTM_WTD[2,4,6] ?WTD = walking time destination
        + b4[-0.207] * egress_BTM_TC[1, 2, 3] ? TC = travel cost
/

U(BIKE)= asc3[0.055]
        + c1[-0.130] * egress_BIKE_TT[4,8,12]
        + c2[-0.1] * egress_BIKE_PST[1,3,5] ? PST = parking search time
/

U(WALKING)= d1[-0.101] * egress_W_TT[12,18,24] ? W = walking

$
```

A.3 Access experimental design

TT = Travel time
COM = Comfort in train with e-scooter
WKTB = Walkin time to BTM stop
WAT = Waiting time train
PST = Parking search time
TC = Travel cost

Choice situation	Privé e-scooter		BTM				Bike		Walking
	TT	COM	WKTB	TT	WAT	TC	TT	PST	TT
1	12	0	4	9	6	3	12	3	18
2	8	1	4	9	9	2	4	1	12
3	4	1	6	6	9	3	4	5	24
4	8	1	6	3	3	1	12	1	24
5	8	1	2	3	9	1	12	3	24
6	4	0	4	9	6	2	8	3	12
7	4	0	2	3	3	3	8	1	18
8	12	0	4	6	9	2	4	1	18
9	12	0	6	6	6	1	4	5	18
10	12	1	2	3	3	3	8	5	12
11	4	0	6	6	6	2	8	3	12
12	8	1	2	9	3	1	12	5	24

A.4 Egress experimental design

TT = Travel time
PST = Parking search time
WAB = Waiting time for BTM
WKTD = Walking time to destination
TC = Travel cost

Choice situation	Privé e-scooter		BTM				Bike		Walking
	TT	PST	WAB	TT	WKTD	TC	TT	PST	TT
1	12	3	3	3	6	3	12	3	24
2	12	1	6	6	4	2	4	1	18
3	12	1	6	6	6	2	8	5	12
4	8	5	3	9	2	3	12	3	24
5	12	3	9	9	2	1	12	3	24
6	8	3	3	3	2	1	8	3	18
7	4	5	9	3	6	1	12	1	24
8	4	1	6	9	4	2	8	1	12
9	4	1	9	3	2	3	8	5	18
10	8	5	9	6	4	2	4	5	12
11	4	3	3	9	6	1	4	5	18
12	8	5	6	6	4	3	4	1	12

A.5 Survey

The survey included 12 scenarios. For convenience, only 2 scenarios' have been shown in this appendix.

Introductie

Tijdens deze survey kijken we naar welke keuzes u maakt wanneer u van en naar het trein station reist. Er bestaan verschillende vervoersmogelijkheden van en naar het treinstation zoals lopen, fietsen en BTM (Bus, Tram en Metro). Tijdens deze survey kijken we naar de gehele reis vanaf uw huis naar uw bestemming en bestaat uit drie delen, zie figuur 1:

1. De reis vanaf uw huis naar het treinstation en wordt in deze survey, **_access_** genoemd.
2. Vervolgens reist u met de trein.
3. De reis vanaf het treinstation naar uw bestemming en wordt in deze survey **_egress_** genoemd.
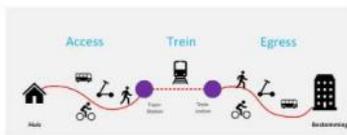
Figuur 1, access, egress en trein.

Tegenwoordig zijn er nieuwe vervoerswijzes, zoals de e-step, zie figuur 2. Vanaf 1 juli 2025 mogen deze e-steps de weg op, mits de e-steps een kenteken hebben. Het grootste voordeel van een e-step is, dat het gratis opgevouwen meegenomen kan worden in de trein en dus zowel voor de access als de egress gebruikt kan worden.

Deze survey bestaat uw drie onderdelen.

1. Persoonlijke eigenschappen. Tijdens dit onderdeel stellen wij vragen omtrent uw persoonlijke informatie.
2. Reis eigenschappen. Tijdens dit onderdeel stellen wij vragen omtrent uw reis informatie.
3. Keuze experiment. Tijdens dit onderdeel wordt er een aantal hypothetische reissituaties aan u voorgelegd waarbij u een keuze moet maken voor een vervoerswijze.

Het doel van deze survey is om te observeren welke vervoerswijzekeuze u zou maken voor de access en egress gedeelte, wanneer u een e-step zou bezitten of wanneer u die in werkelijkheid al bezit.

1

2

Figuur 2, e-step (foto afkomstig van
https://shop.segway.com/nl_nl/ninebot-kickscooter-e2-e-
powered-by-segway.html)

Als u wenst het rapport van dit onderzoek te ontvangen, vul dan
hieronder uw email-adress in.

← →

0%————————100%

Persoonlijke eigenschappen

Wat is uw leeftijd?

○ Jonger dan 18 jaar

○ Tussen 18 en 35 jaar

○ Ouder dan 35 jaar

Wat is uw geslacht?

○ Man

○ Vrouw

○ Non-binair

○ Zeg ik liever niet

Wat is uw hoogst genoten opleiding?

○ Basisonderwijs

○ Middelbaar onderwijs

○ HBO/WO Bachelor

○ WO Master

○ PhD of hoger

○ Zeg ik liever niet

Wat is uw gemiddeld maandelijkse inkomen in euro's?

○ 2500 en lager

○ Tussen 2500 en 4500

○ Hoger dan 4500

○ Zeg ik liever niet

Wat is uw huidige beroep?

○ Deeltijds beroep

○ Voltijds beroep

○ Werkzoekende

○ Student

○ Vrijwilligerswerk

○ Pensioen

○ Niet in staat te werken

○ Zeg ik liever niet

← →

Reis eigenschappen

Hoeveel dagen per week reist u met de trein?

○ 0 - 1

○ 2 - 4

○ 5 - 7

Voor welke motief reist u met de trein?

○ Werk

○ Onderwijs

○ Vrijetijdsbesteding

○ Anders

Met welke vervoerswijze reist u het meest vanaf uw huis naar het treinstation?

○ Lopen

○ BTM (Bus, Tram, Metro)

○ Fiets

○ Deelmobiliteit (e-scooter, fiets, e-fiets, e-auto)

○ Licht-elektrische voertuigen, LEV's (e-fiets, e-step, e-scooter)

○ Auto als bestuurder

○ Auto als passagier

○ Anders

Met welke vervoerswijze reist u het meest vanaf het treinstation naar uw bestemming?

○ Lopen

○ BTM (Bus, Tram, Metro)

○ Fiets

○ Deelmobiliteit (e-scooter, fiets, e-fiets, e-auto)

○ Licht-elektrische voertuigen, LEV's (e-fiets, e-step, e-scooter)

○ Auto als passagier

○ Anders

Bezit u een e-step?

○ Ja

○ Nee en ik heb geen intentie om één te kopen

○ Nee, maar ik overweeg om één te kopen

Hebt u ooit op een e-step gereden? (gedeelde e-step of privé step)

○ Ja

○ Nee

Bezit u een autorijbewijs?

○ Nee

○ Ja en ik bezit een auto

○ Ja, maar ik bezit geen auto

Bezit u een micro-voertuig? voorbeelden hiervan zijn fiets, e-fiets, e-scooter, zelf balancerende voertuigen etc..

○ Ja

○ Nee

[←]   [→]

Keuze-experiment

Tijdens dit keuze-experiment, worden er een aantal reisscenario's aan u voorgelegd, waarin u een keuze moet maken voor een vervoerswijze. Dit keuze experiment is hypothetisch, waarbij u zich moet voorstellen dat u een vouwbare e-step bezit, zie figuur 3. U wordt aangeraden de uitleg hieronder goed door te nemen zodat u vertrouwd raakt met wat er tijdens de scenario's gevraagd wordt en wat u te zien krijgt.

Figuur 3, vouwbare e-step (foto afkomstig van https://shop.segway.com/nl_nl/ninebot-kickscooter-e2-e-powered-by-segway.html)

In figuur 4, is nogmaals de reis van huis naar een bestemming afgebeeld. Eerst reist u van huis uit naar het treinstation (access). Vervolgens reist u met de trein naar een ander station. Vanaf dat station waar u uitstapt, reist u vervolgens naar een eindbestemming (egress). Precies zo is elke scenario ingericht, waarbij u eerst een vervoerswijzekeuze moet maken voor access en vervolgens voor egress en als laatst kijken we naar de gehele reis, waarbij u de e-step kunt gebruiken voor de gehele reis. In totaal zijn er 12 scenario's die u te zien krijgt. Elke scenario bestaat uit drie delen: access, egress en een volledige reis gedeelte. In figuur 7, ziet u een volledige scenario met elke onderdeel afgebeeld. Zo zien de 12 scenario's ook eruit. Voor elke scenario gelden de condities in figuur 5.

Figuur 4, access, trein en egress.

Figuur 5, condities van de scenario's.

Nu volgt de uitleg van de onderdelen van elke scenario namelijk: access, egress en de gehele reis gedeelte.

Access (vraag 1)
Tijdens deze vraag, zie figuur 6a, moet u een vervoerswijze keuze maken voor een reis van huis naar het treinstation (access). U ziet factoren als reistijd en reiskosten en de bijbehorende waardes in minuten of euro's. **Bij elke scenario zijn deze getallen anders**. U dient een keuze te maken op basis van de getallen en factoren die u te zien krijgt.

Figuur 6a, vraag 1, access

Egress (vraag 2)
Tijdens deze vraag, zie figuur 6b, moet u een vervoerswijze keuze maken voor een reis van het treinstation naar een bestemming (egress). Voor egress ziet u ook de fiets staan. U moet aannemen dat u een fiets tot uw beschikking hebt bij het treinstation waar u uitstapt.

Figuur 6b, vraag 2, egress

Gehele reis (vraag 3)

Vraag 3 verschijnt pas als u vraag 1 en 2 hebt beantwoord. Tijdens deze vraag wordt gekeken naar de gehele reis, dus access, egress en trein ertussen. Stel voor dat u bij vraag 1 (access), **BTM** hebt gekozen en bij vraag 2 (egress), **Fiets** hebt gekozen, dan ziet u bij vraag 3, twee mogelijkheden om te reizen (figuur 6c):

1) BTM + Fiets
2) Privé e-step + Privé e-step

Vervolgens wordt aan u de vraag gesteld of u de e-step voor de gehele reis wilt gebruiken of als u wilt reizen op basis van wat u gekozen hebt bij de vragen 1 en 2.

Tijdens deze vraag moet u zich voorstellen dat u de e-step **bezit** en dat u de e-step kunt meenemen in de trein. U kunt dus de e-step gebruiken voor zowel de access als de egress gedeelte. De mate van comfort van de privé e-step in de trein is aangeduid in figuur 6c als "Comfort in de trein met de e-step".

Nu volgen de 12 scenario's. U kunt altijd terug om de uitleg te lezen.

Figuur 6c, vraag 3, gehele reis

Voorbeeld scenario.

Figuur 7, voorbeeld volledige scenario, vraag 1 (access), vraag 2 (egress), vraag 3 (gehele reis)

Scenario 1

Vraag 1: Welke vervoerswijze zou u kiezen om te reizen vanaf uw huis naar het treinstation (***access***)?

	BTM	Fiets	Lopen
🚶 Looptijd naar een BTM halte (minuten)	2		
🕐 Reistijd (minuten)	9	12	24
⧗ Wachttijd voor de trein (minuten)	3	3	3
🔍 Parkeerplek zoektijd (minuten)		5	
€ Reiskosten (euro's)	1		

- 🔘 BTM
- ◯ Fiets
- ◯ Lopen

Vraag 2: welke vervoerswijze zou u kiezen om te reizen vanaf het treinstation naar uw bestemming (***egress***)?

	BTM	Fiets	Lopen
⧗ Wachttijd voor de BTM (minuten)	6		
🕐 Reistijd (min)	6	4	18
🚶 Looptijd naar eindbestemming	4		
🔍 Parkeerplek zoektijd (minuten)		1	
€ Reiskosten (euro's)	2		

- ◯ BTM
- 🔘 Fiets
- ◯ Lopen

Vraag 3: bij deze vraag kijken we naar de gehele reis dus access en egress en trein ertussen. Stel dat u een **e-step bezit.** Zou u deze e-step gebruiken voor de gehele reis of zou u nog steeds de vervoerswijze kiezen die u gekozen hebt bij de vragen 1 en 2 hierboven?

	BTM	Privé e-step
🚶 Looptijd naar een BTM halte (minuten)	2	
🕐 Reistijd (minuten)	9	8
⧗ Wachttijd voor de trein (minuten)	3	3
🔍 Parkeerplek zoektijd (minuten)		
€ Reiskosten (euro's)	1	
💡 Comfort in de trein met de e-step		Comfortabele treinrit omdat de e-scooter geborgen is.

+   +

	Fiets	Privé e-step
⧗ Wachttijd voor de BTM (minuten)		
🕐 Reistijd (min)	4	12
🚶 Looptijd naar eindbestemming		
🔍 Parkeerplek zoektijd (minuten)	1	1
€ Reiskosten (euro's)		

- ◯ Ik zou de e-step kiezen voor de gehele reis
- ◯ Ik zou dezelfde vervoerswijze kiezen zoals ik gekozen heb bij de vragen 1 (BTM) en 2 (fiets)

Vraag 3: bij deze vraag kijken we naar de gehele reis dus access en egress en trein ertussen. Stel dat u een **e-step bezit.** Zou u deze e-step gebruiken voor de gehele reis of zou u nog steeds de vervoerswijze kiezen die u gekozen hebt bij de vragen 1 en 2 hierboven?

	BTM	Privé e-step
🚶 Looptijd naar een BTM halte (minuten)	2	
🕐 Reistijd (minuten)	9	8
⧗ Wachttijd voor de trein (minuten)	3	3
🔍 Parkeerplek zoektijd (minuten)		
€ Reiskosten (euro's)	1	
💡 Comfort in de trein met de e-step		Comfortabele treinrit omdat de e-scooter geborgen is.

+   +

	Fiets	Privé e-step
⧗ Wachttijd voor de BTM (minuten)		
🕐 Reistijd (min)	4	12
🚶 Looptijd naar eindbestemming		
🔍 Parkeerplek zoektijd (minuten)	1	1
€ Reiskosten (euro's)		

- ◯ Ik zou de e-step kiezen voor de gehele reis
- 🔘 Ik zou dezelfde vervoerswijze kiezen zoals ik gekozen heb bij de vragen 1 (BTM) en 2 (fiets)

Scenario 2

Vraag 1: Welke vervoerswijze zou u kiezen om te reizen vanaf uw huis naar het treinstation (***access***)?

	BTM	Fiets	Lopen
🚶 Looptijd naar een BTM halte (minuten)	4		
🕐 Reistijd (minuten)	9	8	12
⧗ Wachttijd voor de trein (minuten)	6	3	3
🔍 Parkeerplek zoektijd (minuten)		3	
€ Reiskosten (euro's)	2		

- ◯ BTM
- ◯ Fiets
- 🔘 Lopen

Vraag 2: welke vervoerswijze zou u kiezen om te reizen vanaf het treinstation naar uw bestemming (***egress***)?

	BTM	Fiets	Lopen
⧗ Wachttijd voor de BTM (minuten)	6		
🕐 Reistijd (min)	9	8	12
🚶 Looptijd naar eindbestemming	4		
🔍 Parkeerplek zoektijd (minuten)		1	
€ Reiskosten (euro's)	2		

- ◯ BTM
- 🔘 Fiets
- ◯ Lopen

Vraag 3: bij deze vraag kijken we naar de gehele reis dus access en egress en trein ertussen. Stel dat u een **e-step bezit.** Zou u deze e-step gebruiken voor de gehele reis of zou u nog steeds de vervoerswijze kiezen die u gekozen hebt bij de vragen 1 en 2 hierboven?

	Lopen	Privé e-step
🚶 Looptijd naar een BTM halte (minuten)		
🕐 Reistijd (minuten)	12	4
⏳ Wachttijd voor de trein (minuten)	3	3
🔍 Parkeerplek zoektijd (minuten)		
€ Reiskosten (euro's)		
🪑 Comfort in de trein met de e-step		Geen comfortabele treinrit, omdat ik de e-step bij mij moet houden.
	+	+

	Fiets	Privé e-step
⏳ Wachttijd voor de BTM (minuten)		
🕐 Reistijd (min)	8	4
🚶 Looptijd naar eindbestemming		
🔍 Parkeerplek zoektijd (minuten)	1	1
€ Reiskosten (euro's)		

🔘 Ik zou de e-step kiezen voor de gehele reis

⚪ Ik zou dezelfde vervoerswijze kiezen zoals ik gekozen heb bij de vragen 1 (lopen) en 2 (fiets)

0% ——————— 100%

Hartelijk dank voor het invullen van deze survey. Uw antwoorden zijn opgeslagen. U kunt nu het scherm sluiten.

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Appendix B Discrete choice modelling

B.1 Python code for access ML model

*Note: in order to apply the base ML model, the explanatory attributes should be removed from the utility function of the private e-scooter.

#importing libraries

```
import pandas as pd
import biogeme.database as db
import biogeme.biogeme as bio
from biogeme import models
import biogeme.messaging as msg
from biogeme.expressions import (Beta, Variable, Integrate, DefineVariable, RandomVariable, exp,
bioDraws, PanelLikelihoodTrajectory, MonteCarlo, log)
from biogeme.database import Database
import os
```

#reading the cleaned dataset

```
df = pd.read_csv('cleaned2.csv')

df['avail_btm'] = 1
df['avail_bike'] = 1
df['avail_pe'] = 1
df['avail_walk'] = 1

df.drop(columns=[
    'before_access_choice', 'before_egress_choice',
    'after_access_choice', 'after_egress_choice'
], inplace=True, errors='ignore')

# Drop rows with missing data
df.dropna(inplace=True)

# Keep only valid alternatives
valid_choices = [1, 2, 3, 4]
df = df[df['acc_final'].isin(valid_choices)]
df['acc_final'] = df['acc_final'].astype(int)

database = db.Database('data', df)
database.panel("id")

globals().update(database.variables)
```

#defining the variables

```python
access_btm_wktb  = Variable('access_btm_wktb')
access_btm_tt    = Variable('access_btm_tt')
access_btm_wat   = Variable('access_btm_wat')
access_btm_tc    = Variable('access_btm_tc')

access_bike_tt   = Variable('access_bike_tt')
access_bike_pst  = Variable('access_bike_pst')

access_w_tt      = Variable('access_w_tt')

access_pe_tt     = Variable('access_pe_tt')
com_pe = Variable('com_pe')
```

#defining the ASC's and the coefficients

```python
ASC_btm = Beta('ASC_btm',0,None, None, 0)
ASC_btm_rnd = ASC_btm + Beta('s_b_a_ASC_btm', 1, None, None, 0) * bioDraws('o_a_ASC_btm',
'NORMAL')


ASC_bike = Beta('ASC_bike',0,None, None, 0)
ASC_bike_rnd = ASC_bike + Beta('s_b_a_ASC_bike', 1, None, None, 0) * bioDraws('o_a_ASC_bike',
'NORMAL')

ASC_walk_rnd = 0

ASC_pe = Beta('ASC_pe',0,None, None, 0)
ASC_pe_rnd = ASC_pe + Beta('s_b_a_ASC_pe', 1, None, None, 0) * bioDraws('o_a_ASC_pe',
'NORMAL')

b_access_btm_wktb = Beta('b_access_btm_wktb', 0, None, None, 0) + Beta('s_b_a_btm_wktb', 1,
None, None, 0) * bioDraws('o_a_btm_wktb', 'NORMAL')
b_access_btm_tt = Beta('b_access_btm_tt', 0, None, None, 0) + Beta('s_b_a_btm_tt', 1, None, None,
0) * bioDraws('o_a_btm_tt', 'NORMAL')
b_access_btm_wat = Beta('b_access_btm_wat', 0, None, None, 0) + Beta('s_b_a_btm_wat', 1, None,
None, 0) * bioDraws('o_a_btm_wat', 'NORMAL')
b_access_btm_tc = Beta('b_access_btm_tc', 0, None, None, 0) + Beta('s_b_a_btm_c', 1, None, None,
0) * bioDraws('o_a_btm_c', 'NORMAL')

b_access_bike_tt = Beta('b_access_bike_tt', 0, None, None, 0) + Beta('s_b_a_bike_tt', 1, None, None,
0) * bioDraws('o_a_bike_tt', 'NORMAL')
b_access_bike_pst = Beta('b_access_bike_pst', 0, None, None, 0) + Beta('s_b_a_bike_pst', 1, None,
None, 0) * bioDraws('o_a_bike_pst', 'NORMAL')

b_access_w_tt = Beta('b_access_w_tt', 0, None, None, 0) + Beta('s_b_a_w_tt', 1, None, None, 0) *
bioDraws('o_a_w_tt', 'NORMAL')
b_access_pe_tt = Beta('b_access_pe_tt', 0, None, None, 0) + Beta('s_b_a_pe_tt', 1, None, None, 0) *
bioDraws('o_a_pe_tt', 'NORMAL')
```

```
b_com_pe = Beta('b_com_pe', 0, None, None, 0) + Beta('s_b_a_pe_com', 1, None, None, 0) *
bioDraws('o_a_pe_com', 'NORMAL')
```

#explanatory variables, all are defined as dummy variables

```
tf0 = (train_frequency == 0) #train frequency 2-4
tf1 = (train_frequency == 1) #train frequency 5-7
tf2 = (train_frequency == 2) #train frequency 0-1

b_access_pe_tf0 = Beta('b_access_pe_tf0', 0, None, None, 0) + Beta('s_b_a_pe_tf0', 1, None, None,
0) * bioDraws('o_a_pe_tf0', 'NORMAL')
b_access_pe_tf1 = Beta('b_access_pe_tf1', 0, None, None, 0) + Beta('s_b_a_pe_tf1', 1, None, None,
0) * bioDraws('o_a_pe_tf1', 'NORMAL')
b_access_pe_tf2 = Beta('b_access_pe_tf2', 0, None, None, 0) + Beta('s_b_a_pe_tf2', 1, None, None,
0) * bioDraws('o_a_pe_tf2', 'NORMAL')

edu0 = (education == 0)
edu1 = (education == 1)
edu3 = (education == 3)

b_access_pe_edu0 = Beta('b_access_pe_edu0', 0, None, None, 0) + Beta('s_b_a_pe_edu0', 1, None,
None, 0) * bioDraws('o_a_pe_edu0', 'NORMAL')
b_access_pe_edu1 = Beta('b_access_pe_edu1', 0, None, None, 0) + Beta('s_b_a_pe_edu1', 1, None,
None, 0) * bioDraws('o_a_pe_edu1', 'NORMAL')
b_access_pe_edu3 = Beta('b_access_pe_edu3', 0, None, None, 0) + Beta('s_b_a_pe_edu3', 1, None,
None, 0) * bioDraws('o_a_pe_edu3', 'NORMAL')

occ0 = (occupation == 0) # full time
occ1 = (occupation == 1) # student
occ3 = (occupation == 3) # part time

b_access_pe_occ0 = Beta('b_access_pe_occ0', 0, None, None, 0) + Beta('s_b_a_pe_occ0', 1, None,
None, 0) * bioDraws('o_a_pe_occ0', 'NORMAL')
b_access_pe_occ1 = Beta('b_access_pe_occ1', 0, None, None, 0) + Beta('s_b_a_pe_occ1', 1, None,
None, 0) * bioDraws('o_a_pe_occ1', 'NORMAL')
b_access_pe_occ3 = Beta('b_access_pe_occ3', 0, None, None, 0) + Beta('s_b_a_pe_occ3', 1, None,
None, 0) * bioDraws('o_a_pe_occ3', 'NORMAL')

cam0 = (current_access_mode == 0) #bike
cam1 = (current_access_mode == 1) #btm
cam3 = (current_access_mode == 3) #walking

b_access_pe_cam0 = Beta('b_access_pe_cam0', 0, None, None, 0) + Beta('s_b_a_pe_cam0', 1, None,
None, 0) * bioDraws('o_a_pe_cam0', 'NORMAL')
b_access_pe_cam1 = Beta('b_access_pe_cam1', 0, None, None, 0) + Beta('s_b_a_pe_cam1', 1, None,
None, 0) * bioDraws('o_a_pe_cam1', 'NORMAL')
b_access_pe_cam3 = Beta('b_access_pe_cam3', 0, None, None, 0) + Beta('s_b_a_pe_cam3', 1, None,
None, 0) * bioDraws('o_a_pe_cam3', 'NORMAL')
```

```
cem0 = (current_egress_mode == 0) #walking
cem1 = (current_egress_mode == 1) #btm

b_egress_pe_cem0 = Beta('b_egress_pe_cem0', 0, None, None, 0) + Beta('s_b_e_pe_cem0', 1, None,
None, 0) * bioDraws('o_e_pe_cem0', 'NORMAL')
b_egress_pe_cem1 = Beta('b_egress_pe_cem1', 0, None, None, 0) + Beta('s_b_e_pe_cem1', 1, None,
None, 0) * bioDraws('o_e_pe_cem1', 'NORMAL')

ee0 = (escooter_experience == 0) #yes
ee1 = (escooter_experience == 1) #no

b_access_pe_ee0 = Beta('b_access_pe_ee0', 0, None, None, 0) + Beta('s_b_a_pe_ee0', 1, None,
None, 0) * bioDraws('o_a_pe_ee0', 'NORMAL')
b_access_pe_ee1 = Beta('b_access_pe_ee1', 0, None, None, 0) + Beta('s_b_a_pe_ee1', 1, None,
None, 0) * bioDraws('o_a_pe_ee1', 'NORMAL')

m0 = (microvehicle_ownership == 0) #yes
m1 = (microvehicle_ownership == 1) #no

b_access_pe_m0 = Beta('b_access_pe_m0', 0, None, None, 0) + Beta('s_b_a_pe_m0', 1, None, None,
0) * bioDraws('o_a_pe_m0', 'NORMAL')
b_access_pe_m1 = Beta('b_access_pe_m1', 0, None, None, 0) + Beta('s_b_a_pe_m1', 1, None, None,
0) * bioDraws('o_a_pe_m1', 'NORMAL')

tp0 = (travel_purpose == 0) #work
tp1 = (travel_purpose == 1) #leisure
tp2 = (travel_purpose == 2) #education

b_access_pe_tp0 = Beta('b_access_pe_tp0', 0, None, None, 0) + Beta('s_b_a_pe_tp0', 1, None,
None, 0) * bioDraws('o_a_pe_tp0', 'NORMAL')
b_access_pe_tp1 = Beta('b_access_pe_tp1', 0, None, None, 0) + Beta('s_b_a_pe_tp1', 1, None,
None, 0) * bioDraws('o_a_pe_tp1', 'NORMAL')
b_access_pe_tp2 = Beta('b_access_pe_tp2', 0, None, None, 0) + Beta('s_b_a_pe_tp2', 1, None,
None, 0) * bioDraws('o_a_pe_tp2', 'NORMAL')

d0 = (driving_license == 0) #yes, but no car
d1 = (driving_license == 1) #No
d2 = (driving_license == 2) #yes, and I also own a car

b_access_pe_d0 = Beta('b_access_pe_d0', 0, None, None, 0) + Beta('s_b_a_pe_d0', 1, None, None,
0) * bioDraws('o_a_pe_d0', 'NORMAL')
b_access_pe_d1 = Beta('b_access_pe_d1', 0, None, None, 0) + Beta('s_b_a_pe_d1', 1, None, None,
0) * bioDraws('o_a_pe_d1', 'NORMAL')
b_access_pe_d2 = Beta('b_access_pe_d2', 0, None, None, 0) + Beta('s_b_a_pe_d2', 1, None, None,
0) * bioDraws('o_a_pe_d2', 'NORMAL')

g0 = (gender == 0) #man
g1 = (gender == 1) #vrouw

b_access_pe_g0 = Beta('b_access_pe_g0', 0, None, None, 0) + Beta('s_b_a_pe_g0', 1, None, None, 0)
* bioDraws('o_a_pe_g0', 'NORMAL')
```

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```
b_access_pe_g1 = Beta('b_access_pe_g1', 0, None, None, 0) + Beta('s_b_a_pe_g1', 1, None, None, 0)
* bioDraws('o_a_pe_g1', 'NORMAL')

com0 = (com_pe == 0) #holding
com1 = (com_pe == 1) #stored

b_pe_com0 = Beta('b_pe_com0', 0, None, None, 0) + Beta('s_b_pe_com0', 1, None, None, 0) *
bioDraws('o_pe_com0', 'NORMAL')
b_pe_com1 = Beta('b_pe_com1', 0, None, None, 0) + Beta('s_b_pe_com1', 1, None, None, 0) *
bioDraws('o_pe_com1', 'NORMAL')
```

#utility functions

```
V_btm = ASC_btm_rnd + b_access_btm_wktb * access_btm_wktb + b_access_btm_tt *
access_btm_tt + b_access_btm_wat * access_btm_wat + b_access_btm_tc * access_btm_tc
V_bike = ASC_bike_rnd + b_access_bike_tt * access_bike_tt + b_access_bike_pst * access_bike_pst
V_walk = ASC_walk_rnd + b_access_w_tt * access_w_tt
V_pe = ASC_pe_rnd + b_access_pe_tt * access_pe_tt + (b_pe_com1 * com1) +
(b_access_pe_ee0*ee0) + (b_access_pe_cam1*cam1 + b_access_pe_cam0*cam0) +
(b_egress_pe_cem1*cem1) + (b_access_pe_d0*d0 + b_access_pe_d2*d2)+ (b_access_pe_tf1*tf1 +
b_access_pe_tf0*tf0)
```

#availability of alternatives

```
V = {1:V_btm,
    2:V_bike,
    3:V_walk,
    4:V_pe
}

av = {
    1: Variable('avail_btm'),
    2: Variable('avail_bike'),
    3: Variable('avail_walk'),
    4: Variable('avail_pe')
}
```

#running the model

```
CHOICE = Variable('acc_final')
obsprob = models.logit(V, av, CHOICE)
condprobIndiv = PanelLikelihoodTrajectory(obsprob)
logprob = log(MonteCarlo(condprobIndiv))
logger = msg.bioMessage()
logger.setDetailed()
biogeme = bio.BIOGEME(database, logprob, numberOfDraws = 2000)
biogeme.modelName = 'ML PANEL 2'
results = biogeme.estimate()
```

#showing the significance

```python
def significance_stars(pval):
    if pval < 0.01:
        return '***'
    elif pval < 0.05:
        return '**'
    elif pval < 0.1:
        return '*'
    else:
        return ''

# Get estimated parameters
params = results.getEstimatedParameters()

# Use standard p-value instead of robust
params['Significance'] = params['p-value'].apply(significance_stars)

# Combine the estimate and the stars
params['Estimate (stars)'] = params['Value'].round(4).astype(str) + params['Significance']

# Display the result
print(params[['Estimate (stars)', 'Std err', 't-test', 'p-value', 'Rob. p-value']])
```

#exporting the results

```python
export_df = params[['Estimate (stars)', 'Std err', 't-test', 'p-value', 'Rob. p-value']]

path = os.path.join('Results', 'access_ML_panel_2000_finaleeee.xlsx')
export_df.to_excel(path, index=True)


# gs = results.getGeneralStatistics()
# pandasResults = results.getEstimatedParameters()
# correlationResults = results.getCorrelationResults()
```

B.2 Python code for egress ML base model

#importing libraries

```
import pandas as pd
import biogeme.database as db
import biogeme.biogeme as bio
from biogeme import models
import biogeme.messaging as msg
from biogeme.expressions import (Beta, Variable, Integrate, DefineVariable, RandomVariable, exp,
bioDraws, PanelLikelihoodTrajectory, MonteCarlo, log)
from biogeme.database import Database
import os
```

#reading the data

```
df = pd.read_csv('cleaned2.csv')

df['avail_btm'] = 1
df['avail_bike'] = 1
df['avail_pe'] = 1
df['avail_walk'] = 1
```

#defining the panel structure

```
df.drop(columns=[
    'before_access_choice', 'before_egress_choice',
    'after_access_choice', 'after_egress_choice'
], inplace=True, errors='ignore')

# Drop rows with missing data
df.dropna(inplace=True)

# Keep only valid alternatives
valid_choices = [1, 2, 3, 4]
df = df[df['egg_final'].isin(valid_choices)]
df['egg_final'] = df['egg_final'].astype(int)

database = db.Database('data', df)
database.panel("id")
```

#defining the attributes and coefficients

```
df['egg_final'] = df['egg_final'].astype(int)

egress_btm_wab  = Variable('egress_btm_wab')
egress_btm_tt   = Variable('egress_btm_tt')
egress_btm_wktd  = Variable('egress_btm_wktd')
egress_btm_tc   = Variable('egress_btm_tc')
```

```
egress_bike_tt   = Variable('egress_bike_tt')
egress_bike_pst  = Variable('egress_bike_pst')

egress_w_tt      = Variable('egress_w_tt')

egress_pe_tt     = Variable('egress_pe_tt')
egress_pe_pst = Variable('egress_pe_pst')

globals().update(database.variables)

#defining the ASC's and the coefficients

ASC_btm = Beta('ASC_btm',0,None, None, 0)
ASC_btm_rnd = ASC_btm + Beta('s_b_a_ASC_btm', 1, None, None, 0) * bioDraws('o_a_ASC_btm',
'NORMAL')

ASC_bike = Beta('ASC_bike',0,None, None, 0)
ASC_bike_rnd = ASC_bike + Beta('s_b_a_ASC_bike', 1, None, None, 0) * bioDraws('o_a_ASC_bike',
'NORMAL')

ASC_walk_rnd = 0

ASC_pe = Beta('ASC_pe',0,None, None, 0)
ASC_pe_rnd = ASC_pe + Beta('s_b_a_ASC_pe', 1, None, None, 0) * bioDraws('o_a_ASC_pe',
'NORMAL')

b_egress_btm_wab = Beta('b_egress_btm_wab', 0, None, None, 0) + Beta('s_b_e_btm_wab', 1,
None, None, 0) * bioDraws('o_e_btm_wab', 'NORMAL')
b_egress_btm_tt = Beta('b_egress_btm_tt', 0, None, None, 0) + Beta('s_b_e_btm_tt', 1, None, None,
0) * bioDraws('o_e_btm_tt', 'NORMAL')
b_egress_btm_wktd = Beta('b_egress_btm_wktd', 0, None, None, 0) + Beta('s_b_e_btm_wktd', 1,
None, None, 0) * bioDraws('o_e_btm_wktd', 'NORMAL')
b_egress_btm_tc = Beta('b_egress_btm_tc', 0, None, None, 0) + Beta('s_b_e_btm_tc', 1, None,
None, 0) * bioDraws('o_e_btm_tc', 'NORMAL')

b_egress_bike_tt = Beta('b_egress_bike_tt', 0, None, None, 0) + Beta('s_b_e_bike_tt', 1, None, None,
0) * bioDraws('o_e_bike_tt', 'NORMAL')
b_egress_bike_pst = Beta('b_egress_bike_pst', 0, None, None, 0) + Beta('s_b_e_bike_pst', 1, None,
None, 0) * bioDraws('o_e_bikepst', 'NORMAL')

b_egress_w_tt = Beta('b_egress_w_tt', 0, None, None, 0) + Beta('s_b_e_walk_tt', 1, None, None, 0) *
bioDraws('o_e_walk_tt', 'NORMAL')
b_egress_pe_tt = Beta('b_egress_pe_tt', 0, None, None, 0) + Beta('s_b_e_pe_tt', 1, None, None, 0) *
bioDraws('o_e_pe_tt', 'NORMAL')
b_egress_pe_pst = Beta('b_egress_pe_pst', 0, None, None, 0) + Beta('s_b_e_pe_pst', 1, None, None,
0) * bioDraws('o_e_pe_pst', 'NORMAL')
```

#defining the utility functions

```
V_btm = ASC_btm_rnd + b_egress_btm_wab * egress_btm_wab + b_egress_btm_tt * egress_btm_tt
+ b_egress_btm_wktd * egress_btm_wktd + b_egress_btm_tc * egress_btm_tc
```

```
V_bike = ASC_bike_rnd + b_egress_bike_tt * egress_bike_tt + b_egress_bike_pst * egress_bike_pst
V_walk = ASC_walk_rnd + b_egress_w_tt * egress_w_tt
V_pe = ASC_pe_rnd + b_egress_pe_tt * egress_pe_tt + b_egress_pe_pst * egress_pe_pst
```

#defining the availability of alternatives

```
V = {1:V_btm,
    2:V_bike,
    3:V_walk,
    4:V_pe
}

av = {
    1: Variable('avail_btm'),
    2: Variable('avail_bike'),
    3: Variable('avail_walk'),
    4: Variable('avail_pe')
}
```

#estimating the model

```
CHOICE = Variable('egg_final')
obsprob = models.logit(V, av, CHOICE)
condprobIndiv = PanelLikelihoodTrajectory(obsprob)
logprob = log(MonteCarlo(condprobIndiv))
logger = msg.bioMessage()
logger.setDetailed()
biogeme = bio.BIOGEME(database, logprob, numberOfDraws = 2000)
biogeme.modelName = 'ML PANEL 3'
results = biogeme.estimate()
```

B.3 Access ML model with panel structure and no explanatory variables

	Estimate	p-value	Standard error
$ASC_{a,bike}$	-2.09***	0.00	0.71
$ASC_{a,btm}$	-1.59*	0.07	0.89
$ASC_{a,pe}$	-3.36***	0.00	0.66
$\beta_{a\_bike\_pst}$	-0.36***	0.00	0.07
$\beta_{a\_bike\_tt}$	-0.25***	0.00	0.04
$\beta_{a\_btm\_c}$	-0.33**	0.04	0.16
$\beta_{a\_btm\_tt}$	-0.15***	0.00	0.05
$\beta_{a\_btm\_wat}$	-0.21***	0.01	0.07
$\beta_{a\_btm\_wktb}$	-0.40***	0.00	0.09
$\beta_{a\_pe\_tt}$	-0.18***	0.00	0.04
$\beta_{a\_walk\_tt}$	-0.40***	0.00	0.05
β_{com_pe}	0.25	0.33	0.26
$\xi_{a\_ASC\_bike}$	1.91***	0.00	0.39
$\xi_{a\_ASC\_btm}$	-1.57***	0.00	0.35
$\xi_{a\_ASC\_pe}$	1.90***	0.00	0.34
$\xi_{a\_bike\_pst}$	0.08	0.39	0.09
$\xi_{a\_bike\_tt}$	0.07	0.20	0.05
ξ_{btm_tc}	0.29**	0.01	0.11
ξ_{btm_tt}	-0.04	0.64	0.08
ξ_{btm_wat}	0.29***	0.00	0.06
ξ_{btm_wktb}	-0.26***	0.00	0.08
$\xi_{a\_pe\_tt}$	0.19***	0.00	0.04
$\xi_{a\_w\_tt}$	0.15***	0.00	0.03
ξ_{pe_com}	1.15***	0.00	0.30

B.4 Access ML model with panel structure and explanatory variables

	Estimate	p-value	Std err
ASC			
$ASC_{a,bike}$	-2.01***	0.00	0.69
$ASC_{a,btm}$	-1.36	0.14	0.92
$ASC_{a,pe}$	-5.22***	0.00	1.01
Attributes			
$\beta_{a\_bike\_pst}$	-0.36***	0.00	0.07
$\beta_{a\_bike\_tt}$	-0.29***	0.00	0.05
$\beta_{a\_btm\_c}$	-0.40**	0.02	0.18
$\beta_{a\_btm\_tt}$	-0.15***	0.00	0.05
$\beta_{a\_btm\_wat}$	-0.18**	0.02	0.08
$\beta_{a\_btm\_wktb}$	-0.42***	0.00	0.10
$\beta_{a\_pe\_tt}$	-0.16***	0.00	0.04
β_{com_pe}	0.33	0.22	0.27
$\beta_{a\_walk\_tt}$	-0.41***	0.00	0.05
Explanatory variables			
$\beta_{access\_pe\_cam3}$	0 (base)		
$\beta_{access\_pe\_cam0}$	-0.39	0.64	0.82
$\beta_{access\_pe\_cam1}$	-1.77***	0.00	0.51
$\beta_{access\_pe\_cem0}$	0 (base)		
$\beta_{access\_pe\_cem1}$	0.26	0.65	0.57
β_{pe_d1}	0 (base)		
β_{pe_d0}	0.74	0.24	0.64
β_{pe_d2}	1.32**	0.04	0.65
β_{pe_ee1}	0 (base)		
β_{pe_ee0}	1.58***	0.01	0.58
β_{pe_tf2}	0 (base)		
β_{pe_tf0}	1.03*	0.07	0.56
β_{pe_tf1}	0.59	0.58	1.07
Random parameters of the ML model (normally distributed)			
ξ_{asc_bike}	1.36***	0.00	0.35
ξ_{asc_btm}	0.62	0.17	0.45
ξ_{asc_pe}	0.44	0.30	0.43
$\xi_{a\_bike\_pst}$	-0.01	0.96	0.11
$\xi_{a\_bike\_tt}$	0.18***	0.00	0.05

ξ_{btm_tc}	0.54***	0.00	0.15
ξ_{btm_tt}	0.05	0.49	0.07
ξ_{btm_wat}	0.34***	0.00	0.08
ξ_{btm_wktb}	-0.31***	0.00	0.09
ξ_{pe_cam0}	0.84	0.67	1.96
ξ_{pe_cam1}	0.16	0.65	0.36
ξ_{pe_cem1}	-2.39***	0.00	0.72
ξ_{pe_d0}	0.83**	0.05	0.42
ξ_{pe_d2}	-0.05	0.90	0.38
ξ_{pe_ee0}	0.11	0.78	0.39
ξ_{pe_tf0}	-0.75	0.43	0.95
ξ_{pe_tf1}	-0.14***	0.00	0.03
$\xi_{a\_pe\_tt}$	0.14***	0.00	0.02
$\xi_{a\_w\_tt}$	-0.20	0.57	0.35
ξ_{pe_com}	1.16***	0.00	0.34

B.5 Egress base ML model with panel structure and no explanatory variables

	Estimate	p-value	Standard error
$ASC_{e,bike}$	0.63	0.24	0.54
$ASC_{e,btm}$	-2.63**	0.02	1.13
$ASC_{e,pe}$	-0.39	0.49	0.57
$\beta_{e\_bike\_pst}$	-0.02	0.73	0.05
$\beta_{e\_bike\_tt}$	-0.02	0.50	0.03
$\beta_{e\_btm\_c}$	0.20	0.27	0.18
$\beta_{e\_btm\_tt}$	0.04	0.47	0.06
$\beta_{e\_btm\_wab}$	0.14**	0.01	0.05
$\beta_{e\_btm\_wktd}$	0.03	0.71	0.08
$\beta_{e\_pe\_pst}$	0.09	0.11	0.06
$\beta_{e\_pe\_tt}$	0.08***	0.01	0.03
$\beta_{e\_walk\_tt}$	-0.06*	0.07	0.03
$\xi_{e\_ASC\_bike}$	1.14***	0.00	0.24
$\xi_{e\_ASC\_btm}$	2.98***	0.00	0.53
$\xi_{e\_ASC\_pe}$	1.50***	0.00	0.26
$\xi_{e\_bike\_pst}$	0.002	0.98	0.09

$\xi_{e\_bike\_tt}$	0.01	0.71	0.04
$\xi_{e\_btm\_tc}$	0.34**	0.02	0.15
$\xi_{e\_btm\_tt}$	-0.12*	0.05	0.06
$\xi_{e\_btm\_wat}$	-0.0003	1.00	0.08
$\xi_{e\_btm\_wktb}$	-0.0046	0.96	0.10
$\xi_{e\_pe\_pst}$	0.12	0.27	0.11
$\xi_{e\_pe\_tt}$	-0.04	0.56	0.07
$\xi_{e\_walking}$	0.12***	0.00	0.02