Access/egress facilities at railway stations

An exploratory study on the future development of railway station areas

Master Thesis Bas Stam
March 2019

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Access/egress facilities at railway stations

An exploratory study on the future development of railway station areas

by

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in partial fulfilment of the requirements for the degree of

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PREFACE

This thesis originated from my interests in urban mobility and multimodal transport in relation to the spatial environment. This thesis contains an extensive research on access/egress transport with a specific focus on the spatial impact on railway station areas. With this thesis, I finish the master track Transport & Planning of the Civil Engineering Master at the Delft University of Technology. The research was performed at the engineering and consultancy agency Witteveen+Bos after an acquaintance during the Delftse Bedrijvendagen in February 2018.

This thesis would not have been established without the support and guidance of several people. First of all, I want to thank my graduation committee. Many thanks to both my daily supervisors Niels van Oort and Hilke van Strijp-Harms for shaping my interests into an executable research and providing me feedback on a regular basis. I would also like to thank Stefan van der Spek for his role as external supervisor and comments which helped me to look at some issues from a different perspective. Moreover, I would like to express my gratitude towards Professor Serge Hoogendoorn for his contribution and valuable input during the formal meetings.

Second, I want to thank Witteveen+Bos and all my colleagues for the great time I had. During my time as a graduate intern, I was also privileged to join several excursions among which a trip to London with the neWBies. Special thanks to Tessa for her time and feedback as 'non-official' committee member. I would also like to thank Martin who designed the flyers for the survey and provided me with hundreds of copies at short notice.

Last, I want to thank everyone who was there for me outside the working hours. I owe many thanks to my parents for their continuous support during the past years. I would also like to thank my brother, girlfriend and friends for being able to completely distract me at the moments I needed it the most.

Enjoy reading!

Bas Stam
Wateringen, March 2019

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EXECUTIVE SUMMARY

A multimodal trip consists of different stages in which more than one transport means is used to travel from origin to destination. Trips in the first and last stage can be described in terms of direction (e.g. access/egress) and in terms of location (e.g. home-end/activity-end). For the majority of multimodal trips in the Netherlands (61%), the train is used to cover the largest distance (i.e. main stage). Hence, it is crucial to provide suitable access/egress facilities at the railway station area.

As a result of ongoing developments, such as urbanisation, climate change and technological advances, the transportation sector evolves at a rapid pace. Consequently, access/egress transport, and therefore the required land use for access/egress facilities at the railway station area, is expected to change accordingly.

This research aimed to create knowledge and set guidelines for the (re)development of railway station areas regarding the required land use for access/egress facilities as a result of access/egress transportation developments. Therefore, the following main research question was formulated:

'How should railway station areas in the Netherlands be (re)developed regarding the required land use for access/egress facilities as a result of access/egress transportation developments on a time horizon up to 20 years?'

The main research question was addressed throughout this research in various phases. First, a **literature review** was conducted to gather knowledge for the foundation of this research. With the information, a **scenario matrix** was constructed to distinguish four future development paths for access/egress transport. Subsequently, a **footprint indicator** was developed to determine the required land use for access/egress facilities. Data on the expected modal split in each of the four scenarios was gathered through a **mode choice experiment**. These values were subsequently used in combination with the footprint indicator for the **spatial assessment** of railway station areas and to answer the main research question.

Literature review

The first part of the literature review showed that many factors influence an access/egress mode choice decision. It was found that factors can be assigned to one of the six categories that were defined during the review, depicted in Figure 1.

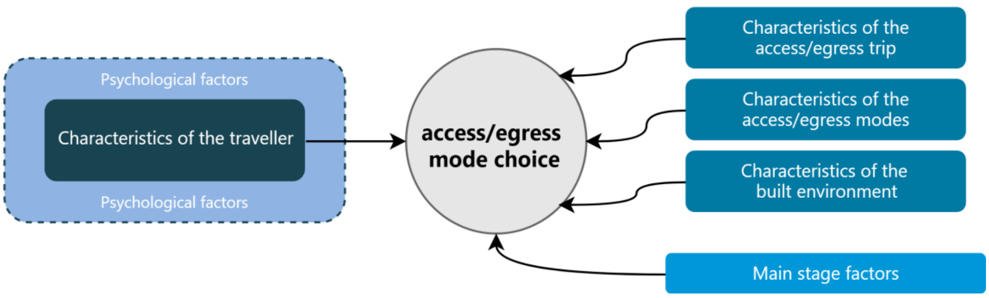


Figure 1 Access/egress mode choice framework

The first category, characteristics of the traveller, shapes the individuals' personal and household situation. Psychological factors such as attitude and perception are also traveller dependent but able to capture the unobserved, or latent, variables. These variables either have no measurement scale or are perceived differently per individual. The third category includes all trip specific determinants. The distance, for example, is widely researched but also the trip purpose and the weather conditions can be assigned to this category. Access/egress mode characteristics form the fourth category and only include factors that are related to the means of transport. Travel time and cost are among the most reviewed factors in this category. The fifth category characterises the built environment in which the access/egress trip, and thus the mode choice, takes place. Determinants among this category can be classified according to the variables density, diversity and design, also known as the '3Ds'. The sixth and last category includes factors that are related to the main stage (i.e. rail service) and were found to influence the access/egress mode choice as well. The review illustrated that the influence of factors varies between studies and strongly depends on the considered scope (e.g. trip stages, means of access/egress transport and transit nodes). Moreover, factors can have mutual relations with other factors assigned to the same, or another category. Especially interesting to see, and visualised in Figure 2, is that certain factors have a specific relation to a means of access/egress transport. These findings can help to clarify and predict access/egress mode choice decisions.

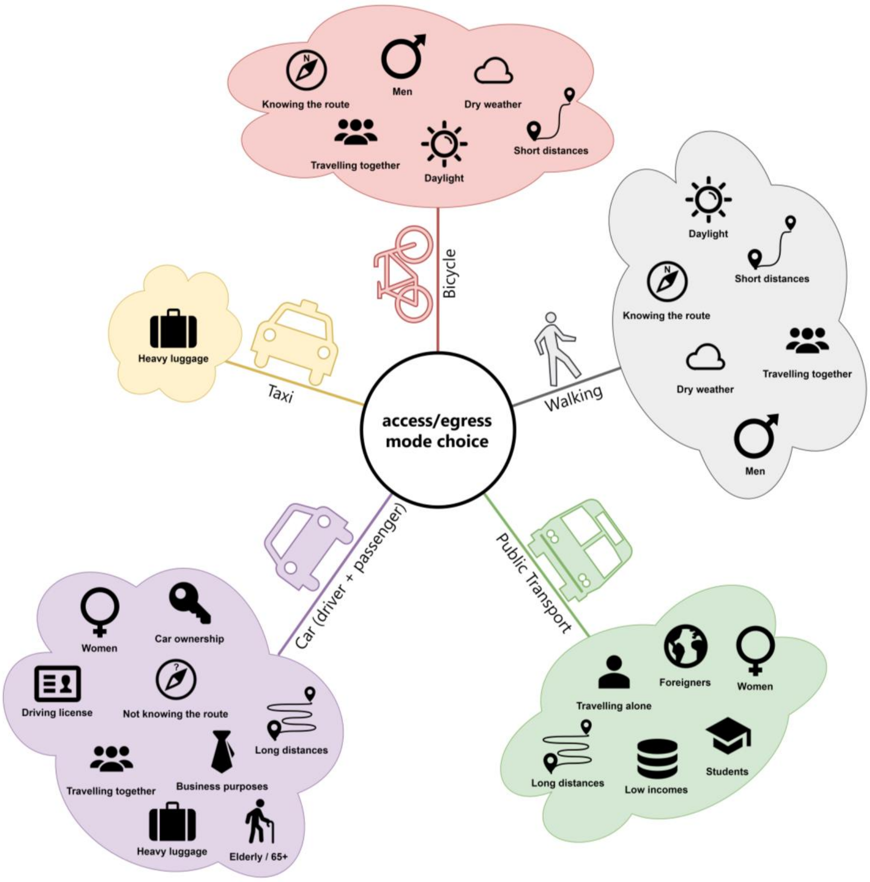


Figure 2 Overview of access/egress mode choice factors in relation to the transport means

The second part of the literature review elaborated on the impact of relevant trends and determined the potential of new and innovating means of transport for the next 20 years. The demand for access/egress transport is expected to be influenced by among others demographic shifts, urbanisation and climate change. The impact of these trends can be captured by the extent to which access/egress mode choice factors are influenced. However, as a result of these trends, in combination with technological developments, new and innovating means of transport emerge. Shared mobility, autonomous mobility and electric mobility thereby play an important role and have the potential to change the supply of access/egress transport in the future. In 20 years, shared mobility, in particular, is expected to significantly change access/egress trips by means of the following services: (1) carsharing, (2) bikesharing, (3) e-scooter sharing, (4) individual on-demand ride services and (5) collective on-demand ride services.

Scenarios

The services among the shared mobility concept are expected to have a crucial role in future mode choice decisions and thus the required land use for access/egress facilities at the railway station area. The success of the services is expected to be dependent on two main driving forces. On the one hand, the degree to which the vehicle sharing economy develops, and on the other hand, the degree to which ride services are offered. Considering high and low penetrations of both the driving forces, four distinguishable scenarios were constructed in which different means of access/egress transport are expected to have a dominant role (Figure 3).

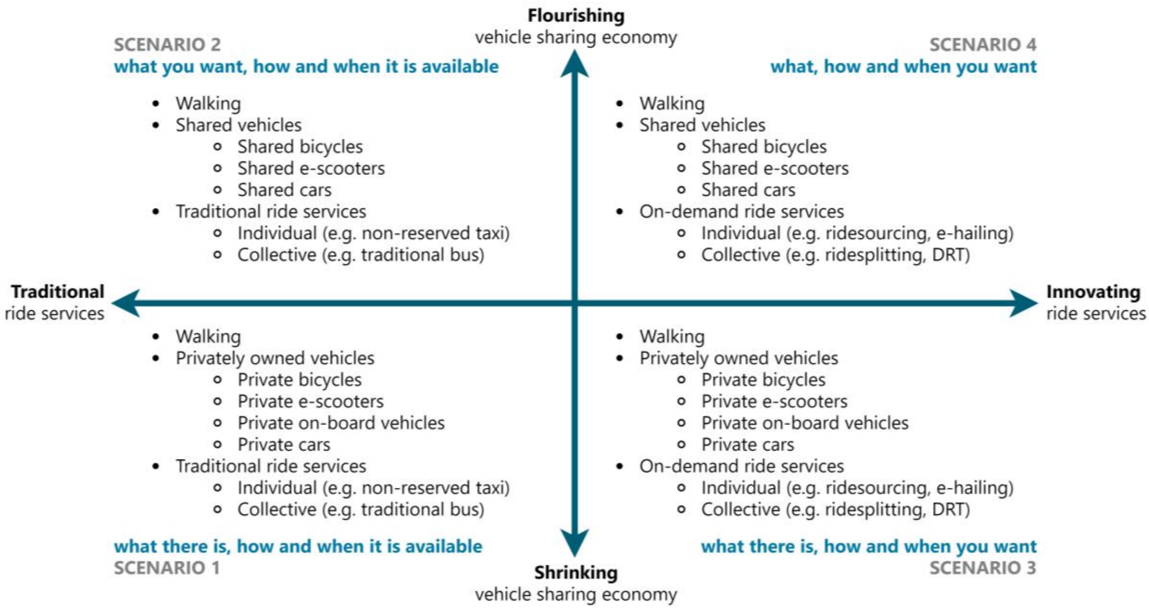


Figure 3 Expected dominating means of access/egress transport in each scenario

Footprint indicator

For all considered means of access/egress transport, the so-called access/egress transport footprint was determined. This indicator was developed and given the following definition:

'The required area per traveller for a means of access/egress transport to park or stop at the railway station area based on the number of departures and arrivals during a peak period.'

The footprint indicator can be expressed in square meter per traveller and consists of three components: (1) storage area, (2) design frequency and (3) occupancy rate (Figure 4).

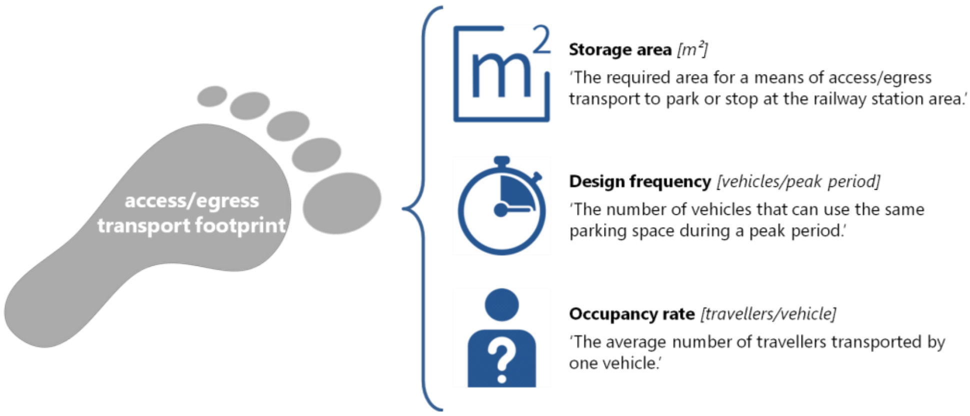


Figure 4 Access/egress transport footprint composition

Storage areas were determined based on existing design vehicles and design guidelines. For new means of access/egress transport, the dimensions of existing vehicles from practice were used as reference. For the determination of the storage areas, not only the dimensions of the parking space (i.e. direct land use), but also indirect land use sections such as parking lanes (adjacent to the parking space) and platforms were considered. Other areas such as driving lanes (to reach the parking lanes) and possible construction elements of the facility were not considered. The second component of the footprint, the design frequency, illustrates how often the same parking space is used during a peak period. This is the period in which the largest share of travellers make use of the railway station and assumed to be normative for the provision of access/egress facilities. Generally, this is either the morning peak (07:00 – 09:00) or evening peak (16:00 – 18:00), dependent per railway station. Each means of transport is assigned a design frequency, dependent on its home-end and activity-end potential and/or the expected operating frequency. The third, and last, component of the footprint is the occupancy rate. These values were collected from literature, if available, or estimated when not based on the characteristics of the vehicle.

An overview of the values for all components is given in Table 1. The footprints are depicted in the last column and calculated with the following formula:

$$Access/egress\ transport\ footprint = \frac{storage\ area}{design\ frequency * occupancy\ rate}$$

Table 1 Overview of the footprints and all three components

Access/egress modes	**Storage area** [m^2]	**Design frequency** [vehicles/peak period]	**Occupancy rate** [travellers/vehicle]	**Footprint** [m^2/traveller]
Walking	0	NA	NA	**0.00**
Private bicycle	0.6	2	1	**0.30**
Shared bicycle[1]	0.6	1.7	1	**0.40**
Private e-scooter	0.2	2	1	**0.10**
Shared e-scooter[1]	0.2	1.7	1	**0.13**
Private on-board vehicle	0	NA	1	**0.00**
Private car	21	1	1.2	**17.50**
Shared car[1]	14	1.7	1.2	**7.50**
Individual traditional ride service	28	6	1.2	**3.89**
Collective traditional ride service	260	24	25	**0.43**
Individual on-demand ride service	28	48	1.2	**0.49**
Collective on-demand ride service	130	48	8	**0.34**

[1] Average of the three vehicle sharing services: roundtrip, one-way and peer-to-peer.

These numbers show that means of access/egress transport that rely on the use of a car, requires the largest amount of area per traveller. The vehicle with the lowest footprint is the e-scooter due to its compact use and foldable design. Because walking and on-board vehicles were not associated with an access/egress facility to park or stop at the railway station area, these means of transport are associated with a footprint of zero.

Mode choice experiment

A mode choice experiment was set up and conducted to observe current and future mode choice decisions. For this experiment, the Almere Centrum railway station in the Netherlands was selected as case study location. This station is used by 25,888 travellers on an average weekday, especially during the morning peak (18.2%) and the evening peak (13.5%).

Flyers to access the online survey were distributed on site for one week during the peak hours. In total, 442 surveys were completed by the train travellers of Almere Centrum. After filtering the outliers, 401 surveys remained useful for further analyses. Some basic features of the dataset were analysed and compared with other data from among others *NS Stations*. Eight Sankey diagrams were created to present the modal splits for home-end and activity-end trips in each of the four scenarios. Figure 5 shows the Sankey diagram for home-end trips in scenario 4, in which shared vehicles and on-demand ride services are available. The left side of the diagram shows the current means of access/egress transport, while the right side represents the chosen means of transport in the considered scenario. Because no attributes were specified in the survey, the observed mode choice in each scenario represents the preferred transport means of travellers.

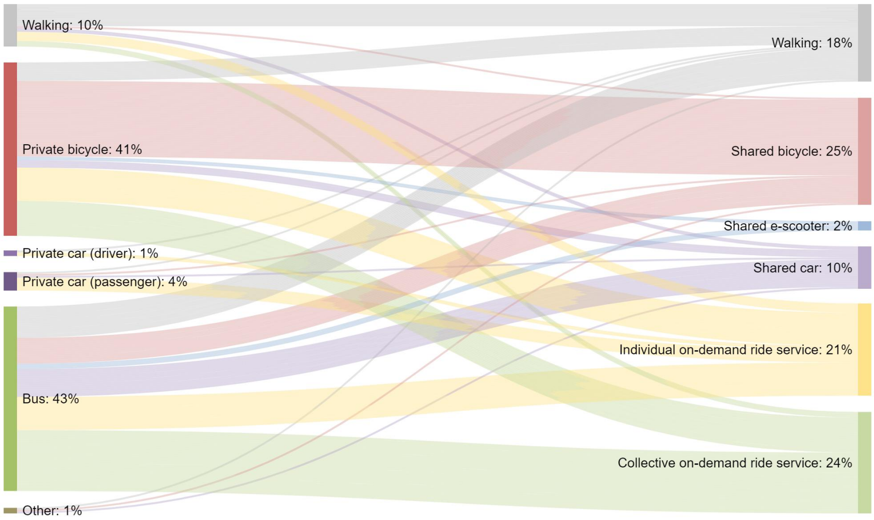


Figure 5 Example of a Sankey diagram (Home-end trips, scenario 4)

Data on the current modal split of home-end trips shows large shares for the bus (43%) and the bicycle (41%). For activity-end trips, these modes are only used by respectively 18% and 10% of the travellers, after walking (67%). In line with these findings, the majority of activity-end trips (54%) are of 1km or less. The distance of home-end trips is on average a little longer, 64% of the trips are within a range of 1-5km. Regarding the preferred means of access/egress transport in the constructed scenarios, the following observations were made:

Home-end trips

- Although the car is currently used for only 5% of the home-end trips, the transport mode is popular in each of the four scenarios (18%, 13%, 17% and 10%). Especially among women, aged 0-24, travelling for school/study purposes. Even trips shorter than 1km will be made by this group.
- The traditional bus remains popular, especially among travellers aged 25-64, travelling for commuting/business purposes, who already make use of the bus. A quarter of the respondents currently takes the bus and has a preference for this ride service.

Activity-end trips

- Although walking accounts for the largest share (67%) of current activity-end trips, the share reduces significantly in each of the four scenarios (44%, 39%, 37% and 42%).
- Characteristics of travellers who currently walk, but who do not prefer to walk, does not significantly differ from the average activity-end traveller. This group represents 20% of the total number of activity-end travellers.
- 30% of the activity-end travellers always prefer to walk. Especially men, aged 25-44, travelling for commuting/business purposes.

Access/egress trips in general

- 21% of the travellers prefer a shared vehicle when available.

    - Especially men, aged 25-64, travelling for commuting/business purposes.
    - In general, the preference of travellers towards different sharing forms is equally divided
- 21% of the travellers prefer a private vehicle, but no shared vehicle.
    - Especially younger women, travelling for school/study and social/recreation purposes.
- 23% of the travellers prefer a flexible ride service when available.
    - Especially travellers aged 45-64.
- 12% of the travellers prefer a traditional ride service, but no flexible ride service.
    - Especially younger women, travelling for school/study purposes.
- 10% of the travellers prefer to use a vehicle that is allowed to be taken on-board.
    - Especially middle-aged travellers, travelling for commuting/business purposes who currently cycle.
- 8% of the travellers prefer to use an e-scooter.
    - Especially middle-aged women, travelling for commuting/business purposes.

The observations on access/egress trips in general were visualised by means of an infographic that is also attached at the end of this executive summary.

Spatial assessment

The modal split data from the mode choice experiment and the developed footprint indicator were united to determine and assess the total required land use for access/egress facilities at the railway station area.

According to this research, 2,772m² is required for access/egress facilities at railway station Almere Centrum in the current situation, based on the number of travellers in the busiest peak period, the morning peak. This value includes the area of parking spaces, driving lanes (adjacent to the parking spaces) and possible platforms which were also considered for the determination of the storage areas. Although this is assumed to be a minimum value, the existing areas of access/egress facilities at Almere Centrum were found to be considerably larger and occupy in total 18,595m². This area also includes parking lanes and possible construction elements of the facilities. Moreover, an analysis on the land use of existing facilities illustrated that facilities are currently overdimensioned and designed according to different values than considered for the footprint indicator of this research.

The four scenarios were assigned a total required land use of 9,808m², 5,340m², 9,079m² and 3,861m² for access/egress facilities respectively. Because the car was found to be a preferred means of transport in combination with its high footprint, a significant amount of area is required to facilitate these travellers. Moreover, because walking is not as preferred in the scenarios as chosen in the current situation, more space is required to facilitate the means of access/egress transport to which these people shift.

Conclusions

According to the outcomes, railway station areas should be designed differently in each scenario. Based on the two driving forces that were chosen for the construction of the scenario matrix, the following (re)development possibilities were observed:

When the vehicle sharing economy develops:

- Car parking facilities require a different design as the dimensions of shared vehicles are expected to be smaller.
- Facilities for bicycles and e-scooters remain needed and keep their value as both private and shared forms require the same type of facilities.

- It is expected that additional area for collective traditional ride services is required when the use of private vehicles is discouraged to stimulate sharing.

When the ride service industry develops:
- Existing individual traditional ride facilities (e.g. taxi stands and Kiss and Ride) remain useful for individual on-demand ride services and are expected to require more space.
- Traditional bus stations are expected to disappear or require adjustments and minibus stations are required for the collective on-demand ride services. Because minibus stations require less space for the same demand, collective ride service facilities are not expected to require a larger area.

Additionally, it is important to consider which means of transport are desired for access/egress trips to/from a specific railway station. For Almere Centrum the outcomes showed that large car parking facilities should be provided in each of the four scenarios. However, it is questionable whether car use to/from railway stations should be stimulated, especially when the railway station is located in the city centre. In these areas space is scarce and cars were found to be the most inefficient means of access/egress transport regarding land use. However, access/egress mode choice can be controlled for by various factors as was observed for Almere Centrum.

Discussion & Recommendations

The results and conclusions that originated from this research are dependent on various assumptions and choices that have been made throughout the process. First of all, of all trends and developments that are expected to influence access/egress transport in the future, services originating from the shared mobility concept were considered only. These services are expected to have the most significant impact on access/egress trips in the considered time horizon of 20 years. Consequently, this research provided a single-sided vision on the (re)development of railway station areas. Research on other trends and developments is required to understand and predict how the access/egress sector evolves in the coming years and what the consequences are for access/egress facilities at the railway station area.

Second, the footprint indicator that was developed can be improved by more accurate estimations of the values for all three components. For the storage area, areas of driving lanes and construction elements of facilities can be included to determine the total required area of the facility more accurately. The design frequencies can be improved by doing further research on the departures, arrivals and residence times of access/egress vehicles. This would also give more information on the number of travellers for which access/egress facilities should be designed which was, in this research, based on the number of travellers in the busiest peak period. Last, occupancy rates for access/egress trips specifically are expected to improve the indicator as regular values were used for this research.

Last, because this research focused on access/egress trips to/from railway stations in the Netherlands, specific means of access/egress transport were considered for the construction of the scenarios and determination of the footprints. For other countries and other transit nodes with different characteristics, other means of access/egress transport are expected to be relevant and should be included. Additionally, the mode choice experiment and spatial assessment of the railway station area were performed for Almere Centrum specifically. These outcomes are expected to be especially relevant for railway stations with similar characteristics. Because the experiment researched the preference of travellers, access/egress mode choice factors and attribute levels should be included for more accurate predictions regarding the access/egress mode choice of travellers in the future.

Main findings modal split survey

NOV, 2018
week 47

401 respondents

km	?	>10	5-10	1-5	<1
Home-end	2%	6%	16%	64%	12%

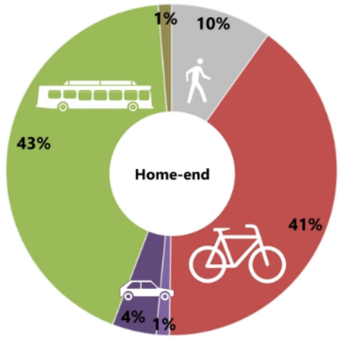
km	<1	1-5	5-10	>10	?
Activity-end	54%	34%	9%	1%	2%

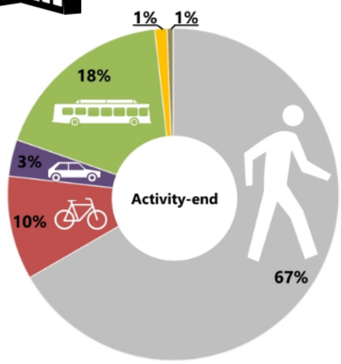
58% **of the trips** are home-end trips

42% **of the trips** are activity-end trips

Current modal split

- Walking
- Bicycle
- Car (driver)
- Car (passenger)
- Bus
- Taxi
- Other

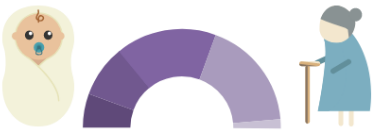




Gender

55% 45%

Age



0-19 (11%) 20-24 (17%) 25-44 (33%) 45-64 (36%) 65+ (3%)

Driver's license

80%

Trip purpose

Commuting / business 72%
School / study 21%
Social / recreation 7%

SHARING IS HOT ... OR NOT

21% **of the travellers** prefer a shared vehicle when available

21% **of the travellers** prefer a private vehicle but **NO** shared vehicle

Sharing forms

free-floating
52% prefer a vehicle that can be picked-up and dropped-off anywhere.

roundtrip / P2P
48% prefer a vehicle with the certainty of availability.

	58% Men		Women 52%	▲ +7%
▲ +4%	40% 45-64		0-19 16%	
	78%	Commuting / business	64%	▼ -9%

FLEXIBLE RIDES ARE HOT ... OR NOT

23% **of the travellers** prefer a flexible ride service when available

12% **of the travellers** prefer a traditional ride service but **NO** flexible ride service

▼ -5%	12%	20-24	20-24	30%	▲ +13%
▼ -10%	23%	25-44	School / study	36%	▲ +15%
▲ +13%	49%	45-64	Driver's license	66%	▼ -14%

46% **of the flexible riders** currently uses the bus

74% **of the non-flexible riders** currently uses the bus

VEHICLE ON-BOARD FANS

10% of the travellers prefer to use a vehicle that is allowed to be taken on-board

IMPORTANT POINT!

A vehicle is allowed to be taken on-board if:

- the vehicle has no combustion engine;
- the vehicle does not exceed the dimensions of 85 x 85 x 85cm.

43% **of the on-board fans** is aged 25-44

78% **of the on-board fans** travels for commuting / business purposes

38% **of the on-board fans** currently uses the bicycle

E-SCOOTER FANS

8% of the travellers prefer to use an e-scooter

79% **of the e-scooter fans** travels for commuting / business purposes

45% ▲ 12% **of the e-scooter fans** is aged 25-44

27% **of the e-scooter fans** currently travels 5-10km

36% **of the e-scooter fans** currently travels by foot

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LIST OF ABBREVIATIONS

2W	Motorised two-wheelers
AE	Activity-End
AEVs	All Electric Vehicles
AV	Automated Vehicle
B+R	Bike and Ride
BRT	Bus Rapid Transit
BTM	Bus, Tram, Metro
CBS	Centraal Bureau voor de Statistiek (Dutch Central Bureau of Statistics)
DRT	Demand Responsive Transit
EVs	Electric Vehicles
FSUTMS	Florida Standard Urban Transportation Model Structure
GHG	Greenhouse gas
HE	Home-End
HEVs	Hybrid Electric Vehicles
HSR	High-speed rail
K+R	Kiss and Ride
LOS	Level of Service
LRT	Light-rail transit
MRT	Mass Rapid Transit
MS	Main Stage
NS	Nederlandse Spoorwegen (Dutch Railways)
P+R	Park and Ride
P2P	Peer-to-peer
PT	Public Transport
PVS	Personal Vehicle Sharing
TOD	Transit Oriented Development
US	United States
VMT	Vehicle Miles Travelled

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1 INTRODUCTION

The Netherlands has one of the densest rail networks in the world and is used by more than 1.2 million passengers every day (Van Hagen & Exel, 2012). For all those trips, the railway station is the start and end of the train journey. The average distance for Dutch residents to reach a railway station from their home is 5.0km (Centraal Bureau voor de Statistiek, 2017c). This value varies significantly between different regions in the Netherlands. Residents of the four largest cities in the *Randstad*[1] live on average 2.5km away from the nearest train station, while residents in the province of Zeeland do have to travel an average of 17.3km to catch a train. Logically, train trips are usually part of a multimodal trip, indicating that more than one transport means is used to travel from origin to destination. Hence, facilitating these means of transport at the railway station area is essential for the overall door-to-door journey, in which the train is used to cover the largest distance.

1.1 Access/egress transport

With the growing importance of access/egress transport, an increasing number of studies focuses on the multimodal character of journeys. Still, the use of notions to describe the different trips of a multimodal journey appears to vary between studies. In general, a multimodal trip can be divided into three stages. For the majority of these trips in the Netherlands (61%), the train is used to cover the largest distance (i.e. main stage) (Kennisinstituut voor Mobiliteitsbeleid, 2014). Consequently, this study explicitly focuses on trips to/from railway stations. Regarding the two non-train stages of a multimodal journey, trips can be described in two different ways. The first one is in terms of direction (e.g. access/egress and first/last mile). However, this option results in different terminologies within the same stage if a trip is made in the other direction (Figure 1.1, i). Studying these trips in terms of location (e.g. home-end/activity-end) instead of direction leads to a consistent usage of terms at both the origin and destination side, also when a trip is made for the second time but in the other direction (Figure 1.1, ii).

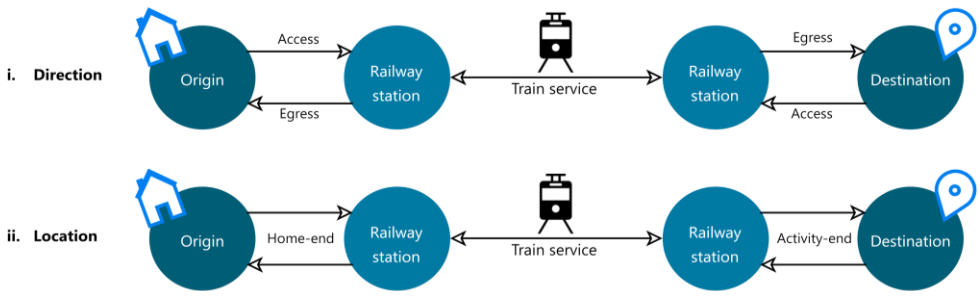


Figure 1.1 Trips of a multimodal journey described at two different ways

Due to the (un)availability of transport means at both trip-ends, the modal split of home-end trips usually differs from activity-end trips. This is emphasised in Figure 1.2, which shows the average modal split of the 20 busiest railway stations in the Netherlands. At the home-end of the trip, the bicycle (43%), walking (23%) and public transport (19%) are most frequently chosen. However, at the activity-end of the trip, the bicycle is used by only 13% of the travellers, after walking (45%) and public transport (33%). These percentages illustrate how the availability of transport means, influences the mode choice of travellers at both ends of the trip. However, from a directional point of view, these differences would not have been observed.

[1] Amsterdam, Rotterdam, The Hague and Utrecht are the four largest cities in the Netherlands and part of the *Randstad*, which is one of the most important and densely populated economic areas in Europe.

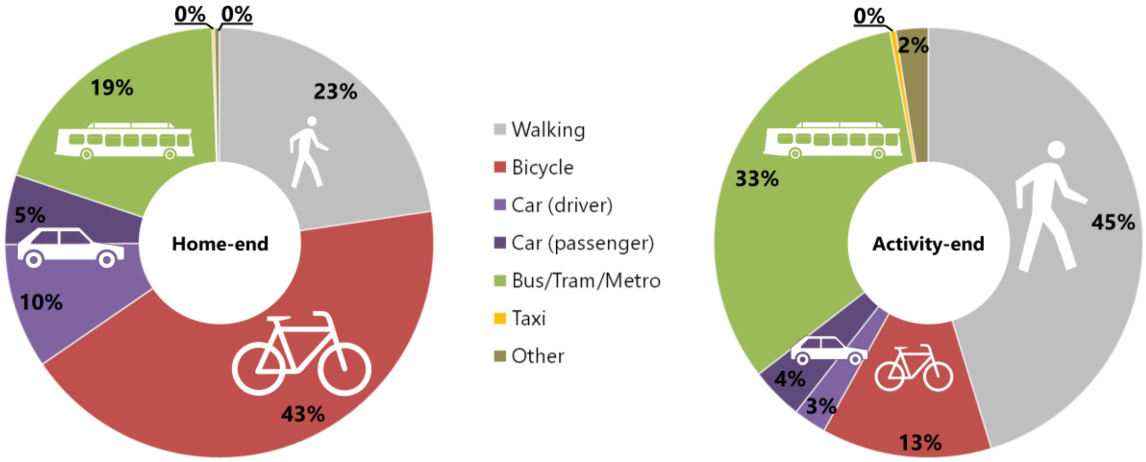


Figure 1.2 Modal split (2014) of the 20 busiest railway stations in the Netherlands (Kennisinstituut voor Mobiliteitsbeleid, 2017)

The same dataset also illustrates how the modal split has changed over the last ten years (Kennisinstituut voor Mobiliteitsbeleid, 2017). The share of the bicycle in particular keeps showing an upward trend. Between 2005 and 2014 the bicycle share for home-end trips increased by 7% and also at the activity-end of the trip, the bicycle gained an additional 3%. The researchers also state that the traditional means of public transport such as bus, tram, metro (BTM) show a declining trend. Regarding ongoing developments, such as urbanisation, climate change and technological advances, the transportation sector evolves at a rapid pace (PwC, 2018). Not only existing, but also new means of transport are expected to improve the overall door-to-door journey in the coming years, which makes the future modal split unpredictable.

1.2 Access/egress facilities at railway stations

The ownership of railway stations in the Netherlands is divided between the two parties *ProRail* and *NS Stations* (ECORYS, 2014). *ProRail*, on the one hand, owns the platforms and all infrastructure (e.g. tunnels, stairs and elevators) that is necessary to make the platforms accessible for all type of travellers. Additionally, they also fund transfer facilities such as benches, clocks, signage, communication systems and various parking facilities (ProRail & NS, 2010). *NS Stations*, on the other hand, is in possession of all station halls and buildings. This organisation, which is a subdivision of the *NS* (*Nederlandse Spoorwegen* in Dutch), has the rights to operate all parts of the railway station, also those which are in possession of *ProRail*. For example, most bicycle facilities are both operated and maintained by *NS Stations*. For other facilities, such as Park and Ride (P+R), the operational tasks are generally outsourced to a private organisation (e.g. *Q-Park*).

To create distinction in the different functions of a railway station, *NS*, *ProRail* and an independent organisation called *Bureau Spoorbouwmeester*, published a report in which four domains are distinguished (Bureau Spoorbouwmeester, 2012). According to the report, a railway station consists of a travel domain, a stay domain, an entrance domain and a surrounding domain. The first three domains are all located within the borders of the station building, while the surrounding domain can have various characteristics. This domain can either be a small square in front of the station, or a complete public transport terminal, often present at larger railway stations. Access/egress facilities are part of the surrounding domain and aim to provide a smooth and safe transfer between the train and other transport means (Bureau Spoorbouwmeester, 2012). Responsibilities within this domain reach beyond the parties from the railway industry. In general, the respective municipally is in possession of the land around the station (ProRail & NS, 2010). Moreover, concessions to operate on the local public transport network can be in the hands of one or more public transport operators. For a reason, railway station area (re)development projects can be entitled as complex, also due to the many different actors involved.

There are no standards which prescribe how to design the surrounding area regarding access/egress facilities (Projectteam Basisstation, 2005). However, a station area should always be designed for pedestrians, since everyone becomes a pedestrian when entering or exiting the railway station. This is in line with the views of Bach, De Groot, and Van Hal (2006), to design an area where urban design and traffic come together from the individual as the starting point. The prioritisation scheme, depicted in Figure 1.3, shows the recommended division of transport means in the surrounding domain, taking into account the vulnerability of the different users (Brouwer & Huijsmans, 2011). Still, the provision of facilities strongly differs per station and is often determined by the number of passengers served by each means of transport. However, as a result of the rapidly evolving transportation sector, access/egress transport, and therefore the required facilities, is expected to change accordingly.

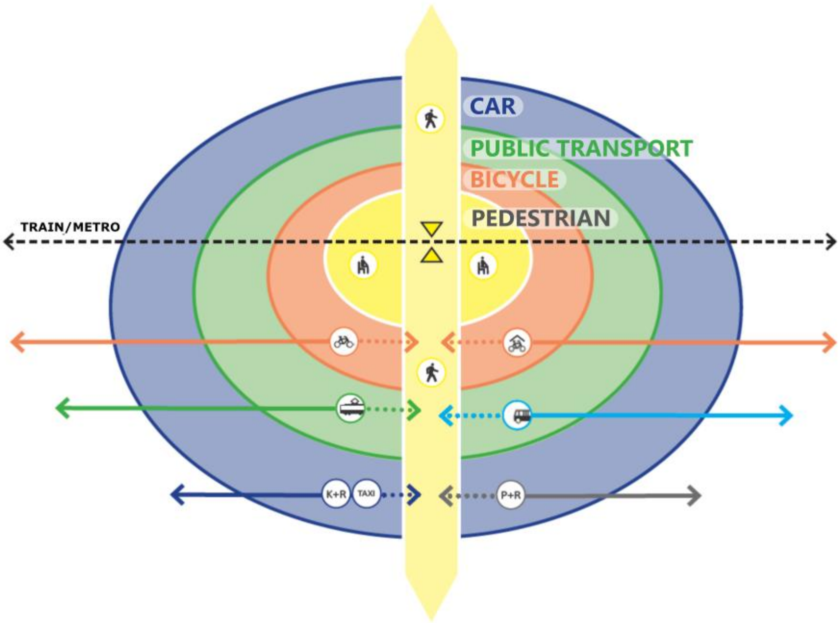


Figure 1.3 Prioritisation of transport means at the railway station area (Brouwer & Huijsmans, 2011)

1.3 Research questions and methodology

This research aims to create knowledge and set guidelines for the (re)development of railway station areas regarding the required land use for access/egress facilities as a result of access/egress transportation developments. Before presenting the research questions and methodology, the research scope is specified to clarify the assumptions and choices made. This makes the research manageable in the amount of time and with the resources available.

1.3.1 Research scope and context

Although access/egress transport plays a role at all type of hubs in many different countries, this study solely focuses on access/egress transport to/from railway stations in the Netherlands. Since most of the multimodal main stages in the Netherlands are carried out by train (61%), railway stations are interesting nodes to consider (Kennisinstituut voor Mobiliteitsbeleid, 2014).

Regarding the time horizon, a period of 20 years is considered to research the redevelopment of railway station areas as a result of a rapidly changing transportation sector. This time horizon is assumed to be on the one hand long enough for innovations and developments to emerge, and on the other hand briefly enough to come up with plausible and relevant conclusions. Also from a practical point of view, 20 years is assumed to be an acceptable time horizon for railway station area (re)development projects.

1.3.2 Research questions

The main research question is:

'How should railway station areas in the Netherlands be (re)developed regarding the required land use for access/egress facilities as a result of access/egress transportation developments on a time horizon up to 20 years?'

In order to answer the main research question, six sub-questions are identified, namely:

1. Which factors influence the mode choice of travellers travelling to/from the railway station?
2. What are the impacts and potentials of trends and developments for access/egress transport to/from railway stations in the next 20 years?
3. Which future development paths for access/egress transport can be distinguished in 20 years?
4. How can the required area for access/egress facilities at the railway station be determined and how does this value differ per means of transport?
5. What is the expected modal split in the predefined development paths for access/egress transport?
6. How does the expected modal split influences the total required land use for access/egress facilities at the railway station area?

1.3.3 Research approach

Different methods will be used to address the research questions that are defined above. The chapters of this report that address the various sub-questions one by one are briefly introduced. An overview of the report structure is provided at the end of this subparagraph in Figure 1.4.

Chapter 2 – Literature review

Sub-questions 1&2: Gather knowledge and provide a foundation for remaining topics

Chapter 2 provides an extensive literature review on two relevant topics regarding access/egress transport. The first part elaborates on the factors that influence the access/egress mode choice of travellers. Literature is searched for in various databases using keywords and synonyms reflecting access/egress transport (factors). A selection of relevant literature is made and analysed thoroughly. The findings can be used to clarify and predict access/egress mode choice decisions. The second part of the literature review elaborates on global trends and developments that are expected to change access/egress transport in the future. The impact and potential of these revolutionary changes are of interest to predict future development paths for access/egress transport in the next chapter. Specific literature is searched for to find this information and analysed regarding this specific aim.

Chapter 3 – Scenarios

Sub-question 3: Construct future development paths for access/egress transport

A scenario matrix is constructed to establish four future development paths for the access/egress transport sector. Each development path can be characterised by its own means of access/egress transport that are expected to play a dominant role in the respective scenario(s). Two driving forces lie at the basis of the matrix and will be derived from the findings of the literature review. To distinguish home-end and activity-end trips, the matrix is transformed into two trip-end specific matrices, based on the expected availability of transport modes at each trip-end.

Chapter 4 – Footprint indicator

Sub-question 4: Develop a methodology to determine the required area for access/egress facilities

To determine the required area for access/egress facilities at railway stations, a so-called access/egress transport footprint is developed. This indicator consists of three components: (1)

storage area, (2) design frequency and (3) occupancy rate, and represents the required area per traveller for a means of access/egress transport to park or stop at the railway station area based on the number of departures and arrivals during a peak period.

Chapter 5 – Mode choice, case study

Sub-question 5: Construct survey, collect data and observe modal splits

Data on mode choice decisions is collected by means of a survey. For this, a specific railway station is chosen as case study. The survey is made online and flyers are handed out to travellers at the station. Because the survey does not specify attributes, future mode choice decisions are based on the preference of the travellers. The outcomes of the survey are analysed and compared with other datasets after which the current and future modal splits are observed.

Chapter 6 – Spatial assessment, case study

Sub-question 6: Apply footprint on collected data to assess railway station areas

The developed access/egress transport footprint is used, in combination with the collected modal split data, to determine the total required land use for access/egress facilities at the railway station area in the future. The land use of existing facilities at the case study location is also evaluated based on the outcomes of this research. The outcomes on the total required land use for access/egress facilities in the constructed scenarios are used to elaborate on the (re)development possibilities.

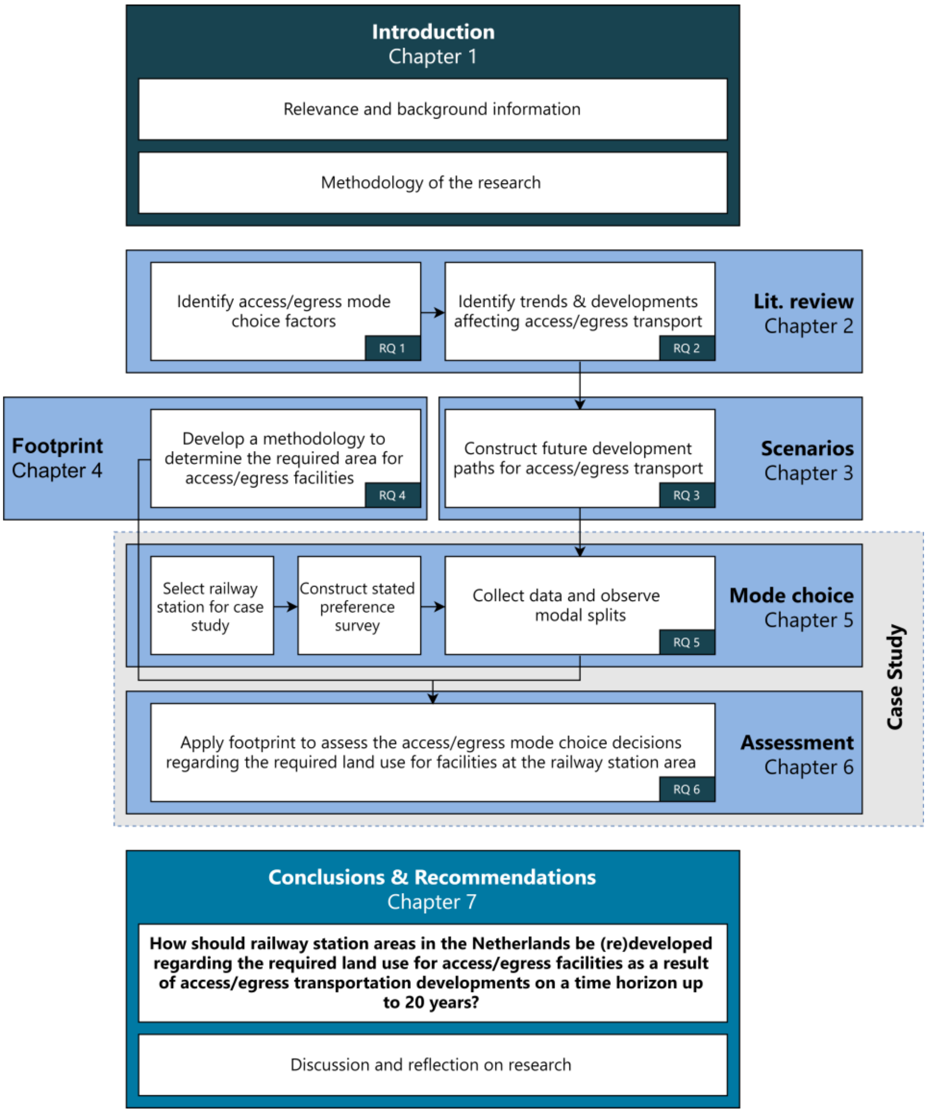


Figure 1.4 Overview of the report structure

1.4 Contribution to science and practice

This research provides contributions to both practice and science, distinguished in the subparagraphs below. At the end of this research, recommendations are provided according to the same categorisation.

1.4.1 Value for science

Although scientific research on multimodal transport is expanding, knowledge of access/egress transport is relatively scarce. Mode choice studies and models have mainly focused on the main mode that is used for a (multimodal) trip, although access/egress transport has a substantial influence on the overall door-to-door journey (Krygsman, Dijst, & Arentze, 2004). Besides, it is commonly agreed upon that the world, including the mobility sector, is rapidly changing due to different trends and developments. However, yet little is known about the trends and developments that will affect access/egress transport in the future and to what extent.

Secondly, as space is becoming scarce, especially in dense urban areas, knowledge of the land that is required for vehicles to park, or stop, is becoming more important. However, so far only the municipality of Amsterdam and the CROW generated values which is relatively little when considering the importance and relevance of the topic (CROW, 2014; Gemeente Amsterdam, 2017). The footprint indicator that is constructed in this report aims to fill this gap. The main scientific value regarding this indicator lays in the recommendations for more accurate estimations of the three components that compose the footprint.

1.4.2 Value for practice

Travellers and transport authorities would benefit from railway station areas where suitable access/egress facilities are provided. Moreover, knowledge of the (re)development of access/egress facilities can be of additional value for municipalities and parties that are involved in these projects.

Insight on the preferred mode choice of travellers and factors that stimulate (or discourage) travellers for choosing specific means of access/egress transport can help decision makers to steer mode choice decisions. Moreover, the footprint indicator that is constructed in this report can be used as a tool to elaborate on the choice for access/egress facilities at the railway station area.

2 LITERATURE REVIEW

2.1 Introduction
This chapter aims to find and analyse existing literature on the topics of mode choice factors and trends and developments that can affect access/egress transport. The sub-questions that can be answered at the end of this chapter are:

1. **Which factors influence the mode choice of travellers travelling to/from the railway station?**
2. **What are the impacts and potentials of trends and developments for access/egress transport to/from railway stations in the next 20 years?**

The next paragraph (2.2) addresses the first sub-question of this research. Mode choice factors are studied thoroughly with a specific focus on the home-end and activity-end stages of a multimodal trip. Hereafter, the literature review elaborates on the impacts and potentials of trends and developments for the access/egress transportation sector to answer the second sub-question of this research (paragraph 2.3). The literature review ends with a conclusion to discuss the main findings of this chapter (paragraph 2.4).

2.2 Factors
This paragraph aims to understand which factors influence access/egress mode choice. Fist, a general introduction on mode choice is given together with some classifications from existing literature (2.2.1). Hereafter, specific literature on access/egress mode choice factors is searched for and reviewed (2.2.2). A research specific classification which consists of six categories is introduced to evaluate the access/egress mode choice determinants. At the end of this paragraph (2.2.3), an infographic summarises and visualises some interesting outcomes on access/egress mode choice factors.

2.2.1 Mode choice
Mode choice is an extensively researched topic without one universally applicable definition. De Witte, Hollevoet, Dobruszkes, Hubert, and Macharis (2013) aimed to gain a better understanding of the notion and analysed 76 studies from different research fields that used the term modal choice. The review illustrates that the interpretation of the term modal choice differs per study and depends on the research perspectives and objective as well. Because the researchers found no general definition, they proposed a modal choice definition from a multi-disciplinary approach:

'the decision process to choose between different transport alternatives, which is determined by a combination of individual socio-demographic factors and spatial characteristics, and influenced by socio-psychological factors'

Additionally, the researchers developed a framework in which the interaction between the determinants and modal choice becomes evident, based on the determinants that they found (Figure 2.1). Three categories can be distinguished: (1) socio-demographic indicators, (2) journey characteristic indicators and (3) spatial indicators. These indicators together constitute the option to make a modal choice. The arrows that connect all the determinants mutually indicate the interrelations and dependencies among them. Socio-psychological indicators, also called subjective factors, influence the way travellers react at the possible options. Determinants such as experiences, familiarity, lifestyle, habits and perceptions are among this category.

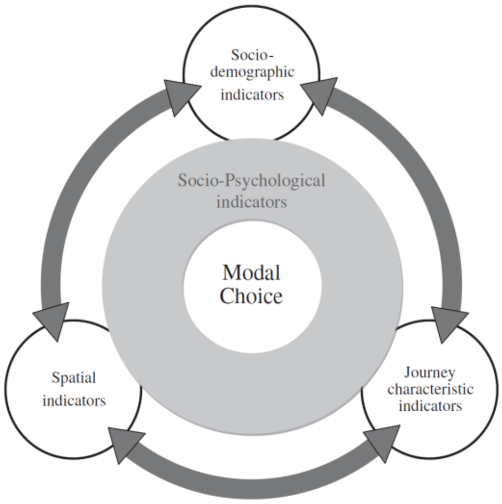


Figure 2.1 Framework for structuring modal choice determinants (De Witte et al., 2013)

Ortuzar and Willumsen (2011) used another classification in their book on transport modelling. They classified the factors that influence mode choice in three groups as well, but differently: (1) characteristics of the trip maker, (2) characteristics of the journey and (3) characteristics of the transport facility. The third category is divided into measurable factors (quantitative) and factors which are less easy, or even impossible, to measure in practice (qualitative).

Both similarities and differences can be observed between the two classifications mentioned above. A similarity is that both studies distinguish traveller and journey specific determinants. However, whereas the third category in the study of De Witte et al. includes spatial factors, Ortuzar and Willumsen added a category for transport specific determinants. When looking in more detail to the factors that are among the respective categories, De Witte et al. assigned the factor 'travel time' to journey characteristics and 'availability of parking' to spatial indicators respectively. Ortuzar and Willumsen categorised both factors under the quantitative characteristics of the transport facility. This indicates that although different studies do use different classifications, the researched determinants do not necessarily differ. Another interesting observation is that Ortuzar and Willumsen did not include any factors to express the built environment at all, while the other study does. De Witte et al. on their turn, paid less attention to the different type of transport variables. A study on mode choice factors by Lindstöm Olsson (2003) points out the variety of possibilities to categorise factors. Because there is no general rule for classifying mode choice factors, the categorisation strongly depends on the interpretation of the researcher(s). Logically, when having an extensive list of mode choice factors, a comprehensive classification can be created to distinguish the different type of factors.

With the aim in mind to find an extensive classification of mode choice factors, a report was found on improving the modal split model of the *Florida Standard Urban Transportation Model Structure* (*FSUTMS*) (Zhao, Li, Chow, Gan, & David Shen, 2002). Their research aimed to incorporate additional variables into the modal split model of the *FSUTMS* by using regression analysis. Besides the already incorporated travel time and cost factors, potential new factors were found in literature on transit use and access. The researchers assigned all factors to four categories: (1) travel mode level of service, (2) land use/urban design, (3) accessibility and (4) transit users' socioeconomic/demographic characteristics. In addition to this classification, Racca and Ratledge (2004) added a fifth category to the classification: (5) characteristics of the trip. According to them, this category holds specific determinants such as trip distance and trip purpose which cannot be assigned to any of the other defined categories. Appendix A contains the list of factors that are included in both studies. All five categories are further discussed to illustrate the composition of the classification for mode choice in general.

The **travel mode level of service** category contains attributes that are related to a transport mode. This category is, although under a different name, also included in the classification of Ortuzar and Willumsen (2011). They distinguished quantitative (e.g. travel time and cost components) and qualitative (e.g. comfort and safety) level of service factors. According to Racca and Ratledge (2004), factors that reflect the transit level of service, significantly influence mode choice decisions of travellers. Since the automobile offers significant advantages over transit in convenience, flexibility and travel time, a particular service of transit is necessary to have people choose transit over the car.

Land use/urban design factors describe the characteristics of the built environment in which the journey and thus modal choice takes place. The '3Ds', introduced by Cervero and Kockelman (1997), are commonly used to distinguish built environment factors in travel behaviour studies. This classification consists of the following three categories: density, diversity and design (Figure 2.2). The categories are not distinguishable by ambiguous and unsettled boundaries and have some overlap in the determinants that can be assigned to each category (Cervero & Murakami, 2008).

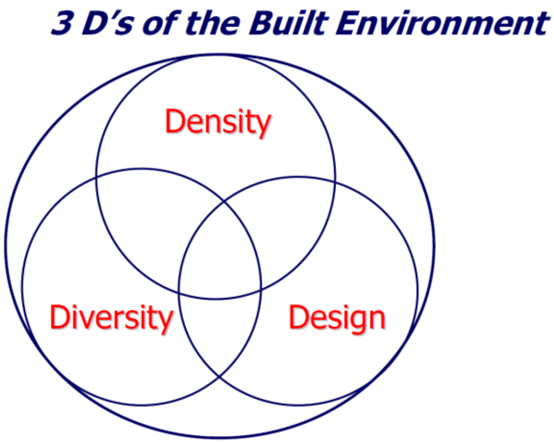


Figure 2.2 The '3Ds' of the built environment (Cervero & Murakami, 2008)

Munshi (2016) reviewed mode choice studies that include built environment factors and found different interpretations of the variables. In general, density describes a variable of interest per unit area such as residents and jobs. The diversity refers to the mixture of purposes the land is used for. An index can be used to describe the ratio of the different forms of land use. The third 'D-variable', design, specifies characteristics of the infrastructure related to the transport modes of interest (e.g. dimensions of intersections, bicycle lanes and sidewalks).

The **accessibility** category includes factors that describe the ease to reach a location which are strong indicators for transit use (Zhao et al., 2002). Having a car available at the origin side of the trip, logically makes the car an attractive option. However, when the origin or destination is located far away from the main road network, taking the car becomes less enticing. Especially when the destination is well-connected by any other means of transport such as public transport. In contrast to the car, public transport modes are often not directly accessible, which emphasises the importance of including accessibility factors at both the origin and destination side of the journey. Factors among this category have a strong relation with the built environment and are classified differently by researchers in different studies. For example, De Witte et al. (2013) assigned the factor 'proximity to infrastructure and services' to the built environment category because it characterises the design of the built environment.

The variables among the **socioeconomic/demographic characteristics** shape the travellers' personal and household situation. These variables have been included by various studies to determine the characteristics of the travellers that are among the participants of the respective research. The variables are not only highly correlated with each other, but reviewing multiple studies also shows contradictory conclusions on the significance of these factors regarding mode choice (Zhao et al., 2002).

Characteristics of the trip may affect the mode choice of travellers and was therefore added as fifth category by Racca and Ratledge (2004) to the other four. Elements which are peculiar to the journey (e.g. weather conditions and trip purpose) can be assigned to this category and are also included in the classifications of De Witte et al. (2013) and Ortuzar and Willumsen (2011).

2.2.2 Access/egress mode choice factors

Access/egress mode choice is a specific topic within the complex field of mode choice. Because multimodal trips consist of different stages, multiple mode choice decisions have to be made. The factors that play a role in this process can vary per stage and can therefore differ from the general mode choice determinants that were discussed in the previous subparagraph as well (Arentze & Molin, 2013; Yap, Correia, & Van Arem, 2016). Various type of studies have included access/egress mode choice factors. However, the factors that have been considered in each study strongly depends on the aim of the research as was concluded by De Witte et al. (2013) during their review on mode choice in general. Because each study interprets factors differently, the collection of factors is a complex and time-intensive process.

For this research, literature was searched for in the databases of multiple academic literature sources such as Google Scholar, ScienceDirect, Scopus and World Transit Research. Keywords and synonyms reflecting access/egress transport (factors) were used to find relevant studies. Subsequently, a selection was made based on the relevance of the factors considered by the studies found. An overview of the selected literature, including information regarding the scope and context, is attached to this report in Appendix B.

Instead of researching access/egress mode choice separately from the main stage, some of the studies combined all trip stages to research the attractiveness of multimodal transport in general (Arentze & Molin, 2013; Creemers, Bellemans, Janssens, Wets, & Cools, 2014; Krygsman et al., 2004; Shelat, Huisman, & Van Oort, 2018; Van Mil, Leferink, Annema, & Van Oort, 2018). Studies that do exclude the main stage, mainly research one of the other stages, either the home-end or activity-end. The number of studies that focus on home-end trips are, compared to studies on activity-end trips, found in greater numbers. For other studies, the distinction between both trip-ends was the motivation to research the differences in factors between both (Halldórsdóttir, Nielsen, & Prato, 2017).

Besides the trip stages, the considered means of access/egress transport and transit nodes are different in each study. Especially studies performed in the Netherlands, mainly focus on the role of the bicycle solely (Puello & Geurs, 2015; Shelat et al., 2018; Van Mil et al., 2018). The bicycle accounts for the largest share of home-end trips (43%) and is therefore an interesting vehicle to study for researchers in this country (Kennisinstituut voor Mobiliteitsbeleid, 2017). In other countries where the bicycle plays a less prominent role, other means of access/egress transport have been researched more frequently. Since the bicycle is considered a poor man's vehicle in Indian cities, other transport means such as rickshaws (i.e. human-powered tricycles) have a dominant role (Goel & Tiwari, 2016). In Vietnam, the motorcycle is extremely popular, also for short distance trips which are attractive to walk (Tran, Zhang, & Fujiwara, 2014). The aim to increase the walking share is a trending topic, also in the United States where short car trips have a predominant role relative to other transport means (Cervero, 2001). Besides studies on existing means of transport, Yap et al. (2016) researched the potential of automated vehicles at the activity-end of the trip.

The variation in researched means of transport per country can also be observed for the type of transit nodes. As mentioned before, the train is used as the main transport mode for the majority of the multimodal trips in the Netherlands. As a result, a large number of researches have focused on railway stations as transit node (Debrezion, Pels, & Rietveld, 2009; Givoni & Rietveld, 2007; Krygsman et al., 2004; Molin & Timmermans, 2010; Puello & Geurs, 2015; Shelat et al., 2018; Van Mil et al., 2018; Yap et al., 2016). However, studies in other countries, where other means of transport are dominating the main stage of multimodal trips, consider other transit nodes such as bus rapid transit (BRT) stations, light-rail transit (LRT) stations, mass rapid transit (MRT) stations and high-speed rail (HSR) stations (Jiang, Christopher Zegras, & Mehndiratta, 2012; Kim, Ulfarsson, & Todd Hennessy, 2007; Mo, Shen, & Zhao, 2018; Wen, Wang, & Fu, 2012).

It can be concluded that studies on access/egress mode choice are mixed regarding the considered trip stages, means of access/egress transport and transit nodes. Most studies are performed with a specific aim, strongly related to the country in which the research takes place. However, as the number of studies on access/egress factors is scarce, all previously mentioned type of studies are included to gain a better knowledge of the factors that influence access/egress mode choice. This means that some factors in the remainder of this review might not be relevant for the scope and context of this study as traffic conditions and demographic characteristics vary by country (Mo et al., 2018). However, this review aims to gain better knowledge of the (type of) factors that can influence access/egress transport and are therefore relevant to include. An overview of all reviewed factors in this literature review is attached to this report in Appendix C.

For this research, access/egress mode choice factors are assigned to one of the following six categories that are defined for this research:

1. Characteristics of the traveller
2. Psychological factors
3. Characteristics of the access/egress trip
4. Characteristics of the access/egress modes
5. Characteristics of the built environment
6. Main stage factors

The categories are composed of existing classifications and findings on access/egress mode choice factors. The framework, depicted in Figure 2.3, illustrates that access/egress mode choice is a complex process and determined by a combination of influences from factors assigned to different categories. Mutual relations between factors can not only be observed among factors in the same category, but also between distinguishable categories. It is therefore important, and also emphasised in multiple studies, to analyse factors from all categories to reduce heterogeneity in decision making (Mo et al., 2018; Molin & Timmermans, 2010). The remainder of this subparagraph elaborates on the different categories and the factors assigned to each category.

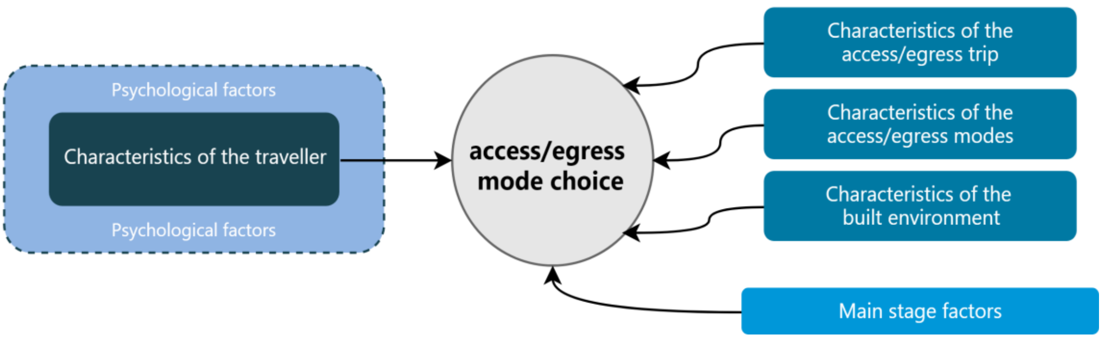


Figure 2.3 Access/egress mode choice framework

Characteristics of the traveller

The researchers that take into account the characteristics of the traveller in their studies have presented contradictory conclusions. By including these type of factors, researchers can determine the representativeness of the sample (i.e. respondents) relative to the population (Yap et al., 2016). However, as the selected studies for this research were performed in different regions across the world, population differences are likely to cause contradictory results.

Multiple studies found access/egress mode choice differences between **gender**. Research of Halldórsdóttir et al. (2017) showed a significant dislike towards bus among men at the activity-end of the trip. In line with this result, a previous study by Kim et al. (2007) already concluded that females are more likely to use the bus at the home-end of the trip. Creemers et al. (2014) found significant differences between gender for other means of transport. They demonstrated that women are more likely to choose the car, and less likely to choose slow means of transport to/from the railway station.

The **age** of travellers is another variable that affects access/egress mode choice. Givoni and Rietveld (2007) found higher shares of car use at the home-end of the trip with increasing age. Additionally, they found high shares of car use at the activity-end of the trip among travellers of 65 years and older. Kim et al. (2007) drew several conclusions regarding the age of travellers in their research on travel behaviour at the home-end of light rail transit (LRT) stations in the United States. They found that the share of transit riders being picked up and dropped off at the station is significantly higher for travellers under 25. Moreover, travellers under 35 were associated with a reduction of the walking share, especially those between 25 and 34 years old.

The **occupation** of travellers was also found to influence the access/egress mode choice. Multiple studies have shown that full-time students can be associated with an increasing bus share (Halldórsdóttir et al., 2017; Kim et al., 2007). In addition, Puello and Geurs (2015) found that students are less likely to travel by bicycle to the railway station at the home-end. Regarding full-time employees, Kim et al. (2007) found high shares of travellers being picked up and dropped off.

As can be expected, having a **driver's license** increases the probability of choosing the car for access/egress transport (Creemers et al., 2014; Kim et al., 2007). Other vehicle-related factors, and moreover frequently researched in the reviewed studies, are **vehicle ownership** and **car availability**. Both determinants can be considered as one influential factor because of the strong correlation between both. Moreover, none of the reviewed studies analysed both of the variables separately. Different contradictory conclusions can be observed regarding the effect of this variable on access/egress mode choice. For example, Givoni and Rietveld (2007) stated that the availability of a car does not have a strong effect on the choice of access mode to the railway station. However, other studies emphasised that owning a vehicle (i.e. having a car available) indeed increased the probability of using the car for access/egress transport (Debrezion et al., 2009; Goel & Tiwari, 2016; Halldórsdóttir et al., 2017). In line with these results, Puello and Geurs (2015) found lower shares of cycling and Kim et al. (2007) found a decreasing share of all means of transport except for drive and park when travellers have a car available. An explanation for the contradictory findings of Givoni and Rietveld (2007), relative to the other researches, can be the availability of parking facilities at the transit node. Givoni and Rietveld (2007) used data from a customer satisfaction survey in which railway stations are not being distinguished by their access/egress facilities.

Other variables that have been found to influence access/egress mode choice are **income**, **race**, **number of children**, **number of workers**, **other motorists**, **season ticket** and **type of train user**. The income of travellers is assumed to have high correlations with the occupation. Kim et al. (2007) found higher bus shares for travellers who have lower incomes. In the same study, African-

Americans were associated with an increased bus share compared to other races. Logically, having a season ticket increases the probability of travelling by the means of transport for which this ticket is valid (Halldórsdóttir et al., 2017). Since students in the Netherlands are allowed to travel for free by public transport, this factor has high correlations with the factor occupation when the study is performed in the Netherlands. Yap et al. (2016) found that the type of train user also affects access/egress mode choice decisions. He concluded that first class train users are willing to travel by automated vehicles when these would be available, while second class train users prefer a bicycle or BTM. Again, this can be a result of income and/or occupation differences.

Psychological factors

Choice behaviour in general is based on available information and influenced by affect, attitudes, motives and preferences Ben-Akiva et al. (1999). This means that not only explanatory variables, but also psychological factors play an important role in mode choice decisions. This is also concluded by Yap et al. (2016) who researched the potential of automated vehicles (AVs) for last mile transport. They found that the travellers' **attitude** towards the sustainability of AVs and the **perception** of trust are the two most important factors for using AVs. Especially when travellers are unfamiliar with a transport mode, the attitude and perception towards the unobserved or latent variables can significantly influence mode choice. Latent variables are described in the book of Ortuzar and Willumsen (2011) as follows:

'Latent variables are factors that, although they influence individual behaviour and perceptions, cannot be quantified in practice (e.g. safety, comfort, reliability). This is because of either their intangibility, as these variables do not have a measurement scale, or their intrinsic subjectivity (i.e. different persons may perceive them differently). Identification of latent variables requires supplementing a standard survey with questions that capture users' perceptions about some aspects of the alternatives (and the choice context). The answers to these questions generate perception indicators that serve to identify the latent variables. Otherwise, these latent variables could not be measured.'

Puello and Geurs (2015) identified some latent variables in their study and found significant results for the **attitude** towards the station environment, the **perception** of connectivity and the **perceived** quality of bicycle facilities. All these factors were found to affect bicycle usage in their study. Arentze and Molin (2013) concluded that travellers have base **preferences** towards transport mode specific service attributes.

Besides intangible factors, psychological factors can also capture the intrinsic subjectivity of variables such as travel time and costs. Components of these factors (e.g. in-vehicle time, waiting time and walking time) can be valued differently among travellers. Waiting and walking time, for example, are valued more negative compared to in-vehicle time, decreasing the share of public transport users when these times reach a particular threshold value (Arentze & Molin, 2013; Yap et al., 2016).

Important to keep in mind is that psychological factors do not directly influence the mode choice of travellers. However, these factors can capture (a part of) the influence of latent variables in other categories.

Characteristics of the access/egress trip

Some of the reviewed studies on access/egress mode choice included trip-related factors. Molin and Timmermans (2010) focussed exclusively on trip condition factors and found significant effects for all researched factors in their stated preference study. The findings of this research and other studies that researched these type of factors are discussed.

The **distance** to/from transfer locations is the most important factor in access/egress mode choice (Krygsman et al., 2004). Multiple studies that were reviewed in this research took into account the trip distance and found results in line with this statement. Especially the distance from the origin to the transit station has been widely researched by the studies reviewed (Debrezion et al., 2009; Givoni & Rietveld, 2007; Goel & Tiwari, 2016; Kim et al., 2007; Mo et al., 2018; Puello & Geurs, 2015). In general, it can be said that an increasing distance increases the probability of choosing motorised transport modes, whereas short trips are mainly made by foot and bicycle. In the research of Debrezion et al. (2009), the access mode choice was modelled as a function of the distance for Dutch railway users. Depending on the distance to the railway station, they found preferences for walking (up to 1.1km), cycling (1.1-4.2km) and public transport (more than 4.2km). Regarding the mode choice at the destination side of the trip, the same influence of trip distance can be expected. Molin and Timmermans (2010) are one of the few, who included the influence of distance at the activity-end of the trip and found results that support these expectations.

The **trip purpose** is, besides the trip distance, the factor with most of the significant influence in this category according to the studies that were reviewed (Givoni & Rietveld, 2007; Halldórsdóttir et al., 2017; Molin & Timmermans, 2010). Although the studies focussed on different type of trip purposes, it can be concluded that the car is preferred at both ends of the trip when the trip is made for business purposes. Also other automobile modes, such as taxi alternatives and Greenwheels, are more often chosen for work-related purposes than for recreational purposes (Molin & Timmermans, 2010). Significant results for other trip purposes were found to a lesser extent. However, Givoni and Rietveld (2007) found that, in addition to business travellers, leisure travellers use the bicycle to a lesser extent compared to those travelling for commuting or school purposes.

The **travel party**, travelling alone or with company, influences the mode choice of travellers. The research of Molin and Timmermans (2010) showed that bicycle alternatives are not chosen less often if one travels together with other persons. Halldórsdóttir et al. (2017) found that having a fellow traveller decreases the shares of bus, walking and biking. On the other hand, travelling with more people increases the chance of being a car passenger as Kiss and Ride (K+R) is becoming a more popular alternative.

The **time of day** is another variable that influences the mode choice of travellers. An increasing share of other means of transport than public transport is found when travelling late in the evening (Kim et al., 2007; Molin & Timmermans, 2010). Reason for this can be the level of service offered by public transport, which decreases at off-peak periods. In addition, the share of slow transport modes in the evening is also considerably lower compared to the situation at daylight (Molin & Timmermans, 2010). Travellers might feel uncomfortable to travel by foot or bicycle when it is dark and prefer to use automobile means of transport.

Other trip characteristics that influence egress mode choice are **weather conditions**, **knowledge of the route** and **amount of luggage** (Molin & Timmermans, 2010). According to the researchers, travelling in dry weather increased the probability of using slow transport modes. Moreover, these transport modes are also more frequently used when knowing the route and not carrying heavy luggage.

Characteristics of the access/egress modes

Each transport mode has its characteristics that can play a role in the modal choice decision of travellers. These characteristics can be expressed by different variables and are often used in studies to determine the potential of new transport modes which are not (yet) available, keeping other mode choice factors constant. Distance, travel time and travel cost are directly related to each other. In general, the longer the distance, the longer the travel time and the higher the costs of the journey. However, distance does not necessarily relate to the chosen transport mode and was therefore included in the previous category on trip characteristics. Travel time and costs are mode dependent and therefore included in this category. In addition to these classic instrumental variables, level of service variables were found to have an essential role in mode choice decisions.

The **travel time** of the access/egress trip is, as mentioned before, strongly depending on the distance to/from the railway station. As for the distance, long travel times have a negative impact on the choice for the respective means of transport (Chakour & Eluru, 2013; Halldórsdóttir et al., 2017). Dependent on the access/egress mode, different travel time components can be distinguished. Travelling by traditional public transport often involves walking, waiting and in-vehicle time, as this service is only accessible at public locations. However, when using a private vehicle, the time spent on or in the vehicle is in most situations the only relevant one. Adding up the time components does not give the right indication regarding mode choice decisions since not all the time components are being valued equally by travellers (Arentze & Molin, 2013; Yap et al., 2016). These influences can be captured by the psychological factors that were discussed as the second individual category.

Another important transport mode dependent factor are the **costs** that are associated with the means of transport. The study of Wen et al. (2012) emphasised that most travellers are cost-sensitive to access modes, meaning that reducing access costs can be an effective measure when a change in the modal split is desired. As for travel time, each transport mode has specific mode dependent costs. Private vehicles can be associated with purchase and parking costs, while public means of transport require a trip specific payment each time the service is used. As for travel time components, cost components are also valued differently by travellers of which the influence can be captured by the psychological factors (Yap et al., 2016).

In addition to the classic instrumental variables, transport modes can be chosen over another based on the **level of service** that is offered by the means of transport. These qualitative factors (e.g. comfort and convenience, safety, protection and security) are less easy or even impossible to measure (Ortuzar & Willumsen, 2011). The influence of these factors on access/egress mode choice can be captured by psychological factors as well.

Characteristics of the built environment

Most of the studies that research the influence of built environment factors on access/egress mode choice are focussed on walking to/from the transit station (Ewing & Cervero, 2010). As active modes, especially walking, are preferred when origins and destinations lie within a small range of the station, the influence of the built environment can be analysed from a transit-oriented development (TOD) approach. This term refers to concentrating developments near transit stations which affects travel behaviour and therefore access/egress mode choice (Park, Ewing, Scheer, & Tian, 2018). Different studies have verified that TOD reduces car usage and enhances the use of public transport and active modes (Cervero, 2001; Park et al., 2018). It is generally accepted that the influencing determinants from the built environment are classified according to the variables density, diversity and design, also known as the '3Ds' (Cervero & Kockelman, 1997).

Density

According to Puello and Geurs (2015), cycling to the railway station is more frequently done in areas with lower residential densities. In line with this result, the study of Halldórsdóttir et al. (2017) found lower shares of cycling in central areas. On the other hand, they found increasing shares for the bus in these central areas which can be characterised by a dense environment. This is in line with the statement made on means of transport that are stimulated by TOD. Additionally, walking is found to be a popular access/egress mode as the (residential) density is relatively high (Cervero, 2001; Goel & Tiwari, 2016; Mo et al., 2018).

Diversity
As for higher (residential) densities, a high degree of land use mixture promotes walking according to the study of Cervero (2001). The results are confirmed by Mo et al. (2018) who found that a higher entropy index (i.e. well-mixed land use) encourages people to walk. Again, in central areas where the degree of mixed-use land can be expected to be more diverse, Halldórsdóttir et al. (2017) found increasing shares for the bus at the home-end and bicycle at the activity-end of the trip.

Design
With the focus on railway stations, the design variable is divided into the design of the surrounding area and the design of the railway station.

... of the surrounding
In line with the positive influence of high densities and diverse land use, ample sidewalks and minimal physical obstructions stimulate travellers to walk to the station (Cervero, 2001). The same study also emphasised the importance of intersection density which encouraged travellers to walk as a result of a better accessible station. Another study by Tran et al. (2014) highlighted the importance of improving sidewalks and pedestrian facilities to have people choose walking over the motorcycle in the city of Hanoi. Regarding other means of transport, Mo et al. (2018) logically mentioned the increasing share of bus opposite from the decreasing walking share for increasing road length densities.

... of the railway station
The design of the railway station refers to the provision of access/egress facilities at the railway station area. Logically, when a railway station offers good parking/transfer facilities, travellers are attracted to use these means of transport (Puello & Geurs, 2015). In line with this, Halldórsdóttir et al. (2017) found that an increasing number of bicycle parking spaces has a positive effect on cycling choices at the activity-end, especially if the spaces are covered. Interesting is that these results are found at the activity-end of the trip, indicating the importance of the availability and quality of facilities to have a private bike only for travelling at the activity-end of the trip. In the study of Cervero (2001) on the potential of walking short distances to the railway station instead of taking the car, it was found that park and ride supplies are deterrent to walking. This is in line with the expectations that transport facilities stimulate travellers to use the facilitated means of transport.

Main stage factors
Access/egress mode choice is not only influenced by factors from those respective stages, but influenced by main stage factors as well. The **travel time of the train journey** is one of them. It is generally known that the main stage distance and travel time, relative to those of the home-end and activity-end stages, play an important role in the decision to make a multimodal trip (Krygsman et al., 2004). The access/egress time as a proportion of the total trip time can be expressed by the interconnectivity ratio. This ratio falls within the range of 0.2-0.5 for multimodal trips in which the train is used for the main stage (Krygsman et al., 2004). The same study analysed two of those multimodal journeys in which cycling and walking are considered as access/egress modes. The researchers found steeper values for bicycle usage, compared to walking, with increasing interconnectivity rates. As they state, this is not only the result of increasing bicycle usage for longer access/egress times, but the use of the bicycle is also varying with the main stage travel times. In addition, Puello and Geurs (2015) found decreasing probabilities for travelling by bicycle when the travel time of the main journey increases.

Another main stage factor that influences access/egress mode choice is the **allowance to bring the bicycle on the train**. Carrying the bicycle on the train has the advantage of having a bicycle for both the home-end and activity-end of the trip. However, restrictions regarding time of day and fees to carry the bicycle on-board, significantly reduce the probability of cycling at the activity-end (Halldórsdóttir et al., 2017).

2.2.3 Infographic

All factors that were found and discussed in the previous subparagraph, somehow influence the access/egress mode choice of travellers. Because a selected amount of literature was reviewed, additional factors might play a role as well. However, the classification provided an extensive framework to which access/egress mode choice factors can be assigned. In general, many different types of factors together constitute the choice of a traveller for a specific means of transport. Especially interesting are the factors with a specific relation to a means of transport. These findings are collected and included in an infographic, depicted in Figure 2.4. These results can contribute to determine how trends and developments might cause modal shifts among access/egress transport users.

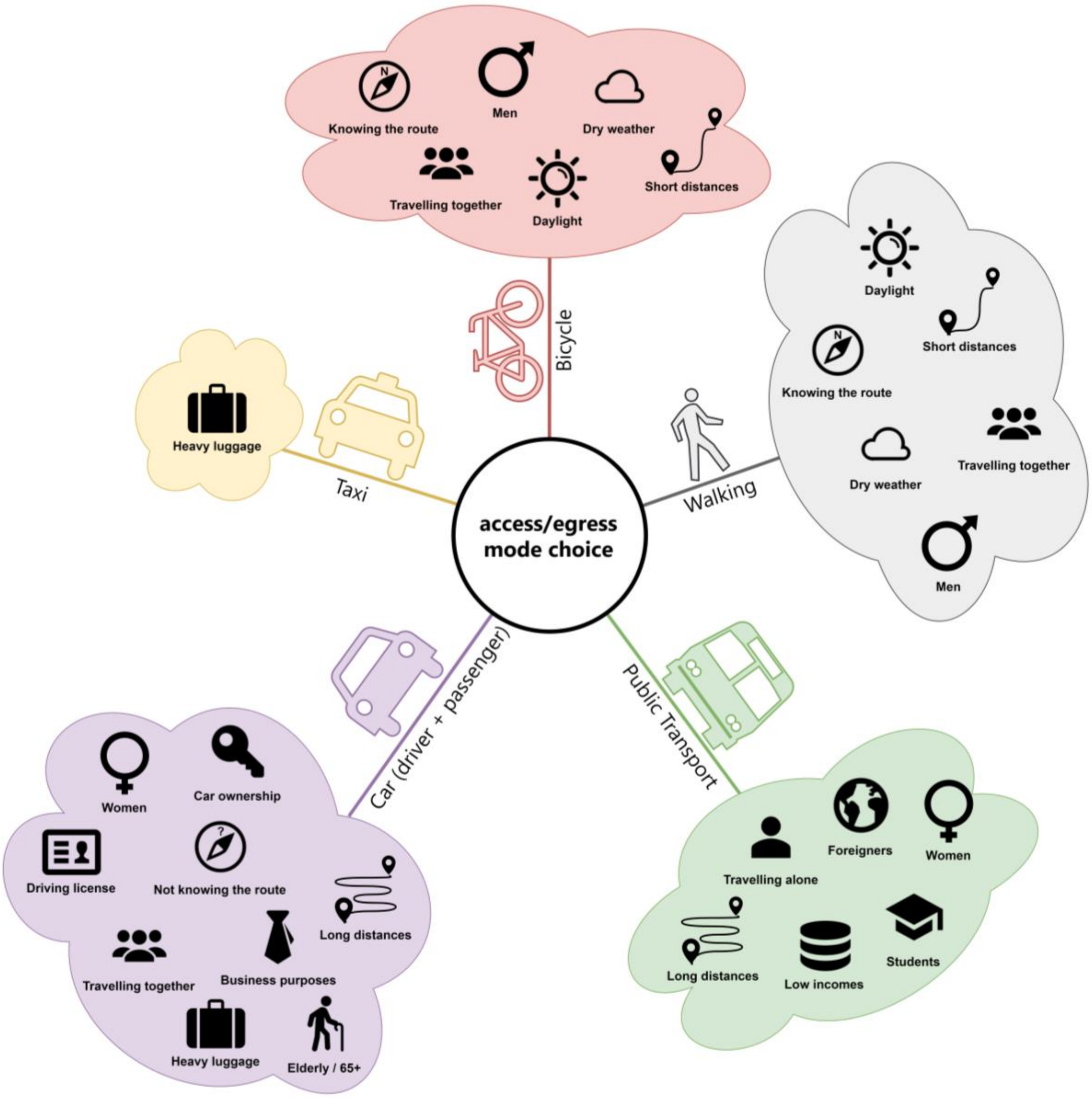


Figure 2.4 Overview of access/egress mode choice factors in relation to the transport means

2.3 Trends and developments

The previous paragraph elaborated upon the factors that influence access/egress mode choice. The review showed that a combination of factors shapes the decisions of travellers, but differently per individual and situation. In addition to these factors, trends and development are expected to influence access/egress mode choice permanently. This paragraph aims to address these trends and developments for the next decades. The next paragraph (2.3.1) gives a small introduction to trends and developments. Hereafter, a selection is made, and the impacts and potentials on access/egress transport are elaborated with a focus on the Dutch context (2.3.2).

2.3.1 Global megatrends

Trends and developments can both be described as evolutional terms which can be used to express a particular change. When there is a general tendency or direction of development, we can speak of a trend (European Foresight Platform, 2014). This definition holds that the same (type of) developments are observable over a longer period (10-15 years). Moreover, when a trend occurs at a global or large scale, it can be interpreted as a megatrend. Frost & Sullivan (2010) proposed the following definition in their research on the world's top global megatrends:

'Megatrends are global, sustained and macro-economic forces of development that impacts business, economy, society, cultures and personal lives thereby defining our future world and its increasing pace of change.'

According to PwC (2018), five global megatrends are reshaping the world, and their implications will be significant for all existing industries, organisations and the wider society. These five trends are depicted in Figure 2.5 and form the basis for the remainder of this paragraph. These trends will be further elaborated, especially regarding observations of these trends in the Netherlands.

Figure 2.5 Five megatrends reshaping the world according to PwC (2018)

2.3.2 Impacts for access/egress transportation

As a result of various trends and developments, the urban transportation sector changes at a fast pace. Van Binsbergen and Hoogendoorn (2016) published an article on the future of urban mobility, considering the evolutionary movements that take place in the sector. The researchers made a distinction in developments that affect the supply of urban transport on the one hand, and the demand for urban transport on the other hand. According to this distinction, the implications of the abovementioned trends will be elaborated. Figure 2.6 shows the relation between the megatrends and the access/egress transport sector in a simplified framework. The remainder of this subparagraph analyses the impacts and potentials of these trends and developments in further detail.

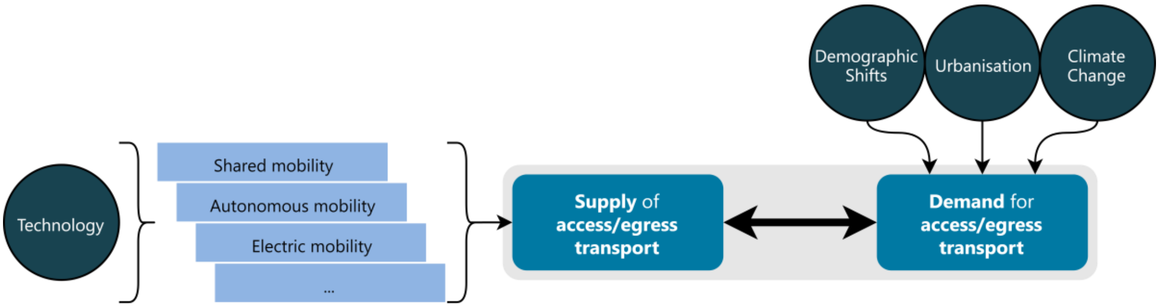


Figure 2.6 Megatrends influencing the supply and demand side of access/egress transport

Demand for access/egress transport

Demographic Shifts

The world's population is increasing and is estimated to reach 8.5 billion by 2030 (European Commission, 2018). Especially countries with well-developing economies show an increasing population growth while the numbers show constant values in most of the developed countries. According to the latest forecast of the *CBS* (*Centraal Bureau voor de Statistiek* in Dutch), the population of the Netherlands reaches 18.4 million inhabitants by 2060 (Centraal Bureau voor de Statistiek, 2017a). Although there will be more deaths than births, the population will mainly increase due to migrant arrivals and increasing life expectancy. In 2000, a newborn child in the Netherlands was expected to live 78 years, while the life expectancy now is 82 (Centraal Bureau voor de Statistiek, 2018a). In addition, the ageing of the population is a result of the high birth rates after the Second World War. It is expected that the population share aged 65 and above increases from 19% (in 2017) to 26% in 2040 (Figure 2.7). In line with this, the ratio of working people decreases as the number of retiree increases. The retirement age in the Netherlands is automatically linked to the life expectancy improvements and currently set at the age of 67. Based on the prognosis, the retirement age is expected to increase in the future but remains dependent on political decisions. The same holds for the number of migration arrivals, which can change significantly due to policy measures in the future.

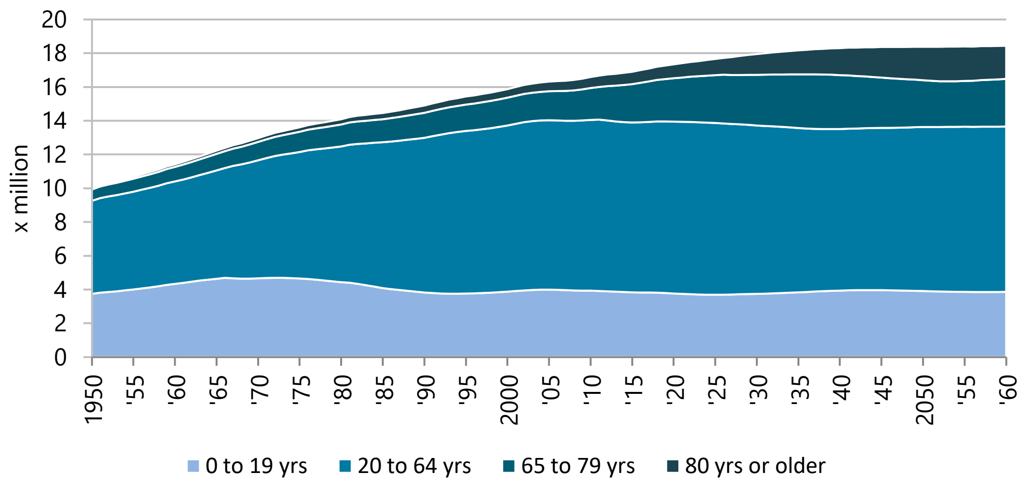


Figure 2.7 Population by age cohort (Centraal Bureau voor de Statistiek, 2017b)

Two other visible trends are the increase of motorised vehicles and driving licences among Dutch residents (Centraal Bureau voor de Statistiek, 2018c). At the 1st of January 2018, 10.1 million motorised vehicles were registered, but vehicle sales keep breaking the records each year for already 25 years with only one exception in 2014. The same report published by the *CBS* shows that the number of driver's licenses among almost all of the age cohorts increases, especially among the group of 18-20 years.

Access/egress impact: According to the first part of the literature review, characteristics of the traveller have an important role in access/egress mode choice decisions. As a result of the diversifying population, the impact of the factors among this category will diversify accordingly. Although the influence of the factors does not necessarily change (elderly might still prefer a car over other transport modes), the number of people for whom the factor applies changes (the ratio of elderly increases) and will affect the demand for access/egress transport in general. Especially the car share is expected to increase when considering the ageing population and increase in vehicle ownership and driver's licenses. Furthermore, psychological factors such as attitude and perception are expected to change as a result of changing value patterns among social groups when their environments changes accordingly (Van Binsbergen & Hoogendoorn, 2016).

Accelerating Urbanisation

On a worldwide scale, the population in cities is growing. The share of people living in the cities is expected to reach 60% by 2030 (European Commission, 2018). Especially in Asia and Africa, the urban population is expected to increase rapidly. The increasing number of residents in the cities of the Netherlands follows this worldwide trend (Centraal Bureau voor de Statistiek, 2016). Especially the large and medium-sized municipalities show increasing numbers, while the number of residents in peripherally located municipalities decreases. The four largest cities in the Netherlands (Amsterdam, Rotterdam, Den Haag and Utrecht) are expected to have 15% more residents in 2030 compared to the situation in 2015. Especially younger adults are attracted by the facilities that these larger cities offer regarding study possibilities, technological innovations, economic activities and cultural offer (Centraal Bureau voor de Statistiek, 2016).

Access/egress impact: As a result of the rapid urbanisation, people get to live closer together in central areas. According to the findings in the previous paragraph (2.2), dense areas stimulate travellers to walk and use public transport. The accelerating urbanisation does not only affects access/egress mode choice factors but also requires new means of transport to develop. The demand for transportation systems that require little space is increasing since space is becoming scarce, especially in dense urban area. Some cities already banned large space consuming vehicles from their centres to create space for other vehicles. With this in mind, more political measures can be expected to keep cities live- and reachable.

Climate Change and Resource Scarcity

Greenhouse gas emissions and pollution are threatening the earth with higher temperatures and rising sea levels as a result. Moreover, the demand for natural resources as water, energy and food is growing with an increasing population and prosperity. However, the earth has a finite number of natural resources. These cautionary developments ask for global action to prevent the risks of pervasive and irreversible impacts to increase. The *Paris Agreement* holds long-term goals that aim to keep the increase in global average temperature below two degrees Celsius. The Netherlands is among the countries that signed the agreement and aims to cut its greenhouse gas emissions level by 85-95% in order to reach the goals by 2050 (Van Vuuren, Boot, Ros, Hof, & Den Elzen, 2016). Renewable types of energy (e.g. wind, solar and biomass) play an important role to achieve the goals and do not rest on the finite resources that are proved by the earth.

Access/egress impact: Although this trend does not directly influence any of the factors that were discussed during the literature review, access/egress transport will be affected by this trend. Especially the demand for environmentally friendly transport systems is expected to affect the current means of transport and allows new ones to emerge. As a result, access/egress mode characteristics will change and can, therefore, influence the mode choice of travellers. As for the accelerating urbanisation trend, active government measures are expected to counteract the consequences of this trend by banning and setting restrictions regarding polluting means of transport to reach the goals of the *Paris Agreement*.

Supply of access/egress transport

Technological breakthroughs are being discovered at a fast pace and are able to transform entire systems in all different kind of working fields. Examples of maturing technologies from the last years are artificial intelligence, augmented reality, blockchain, drones, internet of things, robots, virtual reality and 3D printing. Technological developments in the transportation sector lie at the basis of the changing supply side of access/egress transport, often stimulated by trends that require innovative solutions (e.g. urbanisation and climate change). Three major game changers at the supply side of mobility were addressed by Franckx and Mayeres (2015) who distinguished the rise of collaborative or shared economy, the breakthrough of technologies for automated mobility and major improvements in electric mobility. The remainder of this subparagraph elaborates on these three developments in further detail.

Shared mobility

Shared mobility is the most rapidly growing sector of the sharing economy, a developing phenomenon around renting and borrowing goods and services rather than owning them (Shaheen & Chan, 2016). Rapid developments of transportation applications on the smartphone and other advanced mobile technology lie at the basis of this collaborative economy. In a previous study by both researchers in collaboration with other experts, Shaheen, Chan, Bansal, and Cohen (2015) defined shared mobility as follows:

'a transportation strategy that enables users to gain short-term access to transportation modes on an 'as-needed' basis'

By means of this definition the following passenger transport services can be assigned to the concept of shared mobility: (1) carsharing, (2) bikesharing, (3) scooter sharing, (4) individual on-demand ride services, (5) collective on-demand ride services and (6) ridesharing. The principle of the car-, bike- and scooter- sharing services is simple; a traveller gains the benefit of a private vehicle without the costs and responsibilities of ownership. These services can be distinguished from the other three services which do not share vehicles, but passenger rides. A classification of the mentioned passenger transport services which can be assigned to the shared mobility concept is given in Figure 2.8. Each of the six services will be further elaborated in the remainder of this subparagraph.

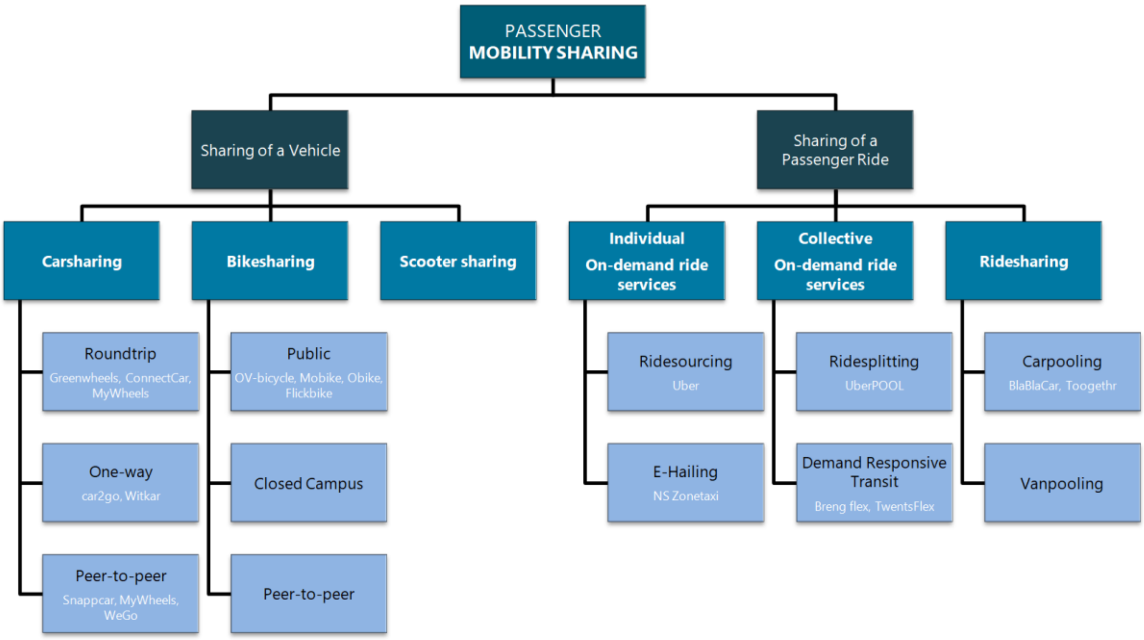


Figure 2.8 Shared (passenger) mobility classification (adapted from (Shaheen & Chan, 2016))

Carsharing

As of October 2016, the carsharing market counts over 157,000 vehicles and approximately 15 million members (Shaheen, Cohen, & Jaffee, 2018). The popularity among this type of sharing service is visible in the Netherlands as well, where the number of shared vehicles increased in one year by 23% to a fleet of more than 30 thousand vehicles in 2017 (CROW-KpVV, 2017). Three business models of carsharing can be distinguished: roundtrip carsharing, one-way carsharing and peer-to-peer (P2P) carsharing.

Roundtrip carsharing is characterised by fixed stations and facilitates only round trips in which the vehicle has to be returned to the original station. As a result of fixed stations where vehicles are both picked up and dropped off, the fleet size and variety offered by the service provider can be extensive. Trips are characterised by longer distances, and the pricing of this service is generally reliant on the number of kilometres driven. Several studies researched the impact of this specific type of car sharing on modal choice decisions and vehicle holdings in North America. Martin and Shaheen (2011) found that travellers who used to travel by different means of public transport such as train and bus made a shift to roundtrip car sharing. This emphasises not only the potential of this service for access/egress purposes but also the competitiveness towards a multimodal trip by train. Another study found that a quart of the respondents sold their vehicle and another 25% postponed the purchase of a new vehicle due to this type of carsharing (Martin, Shaheen, & Lidicker, 2010). In the same study, it was concluded that one carsharing vehicle is able to replace nine to thirteen private vehicles among carsharing members. Potential roundtrip carsharing users were found to be young (aged 25-45), childless and well-educated travellers in urban neighbourhoods who currently make use of non-car forms of urban transport (Franckx & Mayeres, 2015).

Another business model, one-way carsharing, enables users to pick up and return the vehicle at different locations. These locations can either be station-based or located within a specified geo-fenced area (free-floating). A station-based service requires users to use designated stations for pick up and drop off, while the free-floating service provides the highest flexibility in which the vehicle can be picked up and dropped off anywhere within the operating area. For these services, special parking agreements are required between the service provider and the respective municipality. Car2go was the world's first free-floating car service that entered the market in 2010 and currently has 3.3 million members worldwide (car2go, 2018a). Trips are characterised by short distances in city areas, and pricing is generally time dependent. In the study of Martin and Shaheen (2016) on the impact of this service, it was found that this service removed seven to eleven vehicles from the roads. In addition, car2go vehicles were found to reduce vehicle miles travelled (VMT) by 11% and greenhouse gas (GHG) emissions by 10% per household. The study also researched the modal shift as a result of the introduction of car2go vehicles. The service was found to both substitute and complement public transport and active means of transport. However, the majority did not change their mode of transport, indicating that the service mainly replaces private cars.

The third business model, P2P carsharing, also called personal vehicle sharing (PVS), is made available by the users instead of the providers. The role of companies for this type of carsharing is to offer a platform where users are able to share their vehicles (Shaheen et al., 2015). As for the roundtrip service, P2P vehicles have to be returned to the place of rental and can therefore only be used for round trips. In the Netherlands, the number of registered P2P vehicles has increased rapidly and accounted for 86% of the total carsharing fleet in 2017 (CROW-KpVV, 2017). This is a logical development when considering that private vehicles stand idle for 95 per cent of the time (Fraiberger & Sundararajan, 2015). Evidence on the impact of P2P carsharing is limited and does, according to Franckx and Mayeres (2015), not appear to be very robust since the number of registered vehicles do not represent the actual number of vehicles in operation. Table 2.1 shows the different carsharing business models that are discussed, including their characteristics and some examples of providers from the Dutch practice.

Table 2.1 Features of the different carsharing business models

	Roundtrip	**One-way**	**Peer-to-peer**
Characteristics	+ Extensive fleet variety - Fixed pick up and drop off locations	- Limited fleet variety + Flexible pick up and drop off locations	+ Extensive fleet variety - Fixed pick up and drop off locations
Trip pricing	Distance-based	Time-based	Fixed-prices
Providers (Dutch practice)	Greenwheels, ConnectCar, MyWheels, Stapp-In, StudentCar, SharedWheels	car2go, Witkar	Snappcar, MyWheels, WeGo

Access/egress potential: In theory, each of the discussed carsharing business models can provide access/egress transport to/from railway stations. However, the discussed characteristics of the services, make the one business model more suitable than the other.

For home-end trips, roundtrip carsharing vehicles are not considered to have potential. First of all, vehicles of this business model are usually provided at strategic locations with many potential users, which is usually not the travellers' home. Besides, travellers park their vehicle at the home-end railway station to continue their journey by train. This makes a roundtrip vehicle, that is available for the entire duration until returned to the original location, an unsuitable service. At the activity-end of the trip, roundtrip carsharing can be an attractive service, especially when travellers want the certainty to have this vehicle available until returning to the activity-end station.

Travellers who want to have access to a vehicle for only one trip, without the certainty of having a vehicle for the way back, might prefer using a one-way carsharing vehicle. Considering the level of flexibility of both one-way carsharing services, the free-floating service is expected to conquer the one-way carsharing market at the expense of the station-based service. Since vehicles of this business model are spread over the operating area, there is potential for home-end trips as well. However, the availability of vehicles in the area is strongly dependent on the fleet size. Especially at strategic locations, such as railway stations, there is a higher chance of having a vehicle. Depending on your destination, you need some luck to have a free-floating vehicle for the way back.

The third business model, P2P carsharing, also has potential at both the home-end and activity-end of the trip. In this form, travellers register their own private vehicle as a shared vehicle and use this means of transport at their home-end trip. Another user of the P2P carsharing platform is able to use this vehicle at his or her activity-end of the trip, according to the rules and against a compensation which can be determined by the provider of the vehicle. The expected potential of the different carsharing business models is depicted in Table 2.2.

Table 2.2 Expected potential of carsharing business models for home-end and activity-end trips

Home-end trip	Activity-end trip
~~Roundtrip carsharing~~	Roundtrip carsharing
One-way carsharing (free-floating)	One-way carsharing (free-floating)
P2P carsharing	P2P carsharing

Bikesharing

As for the carsharing market, different business models can be distinguished for bikesharing. The three distinct bikesharing forms are: public bikesharing, closed campus bikesharing and P2P bikesharing.

Most of the bikesharing services are public and allow users to access a bicycle for a fee, based on the time the vehicle is used or needed. Public bikesharing services can be roundtrip, station-based or free-floating. The *OV-bicycle* is an example of a roundtrip bikesharing service. This service is available at more than 300 railway stations in the Netherland and allows users to pick up and drop off a bicycle at any railway station where the service is being offered (NS, 2018c). The bicycles have a fixed rental cost per 24 hours and can be rented for 72 hours. The disadvantage of this service remains the inefficient use of the bicycle as it is not possible to let other people use the bicycle at non-station locations when not in use. The free-floating service accounts for this and allows users to pick up and drop off a bicycle anywhere within the borders of service operation, usually the respective municipality. These type of services have increased in both fleet size and memberships and is already provided by many different providers in the Netherlands such as *Mobike*, *Obike* and *Flickbike*. Prices of the trip are time-based and therefore attractive as trips are characterised by short distances. By means of several studies on the impact of bikesharing on the modal split ratio in the United States, it was found that bikesharing in larger cities takes riders from crowded buses, while bikesharing in smaller cities improves access/egress from bus lines (Shaheen & Chan, 2016). In addition, half of the bikesharing members reported reducing their personal automobile use.

Closed campus bikesharing service is a closed community bikesharing service offered by an organisation (e.g. companies and universities). Membership is only for the community members that are part of the organisation. This type of bikesharing service is usually offered at larger campuses or business parks to move from the one building to another. In addition, companies also offer this service to their employees for business purposes.

The principle of P2P bikesharing is the same as for P2P carsharing. Bike owners can rent out their idle bicycles for others to use. The potential of this service to solve parking capacity problems at railway stations in the Netherlands was researched by Van Goeverden and Homem de Almeida Correia (2017). They concluded that the potential is likely to be modest (in the order of 10% for large stations) and more information is needed for more accurate estimations.

Access/egress potential: The potential of the different access/egress bikesharing business models can be determined according to the same considerations that were made for carsharing (Table 2.3).

At the home-end of the trip, free-floating bikesharing vehicles have access/egress potential. However, the vehicle availability strongly depends on the fleet of the service and the considered location. At the activity-end of the trip, both the roundtrip and free-floating vehicles are able to provide a service according to the travellers' needs.

Closed campus bikesharing is assumed to be a suitable activity-end service for trips that start and end at the destination. Considering an everyday trip, starting and ending at the place of residence, this would imply that the vehicle stands idle at the activity-end station for a long period. Therefore, this business model is not assumed to have potential as access/egress service.

As for carsharing, the business model in which vehicles are shared among travellers mutually (P2P) has potential at both ends of the trip.

Table 2.3 Expected potential of bikesharing business models for home-end and activity-end trips

Home-end trip	Activity-end trip
Public bikesharing (free-floating)	Public bikesharing (roundtrip + free-floating)
~~Closed campus bikesharing~~	~~Closed campus bikesharing~~
P2P bikesharing	P2P bikesharing

Scooter sharing

In addition to the bike- and carsharing services, the sharing of scooters is a recently new developing market. Scooter sharing services, both roundtrip and one-way, were first to be found in the cities of Barcelona, Milan and some larger cities in the United States (Shaheen & Chan, 2016). However, the service is expanding its market and already operates in the two largest cities of the Netherlands. Under the name *Felyx*, a free-floating electric scooter (e-scooter) service is offered in the cities of Amsterdam and Rotterdam (Figure 2.9). The batteries of the scooters are replaced by employees of the service provider to make sure the scooters can be used throughout the whole day. A vehicle with the same name, but with completely different characteristics is depicted in Figure 2.10. This type of e-scooter where you stand on rather than sit on, has already conquered the market in the United States (e.g. *Bird*, *Lime*, *Spin* and *Troty*) and will soon be introduced in the Netherlands under the name *SwheelS2Go*, starting in Amsterdam. This vehicle is able to reach high speeds and has a more compact design compared to sitting variant. Since e-scooter sharing is a relatively new service, impacts are still unknown.

Figure 2.9 Sitting variant of the shared electric scooter (*Felyx*)

Figure 2.10 Standing variant of the shared electric scooter (*Spin*)

Access/egress potential: Innovative vehicles with higher speeds are entering the market. Consequently, travel times reduce and the service area of railway stations increases. Besides the two types of e-scooters that were mentioned in this section, the electrification of bicycles (e-bicycle) also allows travellers to travel faster and further. Both the sitting variant of the e-scooter and the e-bicycle were introduced by the *NS* in 2007 but disappeared seven years later due to disappointing usage numbers (NS Zakelijk, 2015). The traditional bicycle remained popular among travellers, also for larger access/egress distances. In addition, the vehicles occupied a significant amount of space at the railway station area and tariffs were not cheap due to the purchase costs.

Since space is becoming scarce, especially in dense urban areas, this transport mode is not expected to have any added value for the access/egress transportation sector. On the other hand, the standing variant with its compact design is able to reach high speeds and requires less parking space compared to any other means of transport. Although further research is necessary to determine the potential of this vehicle, enough advantages are mentioned to include this vehicle as potential access/egress mode in this research. Therefore, for the remainder of this report, the standing variant is meant when talking about an e-scooter. Because no literature is available to elaborate on the type of business models, the same business models are expected to develop as were discussed for the bicycle (Table 2.4).

Table 2.4 Expected potential of e-scooter sharing business models for home-end and activity-end trips

Home-end trip	Activity-end trip
Public e-scooter sharing (free-floating) P2P e-scooter sharing	Public e-scooter sharing (roundtrip + free-floating) P2P e-scooter sharing

Individual on-demand ride services

On-demand ride services require travellers to request a ride through an application on a mobile device. These services have experienced notable growth in the last few years, but they face an uncertain regulatory and policy climate (Shaheen & Chan, 2016). On-demand ride services with an individual nature that can be distinguished are ridesourcing and e-hailing.

Ridesourcing, or ridehailing, is a specific on-demand service in which drivers, using their own personal vehicles, are connected with passengers who request a ride. This arrangement is made possible via a platform where both drivers and passengers are registered. *Uber* is probably the most well-known operator who provides this service in the Netherlands, but can expect competition from for example *Lyft* who already introduced their services in the United States. Compared to the traditional taxi services, ridesourcing services are priced dynamically which means the costs of the trip are dependent on the overall demand. Moreover, ridesourcing drivers usually lack a commercial vehicle license and work part-time (Franckx & Mayeres, 2015). Rayle, Dai, Chan, Cervero, and Shaheen (2016) conducted a survey among 380 ridesourcing users in San Francisco and found that these users were generally younger and more highly educated than the average in the city. It was also found that if the service had not been available, 39% of the users would have travelled by traditional taxi. Ridesourcing has been found to be most frequently used between 10 pm and 4 am, in times when public transport is infrequent or even unavailable (National Academies of Sciences, Engineering, & and Medicine, 2016).

The other individual on-demand ride service, called e-hailing, allows travellers to order taxis via the internet or applications. This form can be seen as a response from the taxi industry towards the modernising transport industry and the rising popularity of ridesourcing. The platforms on which trips are booked can either be maintained by a third party provider or the taxi company itself. The *NS Zonetaxi* is an example of how a third party, *NS* in this case, makes an agreement with taxi companies to provide their service at the railway station area. This service is available at more than 130 stations in the Netherlands and can be booked 30 minutes prior to the start of the ride (NS, 2018b). The fare structure is based on the distance travelled to a predefined zone around the railway station. Numbers provided by the *NS* showed that the service is being used approximately 320 times a week, which is a significant increase since the introduction of the service in 2014 when the service was used 40 times a week (Treinreiziger.nl, 2016).

Access/egress potential: Both individual on-demand ride services that are discussed, ridesourcing and e-hailing, already provide access/egress transport in some regions and have the potential to do so in the future (Table 2.5). Especially the on-demand character of the service offers advantages over conventional ride services. Travellers are able to book a trip according to their needs, flexible in terms of both time and route. Regarding the land use at railway station areas, this service reduces the amount of space that is occupied unnecessarily by vehicles that wait for passengers to make use of the service (e.g. non-reserved taxis).

Table 2.5 Expected potential of individual on-demand ride services for home-end and activity-end trips

Home-end trip	Activity-end trip
Ridesourcing E-hailing	Ridesourcing E-hailing

Collective on-demand ride services
In addition to the individual on-demand ride services, collective forms of this service have the advantage of a higher occupancy rate and are therefore more adequate for dense urban settlements. Ridesplitting and demand responsive transit (DRT) are distinguished.

Ridesplitting is a specific form of ridesourcing in which customers can opt to split both a ride and fare in a ridesourcing vehicle. This form is able to reduce the costs of travelling as multiple travellers are involved and the route is adapted efficiently to the origins and destinations of the customers who request similar trips. *UberPOOL*, a specific service of *Uber*, is also the largest operator of this service. However, as for ridesourcing, *Lyft* again followed this path in the United States with their service called *Lyft Line*.

The second collective on-demand ride service is DRT. The concept of DRT relies on the flexibility of public transport in terms of timing and/or route choices compared to traditional public transport services (Franckx & Mayeres, 2015). Different from ridesplitting, drivers are employees of the respective service provider rather than ridesharing participants and also the vehicles are part of a larger fleet. Moreover, the number of people which DRT aims to transport is much larger compared to those of ridesplitting. The service is also described as 'micro-transit', since a public transport service is offered by smaller vehicles. Practical examples can already be found in several cities in the United States with an increasing number of users (Shaheen & Chan, 2016). In the Netherlands, *Breng flex* is a newly introduced service in the region of Arnhem Nijmegen and allow travellers to book a seat and decide their pick up and drop off location for a fixed price of €3.50. Another flexible transit service is *TwentsFlex*, which can be found in the eastern part of the Netherlands. The service has the same characteristics of the *Breng flex* and has 124 locations where travellers can be picked up and dropped off for two Euros. As concluded by Franckx and Mayeres (2015), DRT still confronts a range of challenges especially regarding routing decisions which are complex to model and optimise. According to the study of Alonso González, Van Oort, Cats, and Hoogendoorn (2017), DRT services can attract a larger number of users than taxi-like services, especially in an ecosystem where initial barriers can be lessened.

Access/egress potential: The collective on-demand ride services have the potential to provide access/egress transport to/from railway stations in the future (Table 2.6). The services share the same benefits as mentioned for the individual on-demand ride services. However, considering the higher occupancy rates that can be achieved, these services are able to transport larger numbers of people.

Table 2.6 Expected potential of collective on-demand ride services for home-end and activity-end trips

Home-end trip	Activity-end trip
Ridesplitting Demand Responsive Transit	Ridesplitting Demand Responsive Transit

Ridesharing

Shared rides between drivers and passengers with similar origin-destination pairings can be defined as ridesharing (Shaheen et al., 2015). Different from ridesourcing and ridesplitting, drivers share the same destination with their passengers. Carpooling and vanpooling are two types of ridesharing services which are distinguishable by the number of persons that make use of the service. As the location of both the origin and destination plays an important role in this service, groups logically consist of family members or organisation employees. *BlaBlaCar* and *Toogethr* are the two main platforms in the Netherlands which provide members to share their trip and allows other members to join the ride. According to Chan and Shaheen (2012), the potential of ridesharing is influenced by three areas: technological developments to improve the access and use of the system, well-located meeting places where ridesharing users can be picked up and dropped off, and supportive policies to stimulate the concept.

> **Access/egress potential:** Ridesharing services have the potential to use vehicles more efficiently and share rides among people with similar or on route origins and destinations. In general, railway stations are part of a multimodal trip where people transfer and are not considered to be origins or destinations. Ridesharing has the potential to replace an entire multimodal trip but is not expected to have potential for either home-end or activity-end trips. (Table 2.7).

Table 2.7 Expected potential of ridesharing services for home-end and activity-end trips

Home-end trip	Activity-end trip
~~Carpooling~~	~~Carpooling~~
~~Vanpooling~~	~~Vanpooling~~

Autonomous mobility

The automation of vehicles goes step-by-step and already different types of automation can be distinguished. The most commonly used classification of vehicle automation is given by the SAE International (2018) and distinguishes six levels. The first three levels (levels 0-2) assume that a human driver will control the dynamic driving tasks and/or monitor the environment with or without help from any assistance system which differences among the levels of automation. The remaining levels (3-5) assume that both the dynamic tasks and the monitoring of the environment are performed by an automated driving system. For level 3 automation, the driver has to be available for occasional control, while in full automation (level 4 and 5) he or she is not. These levels are distinguishable in the way the vehicles are able to drive in an environment with specific (level 4) or all type of transport modes (level 5). The evolution of autonomous vehicles and the estimation of their commercial introduction has been studied by multiple researchers. Milakis, Snelder, Van Arem, Van Wee, and Homem de Almeida Correia (2017) found various estimations by different studies, of which the majority was conducted in the United States. The approaches vary from questionnaire surveys among experts, online surveys among the average population, analyses of comparative vehicle technologies and scenario analyses. Their study suggests that, according to four predefined scenarios, fully autonomous vehicles will be commercially available between 2025 and 2045 and penetrates the market rapidly after the introduction (Milakis et al., 2017). However, the researchers also emphasise the complexity of the urban environment and unexpected incidents which may influence this development path. Shladover (2018) provided an overview of the deployment times for the different levels of automation and estimated the highest level of automation to deploy in somewhere around 2075 based on technological feasibilities (Figure 2.11).

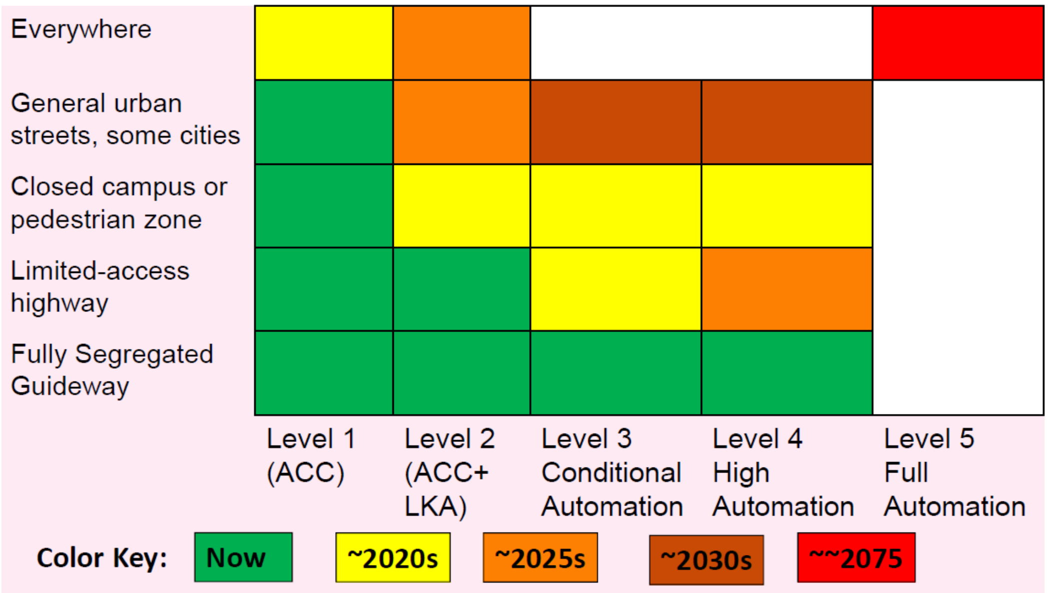


Figure 2.11 Estimated deployment times for different levels of automation (Shladover, 2018)

Access/egress potential: Autonomous means of mobility for access/egress transport becomes especially interesting when vehicles do not rely on responsibilities from the driver (level 4 and 5) and are able to operate among all circumstances in every environment (level 5). For travellers, this would enable the possibility to be picked up and dropped off at the railway station on an on-demand basis. Additionally, vehicles do not have to stand idle at the railway station area but arrive when travellers request a vehicle or ride. Research shows that this scenario is still far from being the reality within 20 years, the considered time horizon for this research. Until then, the other levels of automation are expected to develop and also reach the access/egress market without any significant advantages for these specific type of trips or the railway station area.

Electric mobility

The introduction of electric propulsion systems has led to a transformation of traditional vehicles into 'new' modes of transport. An electric bicycle (e-bike) provides a much greater service area than traditional human-powered bicycles and the electrification of cars will help to reach the goal of the *Paris Agreement* as these vehicles are free of direct pollution. Within the car industry, two main types of electric vehicles (EVs) can be distinguished: Hybrid Electric Vehicles (HEVs) and All Electric Vehicles (AEVs) (Das, Tan, & Yatim, 2017). HEVs combine conventional engine systems with electric propulsion systems while AEVs are fully electric and do not rely on any type of fossil fuels at all.

In the Netherlands, 8,627 types of AEVs were welcomed in 2017 while the number of HEVs slightly decreased (Rijksdienst voor Ondernemend Nederland, 2018). The government and local authorities together aim to stimulate electric mobility by offering subsidies for driving electric cars and investing in charging stations on a large scale. As described by Franckx and Mayeres (2015), electric cars faced two major disadvantages compared to conventional ones. The first one is the limited range in which these vehicles are able to operate and the second is the acquisition costs which were found to be relatively high. The electrification of cars in combination with the shared mobility market models have proved to deal with those issues better compared to personal ownership (Franckx & Mayeres, 2015). First of all, the shared vehicles are mostly used for short trips and do not require a long endurance of the battery. Secondly, as shared vehicles do not stand idle as long as most of the private vehicles do, the vehicles have higher annual mileage which makes the investment more profitable.

The electrification of vehicles does not only affects the car and bicycle industry, but leads to innovations in the public transport (PT) sector as well. Whereas the train, tram and metro already rely on this type of propulsion, buses are being electrified on a large scale. Logically, and also researched by Wiercx, Huisman, Van Oort, and Van Arem (2019), the operation and level of service provided by the bus can be influenced as a result of charging the vehicle. This means that the type and number of charging facilities should be well considered as access/egress mode choice is influenced by those determinants.

> **Access/egress potential:** The electrification of vehicles is expected to change the characteristics of vehicles, which was one of the main categories in the access/egress mode choice framework (paragraph 2.2). Dependent on the type of factors and to which extend factors are affected, travellers might choose different means of transport to travel to/from the railway station. However, since access/egress trips are characterised by short distances, the electrification of vehicles is assumed to not significantly change the level of service and therefore mode choice decisions. Still, the electrification is relevant regarding the facilities that are required at the railway station area for all means of transport that rely on this form of propulsion.

2.4 Conclusion

The literature review aimed to find and analyse existing literature on the topics of access/egress mode choice factors and trends and developments that can affect access/egress transport.

The first part of the literature review showed that many factors influence an access/egress mode choice decision. It was found that factors can be assigned to one of the following six categories: (1) characteristics of the traveller, (2) psychological factors, (3) characteristics of the access/egress trip, (4) characteristics of the access/egress modes, (5) characteristics of the built environment and (6) main stage factors. The first category, characteristics of the traveller, shapes the individuals' personal and household situation. Psychological factors such as attitude and perception are also traveller dependent but able to capture the unobserved, or latent, variables. These variables either have no measurement scale or are perceived differently per individual. The third category includes all trip specific determinants. The distance, for example, is widely researched but also the trip purpose and the weather conditions can be assigned to this category. Access/egress mode characteristics form the fourth category and only include factors that are related to the means of transport. Travel time and cost are among the most reviewed factors in this category. The fifth category characterises the built environment in which the access/egress trip, and thus the mode choice, takes place. Determinants among this category can be classified according to the variables density, diversity and design, also known as the '3Ds'. The sixth and last category includes factors that are related to the main stage (i.e. rail service) and were found to influence the access/egress mode choice as well. The review illustrated that the influence of factors varies between studies and strongly depends on the considered scope (e.g. trip stages, means of access/egress transport and transit nodes). Moreover, factors can have mutual relations with other factors assigned to the same, or another category.

The second part of the literature review elaborated on the impact of relevant trends and determined the potential of new and innovating means of transport for the next 20 years. The demand for access/egress transport is expected to be influenced by among others demographic shifts, urbanisation and climate change. The impact of these trends can be captured by the extent to which access/egress mode choice factors are influenced. However, as a result of these trends, in combination with technological developments, new and innovating means of transport emerge. Shared mobility, autonomous mobility and electric mobility thereby play an important role and have the potential to change the supply of access/egress transport in the future. In 20 years, shared mobility, in particular, is expected to significantly change access/egress trips by means of the following services: (1) carsharing, (2) bikesharing, (3) e-scooter sharing, (4) individual on-demand ride services and (5) collective on-demand ride services. The first three are vehicle sharing services which allow travellers to use a vehicle without the costs and responsibilities of ownership. Three business models can thereby be distinguished: (1) roundtrip, (2) free-floating and (3) peer-to-peer. For all shared vehicles considered in this research (car, bicycle and e-scooter), the same business models are expected to develop at the home-end and activity-end of a multimodal trip. For home-end trips, these are free-floating and P2P vehicle sharing. At the activity-end of the trip, all three business models are expected to develop. The other two services among the shared mobility concept are flexible ride services which allow travellers to request a ride when they need one. Both individual and collective on-demand ride services are expected to develop at both ends of a multimodal trip.

In the next chapter, future developments paths are constructed based on the findings of the literature review.

3 FUTURE DEVELOPMENT PATHS FOR ACCESS/EGRESS TRANSPORT

3.1 Introduction

The literature review provided enough background information on access/egress transport to construct future development paths by the researcher. This chapter aims to give an answer to the third sub-question, which was defined as:

3. **Which future development paths for access/egress transport can be distinguished in 20 years?**

The next paragraph (3.2) elaborates upon the construction of the scenario matrix by means of two driving forces. These driving forces are expected to have a significant impact on access/egress mode choice decisions in 20 years. Hereafter, two specific trip-end matrices are built to distinguish home-end and activity-end mode choice possibilities (paragraph 3.3). The chapter ends with a conclusion (paragraph 3.4).

3.2 Scenario matrix

This paragraph aims to identify future development paths for access/egress transport in the Netherlands for the next 20 years, which was defined as the time horizon for this research. Through scenario analysis, four alternative future development paths are presented. The scenario development process involves two main sequential steps which are discussed in the following subparagraphs. First, two driving forces are identified which lie at the basis of the construction of the scenario matrix (3.2.1). These driving forces also represent the axes along which the scenario matrix is constructed. The second subparagraph (3.2.2) elaborates on the four scenarios that are created, including the expected dominating means of access/egress transport in each scenario.

3.2.1 Driving forces

For the construction of the scenario matrix, two driving forces are identified. Driving forces are the key drivers that play an important role in the development of the subject dealing with. The literature review touched upon various trends and developments that are expected to change access/egress trips in the future. However, shared mobility is expected to have the largest impact on future mode choice decisions as this concept offers various new services with access/egress potential. Consequently, the required land use for access/egress facilities at the railway station area is expected to change accordingly. The other trends and developments are excluded from the scenario matrix to make the scenarios not too extensive and to make the research manageable in the available amount of time. The success of the access/egress services among the shared mobility concept is assumed to be dependent on two innovative notions, which lie at the basis of the construction of the scenario matrix. The first driving force, or axis, is the degree to which the vehicle sharing economy develops. The two extremes that are distinguished are on the one hand a flourishing vehicle sharing economy, and on the other hand, a shrinking market without shared vehicles. The second driving force and other axis of the scenario matrix is the degree to which ride services develop. Again, two extremes are considered for this driving force. On the one hand, an innovating ride service market in which flexible on-demand transport rides are offered, and on the other hand, a traditional market where transport rides are offered according to fixed routes and timetables.

3.2.2 Development paths

Four scenarios are constructed, combining high and low penetrations of both of the aforementioned driving forces. The scenario matrix is depicted in Figure 3.1 and shows the four scenarios along the two axes that are identified.

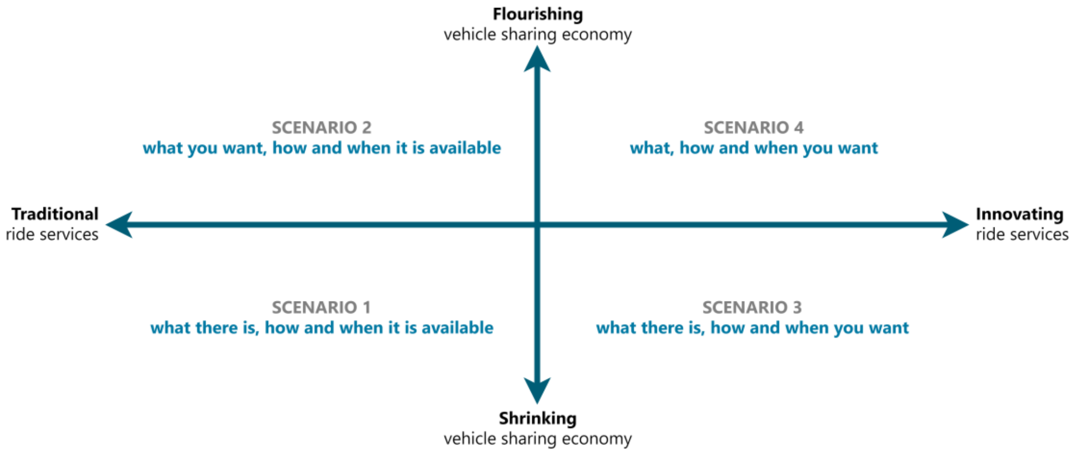


Figure 3.1 Scenario matrix for access/egress transport

Each scenario can be characterised by its own means of access/egress transport that are expected to dominate the market in those situations. All four scenarios will be explained individually in more detail to get an impression on how access/egress transport evolves in 20 years.

Scenario 1: what there is, how and when it is available

walking, privately owned vehicles and traditional ride services

In 20 years, transportation to/from railway stations is hard to distinguish from several years ago. Shared mobility vehicles, of which the numbers were rapidly increasing, have not been proven to be a great success. On the other hand, ride services have not become flexible, and public transport is still provided according to traditional fixed routes and timetables. The majority of the people remains attached to their privately owned vehicles. Providing facilities for these private means of transport (e.g. P+R, K+R and bicycle racks) have the highest priority at railway station areas. As these privately owned transport modes are generally only available for the home-end trip, traditional public transport remains frequently used at the activity-end stage of the trip.

Scenario 2: what you want, how and when it is available

walking, shared vehicles and traditional ride services

Shared vehicles are embraced by all parties. Travellers are convinced by the advantages of the vehicles, providers keep expanding and improving their fleets, and the government is well-willing to cooperate and stimulates the use of vehicles among the shared mobility concept. Shared vehicles can be chosen from at railway station areas where facilities are provided. Although the vehicle sharing economy emerged at a rapid pace, transport rides are still provided the old-fashioned way. Public transport services operate according to traditional fixed routes and timetables.

Scenario 3: what there is, how and when you want

walking, privately owned vehicles and on-demand ride services

In the next 20 years, ride services innovate at a rapid pace, leading to flexible services in terms of routes and timetables. With the increasing amount of information available, these services are able to operate efficiently according to the demand of travellers. On the other hand, the different types of shared vehicles have not been proven to be a success and travellers rather use their own privately owned vehicles when on-demand rides do not provide the service they are looking for.

Scenario 4: what, how and when you want

walking, shared vehicles and on-demand ride services

The access/egress transport sector undergoes significant changes and is nothing like how we currently travel to/from the railway station. Both the vehicle sharing economy and ride services have developed at a rapid pace. Travellers either choose for shared vehicles or travel flexibly with the on-demand ride services that are offered on a large scale.

The scenario matrix that was depicted at the beginning of this subparagraph is extended with the expected dominating means of access/egress transport in each of the discussed scenarios (Figure 3.2). Shared vehicles and on-demand ride services were already discussed during the literature review and do not require any further explanation. However, traditional ride services and privately owned vehicles are also included in the scenarios but have not been discussed yet. Relevant information on these means of transport is given under the extended scenario matrix.

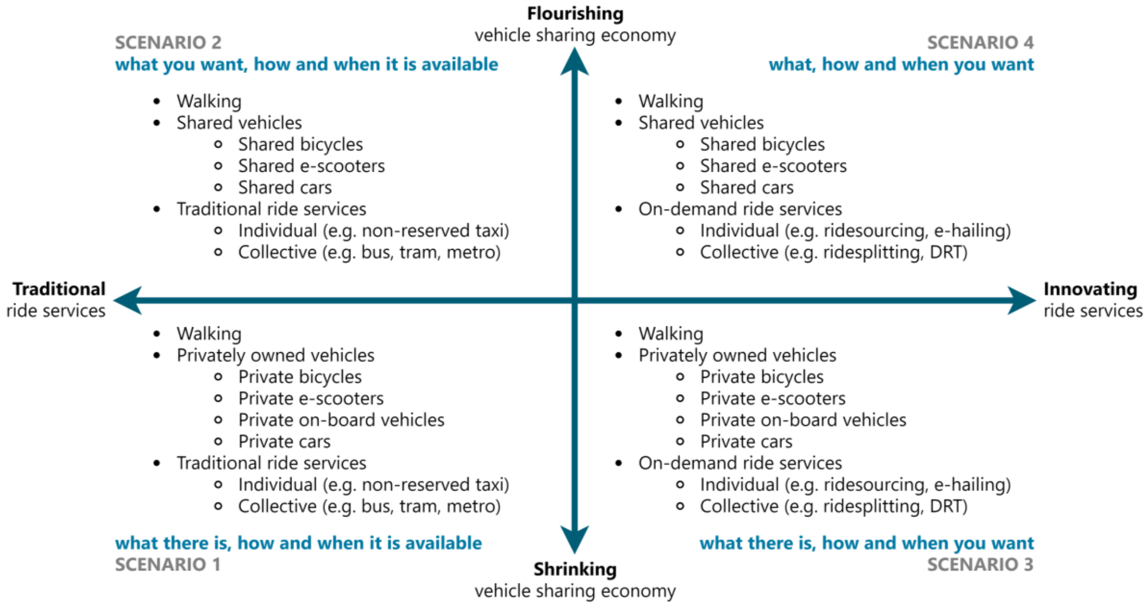


Figure 3.2 Expected dominating means of access/egress transport in each scenario

Traditional ride services can be distinguished from the on-demand ride services in terms of flexibility. As for on-demand ride services, individual and collective forms can be distinguished. Taxis that are waiting for passengers to enter the vehicle (i.e. non-reserved taxis) are an example of the traditional individual ride service. This service is disparate to e-hailing, which allows travellers to reserve a taxi. Individual traditional rides are often provided at larger transit nodes and other crowded locations where demand is guaranteed. Public transport services (e.g. bus, tram, metro) represent the collective variant, as rides are provided according to fixed routes and timetables. In the remainder of this research, the traditional bus is the only collective traditional ride service considered. The other traditional means of public transport (tram and metro) rely on rail infrastructure and do not have a flexible (route) variant. Moreover, the availability of these rail dependent means of transport strongly depends on the region that is considered.

Regarding the private means of transport that are included in the scenario matrix, the majority of the vehicles do not require any explanation. Cars and bicycles are familiar to everyone, and the e-scooter was already introduced during the literature review. The fourth and last type of private vehicles are on-board vehicles. This category includes all vehicles that can be labelled as hand luggage, according to the regulations of the *NS*. In general, a vehicle is allowed to be taken on the train (free of charge) if (NS, 2015):

- the vehicle has no combustion engine;
- the vehicle does not exceed the dimensions of 85 x 85 x 85cm.

Still, employees of the *NS* have the rights to deny access to the train if the on-board vehicle causes or will cause nuisance (NS, 2015). Existing examples of vehicles that are allowed to be taken on the train are, among others, the folding bicycle, folding e-scooter (sitting), the hoverboard, the electric unicycle and the electric skateboard (Figure 3.3).

1	2	3	4	5
Folding bicycle	**Folding e-scooter (sitting)**	**Hoverboard**	**Electric unicycle**	**Electric skateboard**
BTWIN	GiGi	SwheelS	FASTWHEEL	Onewheel
83x67x45cm	72x33x84cm	22x64x24cm	33x47x17cm	23x29x73cm

Figure 3.3 Examples of allowed on-board vehicles according to the regulations of the *NS*

3.3 Availability of transport modes

The introduction of this report already emphasised the relation between modal choice decisions and the availability of transport modes. The scenario matrix in Figure 3.2 delineates the expected dominating means of access/egress transport in general but does not account for differences between home-end and activity-end trips. In the two subparagraphs of this section, the general scenario matrix is adjusted for these trip stages respectively. Choices are based on the potential of each service for either home-end or activity-end trips. For shared vehicles and on-demand ride services, the potential was already elaborated in the second part of the literature review.

3.3.1 Home-end

The home-end scenario matrix is depicted in Figure 3.4 and shows the expected dominating means of transport at this trip-end for each scenario. In scenarios 1 and 3, where private means of transport are included, all four types of private vehicles are included. However, for the other scenarios (2 and 4), in which shared vehicles are expected to dominate the market, only the free-floating and P2P services are considered. These are the only type of shared vehicles that are expected to be available for home-end trips, based on the findings from the literature review in the previous chapter. In scenarios 1 and 2, only collective traditional rides are included as ride service option. Individual traditional ride services are not expected to be available near the travellers' house. The other scenarios (3 and 4) that include on-demand ride services include both individual and collective forms since these services can be consulted at any location at any moment.

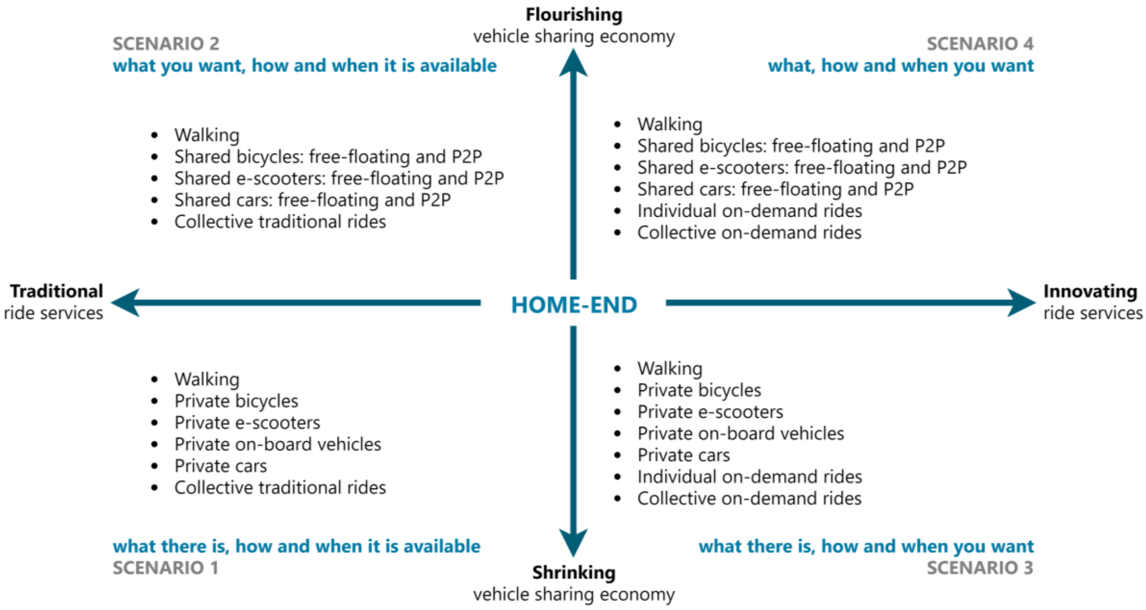


Figure 3.4 Expected dominating means of access/egress transport for home-end trips in each scenario

3.3.2 Activity-end

In addition to the home-end scenario matrix, an activity-end scenario matrix is constructed (Figure 3.5). Access to privately owned vehicles at the activity-end of the trip is not as obvious as for home-end trips. However, many travellers currently have a bicycle parked at railway stations overnight. For e-scooters, this is also expected to occur. However, cars are not expected to be parked overnight at railway stations and are therefore not included in the scenarios (1 and 3) that include privately owned vehicles. Private on-board vehicles, on the other hand, are included as these vehicles can be taken on-board in the train. Regarding the shared vehicles that are included in scenarios 2 and 4, all three sharing forms were considered to be available for activity-end trips. In contrast to the home-end scenario matrix, individual traditional rides are available. In scenarios 3 and 4, again, both individual and collective on-demand ride services are considered.

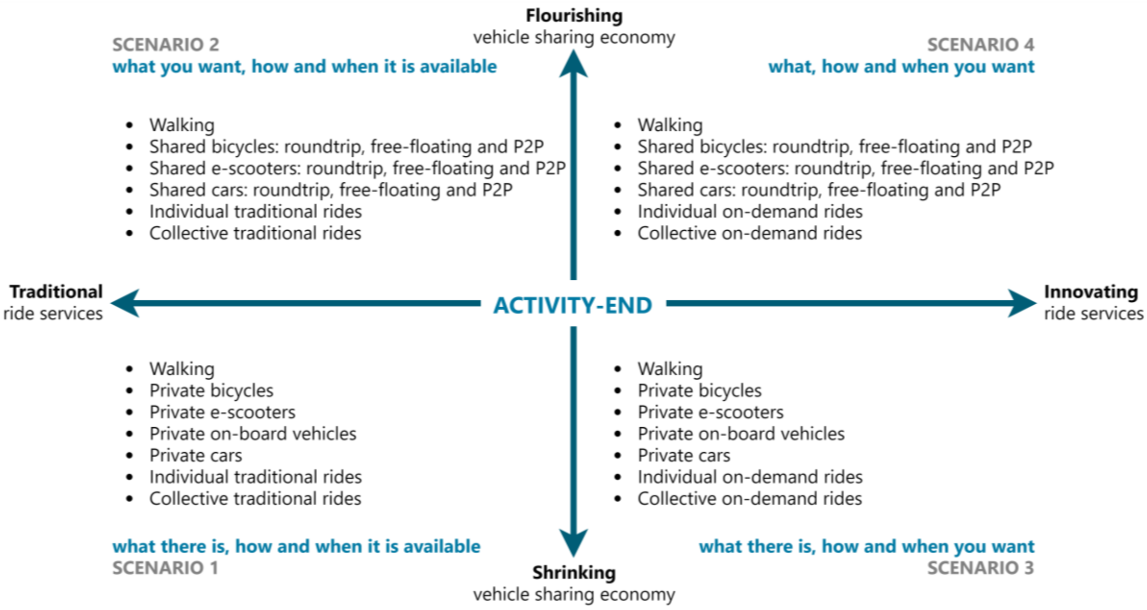


Figure 3.5 Expected dominating means of access/egress transport for activity-end trips in each scenario

3.4 Conclusion

In this chapter, four future development paths for access/egress transport were constructed. The vehicle sharing economy and the transport ride service industry were chosen to be the underlying driving forces for the future development paths of access/egress transport. These key drivers are expected to have a crucial role in future mode choice decisions and thus the required land use for access/egress facilities at the railway station area. Considering high and low penetrations of both the aforementioned driving forces, four distinguishable scenarios were constructed:

Scenario 1: what there is, how and when it is available
walking, privately owned vehicles and traditional ride services
Scenario 2: what you want, how and when it is available
walking, shared vehicles and traditional ride services
Scenario 3: what there is, how and when you want
walking, privately owned vehicles and on-demand ride services
Scenario 4: what, how and when you want
walking, shared vehicles and on-demand ride services

Each scenario was assigned with its own means of access/egress transport that are expected to have a dominant role in the respective scenario. Because mode choice decisions are strongly dependent on the availability of transport modes, two unique trip-end scenarios were distinguished based on the findings from the literature review.

In the next chapter, a methodology is developed to determine the required area for access/egress facilities at the railway station area.

4 ACCESS/EGRESS TRANSPORT FOOTPRINT

4.1 Introduction

In this chapter, a method will be developed to determine the required area for access/egress facilities at the railway station area. At the end of this chapter an answer can be given to the fourth sub-question of this research, which was defined as:

4. **How can the required area for access/egress facilities at the railway station be determined and how does this value differ per means of transport?**

The next paragraph (4.2) introduces the footprint concept and explains how this method can be used to assess access/egress mode choice decisions in the future regarding the required land use for access/egress facilities. Hereafter, all three components of the footprint are elaborated and determined in three separate paragraphs (4.3, 4.4 and 4.5). The next paragraph (4.6) unites the components and elaborates on the footprints that are generated. A conclusion is written to elaborate and summarise this chapter (paragraph 4.7).

4.2 Footprint as measurement scale

The concept of footprints originates from a publication by Rees (1992) who analysed the total area of land required to sustain an urban region (i.e. ecological footprint). Other types of footprints were inspired by the ecological footprint and are created as a result of climate change (e.g. carbon footprint) and the exhaustion of natural resources (e.g. water footprint and energy footprint). Since then, many studies and companies used different footprint concepts in different forms and for different purposes.

This study introduces a new type of footprint which can be listed among the footprint concepts. The so-called **access/egress transport footprint** is given the following definition:

'The required area per traveller for a means of access/egress transport to park or stop at the railway station area based on the number of departures and arrivals during a peak period.'

To the authors' knowledge, there are no studies that use this form of footprint in any equivalent way. The indicator can be used for railway station area (re)development projects, to assess the choice for facilitating different means of access/egress transport. The access/egress transport footprint can be expressed in square meter per traveller and can be calculated for each means of access/egress transport that was included in the scenario matrices. The footprint consists of three distinct components: (1) storage area, (2) design frequency and (3) occupancy rate (Figure 4.1). When the values for each component have been established, the following formula can be used to determine the footprints:

$$Access/egress\ transport\ footprint = \frac{storage\ area}{design\ frequency * occupancy\ rate}$$

In the following paragraphs, each component of the footprint indicator is further explained and values are generated for all means of access/egress transport that are considered in this research.

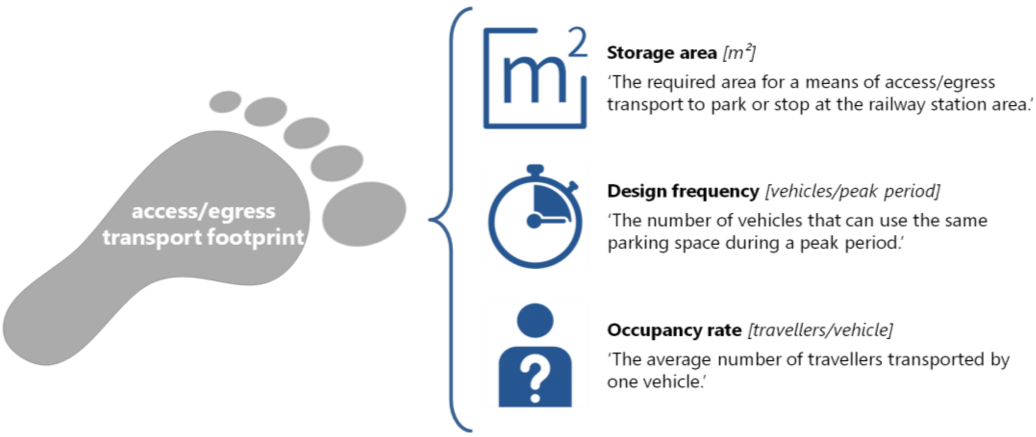


Figure 4.1 Access/egress transport footprint composition

4.3 Storage area

The land use occupation by different means of transport is probably the most obvious element of the access/egress transport footprint. Creating knowledge and collecting information on this notion is essential as space is becoming scarce, especially in dense urban areas. A handful of values can be found, but relatively little when considering the importance and relevance of the topic. The municipality of Amsterdam generated values for the car (20m^2), tram (7m^2) and bicycle (2m^2) to justify their preference regarding means of transport that occupy little space (Gemeente Amsterdam, 2017). In addition, the CROW (2014) generated parking values for the car (15.00 – 31.25m^2), tram (0m^2) and bicycle (1.07 – 1.88m^2) to conclude how disadvantageous the car is compared to other means of transport. The methodology used by the municipality of Amsterdam is unknown, and the CROW made use of standard design values but concluded that their data is of moderate quality. Their values represent the parking space only without accounting for the land that is required to reach the designated area such as parking and driving lanes. In addition, public transport modes such as the tram that do not park but only make a stop, are associated with a land use of zero, which gives a wrong indication of the land that is actually needed.

The first component of the footprint indicator, the storage area, includes both the direct and indirect area that is required for means of access/egress transport to park or stop at the railway station area. The direct area represents the parking space. This is where the vehicle parks or stops, dependent on the considered service. The indirect area comprises the parking lanes (adjacent to the parking space) and possible platforms where passengers wait. Other indirect land use sections such as driving lanes (to reach the parking lanes) and possible construction elements of the facility do also contribute to the storage area but are not taken into account in this research. These areas strongly depend on the type and layout of the respective facility. Moreover, driving lanes are often difficult to allocate to one specific means of transport as these are used by multiple means of transport to reach their designated facility.

In this paragraph, the storage areas for all means of access/egress transport that were included in the scenario matrices are determined. First, the design standards of railway stations in the Netherlands are consulted (Projectteam Basisstation, 2005). In here, *ProRail* defined norms and guidelines for some facilities at the railway station area. Because the report is incomplete, other sources and methods are consulted. For most of the traditional means of access/egress transport (private bicycle, private car and bus), design vehicles and design guidelines are available. Design vehicles have standard dimensions which can be used for the design of the respective transport facilities. Appendix D contains information on all existing design vehicles that are relevant for this research, including dimensions. However, this information is not available for all transport means that are considered in this research. Especially relatively new means of transport do not have any standards or guidelines to follow. For the estimation of these values, existing values are adapted, and dimensions of vehicles from practice are consulted.

Walking

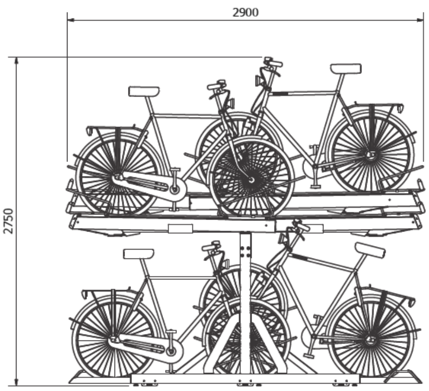
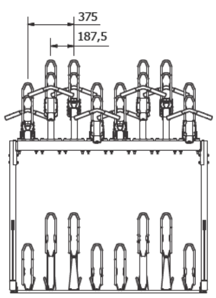
Although pedestrians do need infrastructure to move around the railway station area, walking is not associated with a facility where travellers park or stop. Still, the provision of among others sidewalks is crucial to make the railway station accessible. Besides, every traveller, regardless of the means of transport that is used to arrive at the railway station, becomes a pedestrian when entering the railway station. However, because this research focuses on the required land use for access/egress facilities, walking is associated with a storage area of **0m²**.

Bicycles

Park and Ride (P+R) facilities for bicycles, also called Bike and Ride (B+R) facilities, have to be present at all railway stations in the Netherlands. This is defined by *ProRail* in their report on standards and guidelines for bicycle facilities at railway station areas (Projectteam Basisstation, 2005). Unless the capacity at a railway station cannot be achieved, bicycles are being placed at one level. However, due to the bicycle parking capacity shortage at most railway stations in the Netherlands, high-low systems and/or floor racks are applied to increase the capacity. For all different bicycle parking systems that exist, standard values that are described in the normative document *Fietsparkeur*, have to be met (Stichting FietsParKeur, 2004). These values are based on the dimensions of the bicycle design vehicle: 1.94 x 0.64 x 1.23 x 0.90m (length x width x steering height x seat height) (CROW, 2012).

Four different bicycle parking systems were analysed in Appendix E.1, and the storage areas were found to vary between 0.55m² – 1.11m². Logically, floor racks in which bicycles can be placed on top of each other have a lower storage area compared to a single level parking system. For the remainder of this research, double-sided floor racks with extension rail are considered as reference bicycle parking facility. This popular bicycle parking system relies on the high-low system and can provide a high capacity on a relatively small area. This parking system has a storage area of **0.6m²** (Table 4.1). It should be mentioned that this form of parking is not useful, or in some cases not even usable, for specific type of bicycles (e.g. bicycles with baskets/bags and electrified bicycles). The spacing between bicycles might be inadequate or the upper floor rack can be unreachable due to the weight of the vehicle. Moreover, a double-sided system should be accessible from both sides and requires a parking lane of at least 3.0m which might not always fit within the available area of the facility.

Table 4.1 Determination of storage area for bicycles

Standards/guidelines	- Reference design vehicle (1.94 x 0.64 x 1.23 x 0.90m) (CROW, 2012) - *Basisstation* (Projectteam Basisstation, 2005) - *Fietsparkeur* (Stichting FietsParKeur, 2004)
Access/egress facility	Choice: Floor racks with extension rail, double-sided  Characteristics: - Parking space length 1.45m - Parking lane width 3.00m - Running meter per bicycle 0.1875m

Storage area	Depth * running meter per bicycle $\left(1.45\text{m} + \frac{3.00\text{m}}{2}\right) * 0.1875\text{m} = 0.6\text{m}^2$ (rounded up)
Included:	Parking space and share of parking lane (adjacent to the parking space).
Excluded:	Other infrastructure such as driving lanes to reach the parking lanes and possible construction elements of the facility.

Currently, no distinction is made between facilities for private bicycles on the one hand and shared bicycles on the other hand. Because bicycles of roundtrip and free-floating bikesharing services are usually produced in large numbers with the same dimensions, there might be potential to design more efficient bicycle parking systems in the future. However, deviating from current standards is only possible when providers of share bicycle services are willing to cooperate and design according to the same standards. Moreover, sufficient demand is needed to redesign bicycle facilities and to distinguish shared bicycle facilities from private ones. Still then, the benefits of new bicycle parking systems should be further researched to research its potential. For now, all bicycles in this research are associated with a storage area of **0.6m²**, and no distinction is made between private and shared bicycle facilities.

E-scooters

Because e-scooters are relatively new means of transport, no design vehicle exist. Therefore, an existing e-scooter from practice is used as reference to determine the storage area for this vehicle (Figure 4.2). This e-scooter from practice has the advantage of being foldable, which requires little parking space. Due to the rapidly growing e-scooter market, new features and designs are expected to develop on a short term.

Figure 4.2 Dimensions of an e-scooter when in use (left) and when folded (right) (Mi, 2018)

In practice, e-scooters are parked (at designated areas) on the street. However, it can be expected that an increase of e-scooter usage also leads to more efficient parking facilities. For example, lockers would make it possible to store (foldable) e-scooters efficiently and charge them when not in use. The folded e-scooter from practice has small dimensions (1.08 x 0.43 x 0.49m) relative to the reference design bicycle (1.94 x 0.64 x 1.23m). The facility that was considered for bicycles (floor rack with extension rail, double-sided) has an efficient design with a height of 2.75m to park two bicycles on top of each other. This height would be sufficient for 5.6 (= 2.75m / 0.49m) folded e-scooters, although the spacing between bicycles (37.5cm) is slightly smaller than the width of the e-scooter (43cm). However, the bicycle facility requires a wide parking lane of 3.0m for the extension rail which is not required for e-scooters as a result of their small length. For the remainder of this research, it is assumed that three folded e-scooter require the same storage area as one bicycle parked in a double-sided floor rack with extension rail. E-scooters are therefore assigned a storage area of **0.2m²** (Table 4.2). Again, it is assumed that both private and shared vehicles require the same amount of area. Still, further research is required to find the most suitable and efficient type of facility for e-scooters, including the corresponding storage area.

Table 4.2 Determination of storage area for e-scooters

Standards/guidelines	-
Access/egress facility	Dimensions of considered reference vehicle: 1.08 x 0.43 x 0.49m. Assumption: E-scooters are folded and stored in lockers. Three e-scooters are assumed to require the same storage area as one bicycle in a double-sided floor rack with extension rail.
Storage area	$\frac{\text{Storage area bicycle}}{3} = \frac{0.6\text{m}^2}{3} = 0.2\text{m}^2$

On-board vehicles

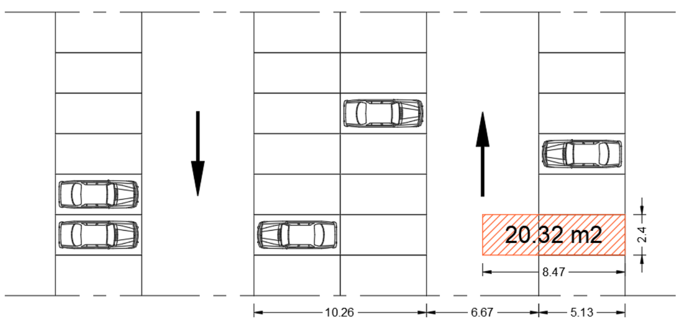
As mentioned in Chapter 3, on-board vehicles have limited dimensions which allow travellers to take these vehicles on-board of the train. As for pedestrians, space is required for travellers with these vehicles to move around the railway station area. However, this research focuses on facilities at the railway station area where vehicles park or stop, which do not apply to on-board vehicles. On-board vehicles are therefore also associated with a storage area of **0m²**.

Cars

Car parking facilities at railway stations can have different forms (e.g. parking lots at ground level, parking garages, underground facilities). The decision for a specific type strongly depends on the available area in the built environment of the railway station. The *Dutch design standards and recommendations on parking facilities for passenger cars* (NEN 2443), provides values to design car parking facilities for the Dutch context (Normcommissie 351 041 ''Parkeergarages'', 2013). These values are based on the dimensions of the car design vehicle: 4.88 x 1.83 x 1.73m (length x width x height) (CROW, 2012).

Different car parking forms (perpendicular, angular and parallel) were analysed in Appendix E.2, and the storage areas were found to vary between 20.32m² – 25.00m². As for the other storage areas, these values include the area of the parking space and also accounts for the area along the parking spaces (i.e. parking lane). The area of this 'road' is equally divided over the number of parking spaces. For the remainder of this research, the most efficient parking form is considered as reference car parking form. Cars are therefore assigned a storage area of **21m²**, the value for perpendicular car parking (Table 4.3). Because P2P carsharing also relies on the use of privately owned cars, the same storage area is considered for facilitating vehicles of this form of carsharing.

Table 4.3 Determination of storage area for private cars

Standards/guidelines	- Reference design vehicle (4.88 x 1.83 x 1.73m) (CROW, 2012) - NEN 2443 (Normcommissie 351 041 ''Parkeergarages'', 2013)
Access/egress facility	Choice: Perpendicular car parking  Characteristics: - Parking space width 2.40m - Parking space length 5.13m - Parking lane width 6.67m - Running meter per car 2.40m (=parking space width)

Storage area	Depth * running meter per car $\left(5.13\text{m} + \frac{6.67\text{m}}{2}\right) * 2.40\text{m} = 21\text{m}^2$ (rounded up)
Included:	Parking space and share of parking lane (adjacent to the parking space).
Excluded:	Other infrastructure such as driving lanes to reach the parking lanes and possible construction elements of the facility.

As for shared bicycles, shared cars are often produced in large fleets for which practical dimensions can be chosen. This makes that most of the shared vehicles are characterised by their compact designs which require less parking space. However, in current practice, no distinction is made in the dimensions of a parking space for a private or a shared vehicle. Because these differences are significantly larger for cars than for bicycles, an additional storage area will be calculated for shared cars in this research. To determine the space that is necessary for parking these vehicles, a shared car from practice is chosen as reference. A *Smartfortwo* is considered, a free-floating car of which 300 were introduced in Amsterdam at the 24th of November in 2011 (car2go, 2018b). Figure 4.3 shows the vehicle including its dimensions.

Figure 4.3 Car2go vehicle including dimensions (car2go, 2018b)

In comparison to the floor area of the standard design vehicle (8.93m^2), the area of the shared car vehicle is a factor two smaller (4.48m^2). Car parking facilities for these vehicles can be designed with significantly lower values compared to the values discussed for the privately owned vehicles. Since no standard design values exist, assumed is that the required land use for these vehicles is also a factor two smaller. Therefore, in the remainder of this research, roundtrip and free-floating cars are assigned a storage area of **11m²** (Table 4.4).

Table 4.4 Determination of storage area for shared cars

Standards/guidelines	-
Access/egress facility	Dimensions of considered reference vehicle: 2.70 x 1.66 x 1.56m. <u>Assumption:</u> Shared cars are produced in large fleets with smaller dimensions compared to private cars. It is assumed that shared cars require half the storage area of private cars as the floor area of shared cars is half the floor area of private cars.
Storage area	$\frac{\text{Storage area private car}}{2} = \frac{21\text{m}^2}{2} = 11\text{m}^2$ (rounded up)

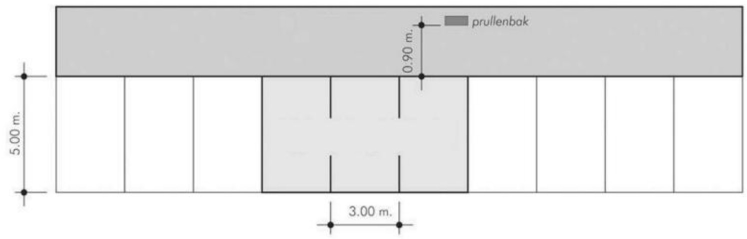
Individual traditional ride service vehicles

During the construction of the scenario matrix, non-reserved taxis were mentioned as an example of the individual traditional ride service for this research. Facilities for these vehicles at the railway station area can be characterised by an access/egress road leading to and from parking spaces which are occupied for a short period of time (Figure 4.4). Platforms alongside the parking spaces allow travellers to wait for the vehicles to arrive.

Figure 4.4 Example of a taxi stand at a railway station (CROW, 2005b)

Guidelines regarding the dimensions of taxi stands are provided by the CROW (2005b). Storage areas for different designs (perpendicular and parallel) were analysed in Appendix E.3 and found to vary between 27.70m² – 31.20m². The perpendicular form is again the most efficient design and considered as reference taxi stand. Therefore, individual traditional ride service vehicles are assigned a storage area of **28m²** (Table 4.5). Although the layout with the lowest storage area is the perpendicular form, in practice most taxi stands are designed according to the parallel layout. This form makes it easier to manoeuvre in and out the taxi stand, but does, according to the numbers, requires some additional area.

Table 4.5 Determination of storage area for individual traditional ride service vehicles

Standards/guidelines	- Dimensions of taxi stands (CROW, 2005b)
Access/egress facility	<u>Choice:</u> Perpendicular taxi stands  Characteristics: - Parking space width 3.00m - Parking space length 5.00m - Platform width 0.90m - Parking lane width 6.67m - Running meter per car 3.00m (=parking space width)
Storage area	Depth * running meter per car $\left(5.00\text{m} + 0.90\text{m} + \frac{6.67\text{m}}{2}\right) * 3.00\text{m} = 28\text{m}^2$ (rounded up)
Included:	Taxi stand, platform and share of parking lane (adjacent to the taxi stand).
Excluded:	Other infrastructure such as driving lanes to reach the parking lane and possible construction elements of the facility.

Collective traditional ride service vehicles

During the construction of the scenario matrices, it was decided that only buses are taken into consideration for collective traditional ride services. As for all transport facilities, bus stations can be designed in many different ways. The first distinctive feature is the stopping platform of each bus line at the station, which can be fixed or flexible. As a result of this distinction, bus stations can either have a static or dynamic characteristic (CROW, 2005a). In addition, the distribution of the platforms over the bus station can be chosen in many different ways for various reasons. To determine the storage area for collective traditional ride service vehicles, a bus with a length of 12m is taken as design vehicle (CROW, 2005a). In Appendix E.4, the storage areas for different layouts were analysed and found to vary between $240m^2$ – $288m^2$. Because the decision for a specific layout is strongly depending on the available land in the area, simply choosing the layout which requires the least amount of area is often impossible in practice. Although this holds for all other means of transport as well, the layout for bus stations is less flexible due to the length of the vehicles and requirements that come along. Therefore, the average value of the four different layouts is used. In the remainder of this research, collective traditional ride service vehicles are assigned a storage area of **$260m^2$** (Table 4.6).

Table 4.6 Determination of storage area for collective traditional ride service vehicles

Standards/guidelines	- Dimensions of bus platform layouts (CROW, 2005a)
Access/egress facility	<u>Choice:</u> Average storage area of the four analysed layouts (Appendix E.4)
Storage area	$\frac{288m^2 + 240m^2 + 260m^2 + 247m^2}{4} = 260m^2$ (rounded up)
Included:	Bus stop, platform and share of parking lane (adjacent to the bus stop).
Excluded:	Other infrastructure such as driving lanes to reach the parking lane and areas where buses stand idle, and possible construction elements of the facility.

Individual on-demand ride service vehicles

Facilities for individual on-demand ride service vehicles are already existing under the name of Kiss and Ride (K+R) facilities. These facilities are characterised by parking spaces or lanes where travellers can be picked up and dropped off (Figure 4.5). The time that vehicles are allowed to occupy a parking space is restricted to some minutes, which varies per location.

Figure 4.5 Example of a Kiss and Ride facility at a railway station (CROW, 2005b)

Regular cars are used for the different individual on-demand ride services that are distinguished in this report (ridesourcing and e-hailing). Because the values that were calculated for regular car parking facilities are based on facilities with a not intensively used character, these values are not suitable to use. Taxi stands on the other hand, do also have an intensively used character and are therefore used as reference for designing K+R facilities (Appendix E.3). Therefore, individual on-demand ride service vehicles are also assigned a storage area of **$28m^2$** (Table 4.7).

Table 4.7 Determination of storage area for individual on-demand ride service vehicles

Standards/guidelines	-
Access/egress facility	Assumption: Same facility as individual traditional ride service vehicles
Storage area	28m²

Collective on-demand ride service vehicles

Ridesplitting and Demand Responsive Transit (DRT) were mentioned in this report as examples of the collective on-demand service. Since no design vehicle for these services exists, an existing vehicle from a collective on-demand service from practice, called *TwentsFlex*, is used (Figure 4.6).

Figure 4.6 Vehicle used for the collective on-demand service *TwentsFlex* (TwentsFlex, 2018)

These minibuses are smaller than the ones used for traditional collective rides, but significantly larger than a traditional passenger car. The vehicle that is used for the service of *TwentsFlex* is a *Mercedes-Benz Sprinter*. These minibuses have a floor area of 15.2m² (6.97 x 2.18m) and are able to transport a maximum of eight passengers (Mercedes-Benz, 2018). This floor area is half the floor area of the traditional collective buses that are considered in this research, which have a floor area of 30.6m² (12 x 2.55m; length x width). Although it is unknown which type of facilities are the most efficient for the minibuses that are considered, for now it is assumed that half of the area is required as was found for collective traditional vehicles. It is expected that the value is even lower as a result of smaller margins for turning and (dis)embarking compared to the buses of 12m. Still, in the remainder of this report, collective on-demand vehicles are assigned a storage area of **130m²** (Table 4.8).

Table 4.8 Determination of storage area for collective on-demand ride service vehicles

Standards/guidelines	-
Access/egress facility	Dimensions of considered reference vehicle: 6.97 x 2.18m. Assumption: It is assumed that minibuses require half the storage area of buses as the floor area of minibuses is half the floor area of buses.
Storage area	$\frac{\text{Storage area collective traditional ride service vehicles}}{2} = \frac{260\text{m}^2}{2} = 130\text{m}^2$

An overview of all storage areas that have been determined in this paragraph are given in Table 4.9 and Figure 4.7.

Table 4.9 Overview of the storage areas

Means of access/egress transport	Storage area [m^2]
Walking	0 m^2
Private bicycle	0.6 m^2
Shared bicycle	0.6 m^2
Private e-scooter	0.2 m^2
Shared e-scooter	0.2 m^2
Private on-board vehicle	0 m^2
Private car	21 m^2
Shared car[1]	14 m^2
Individual traditional ride service vehicles	28 m^2
Collective traditional ride service vehicles	260 m^2
Individual on-demand ride service vehicles	28 m^2
Collective on-demand ride service vehicles	130 m^2

[1] Average of the three vehicle sharing services.

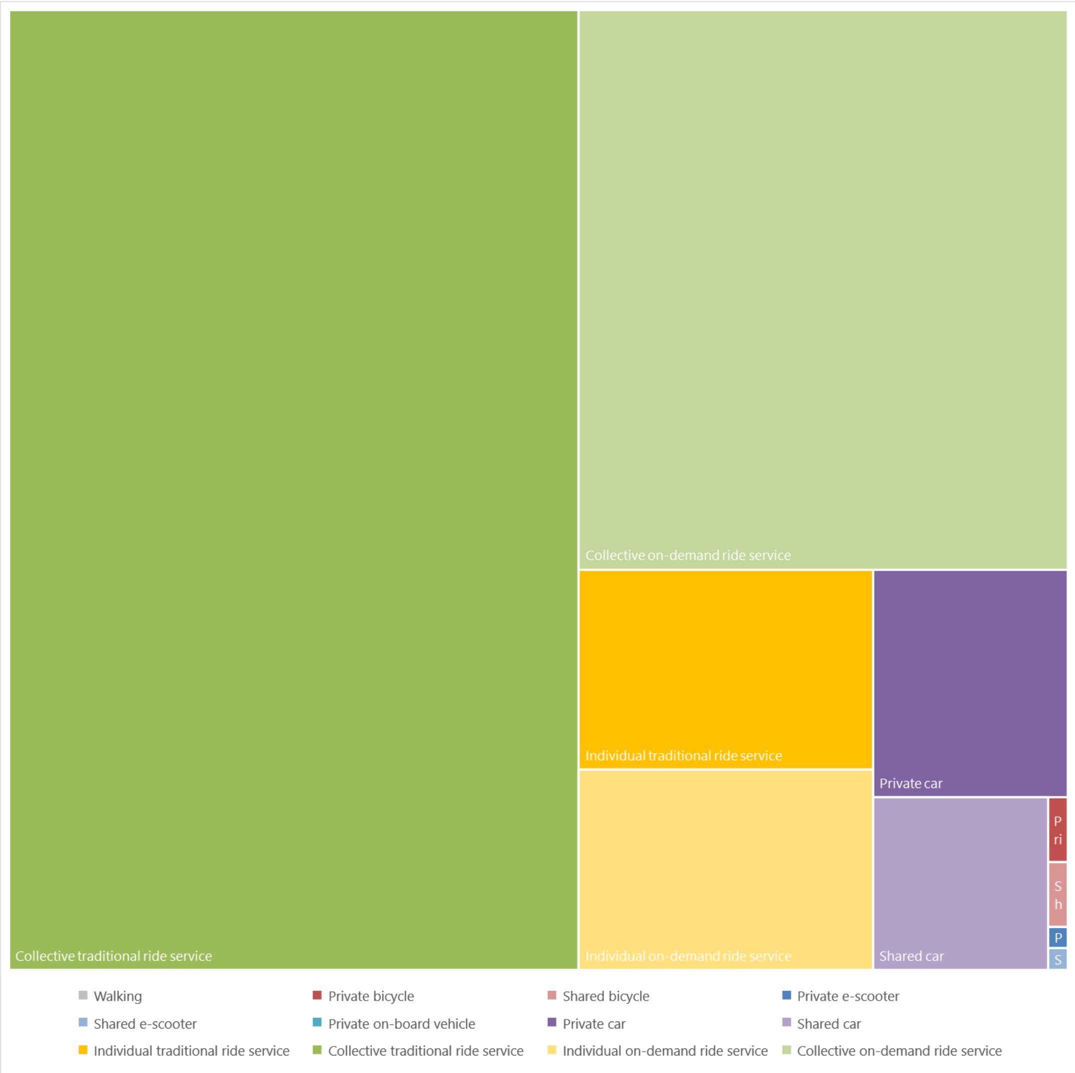


Figure 4.7 Visual comparison of the storage areas

4.4 Design frequency

The first component of the footprint, the storage area, elaborated on the amount of area that is required for means of access/egress transport to park or stop at the railway station area. This value is expressed in square meters and illustrates how large, or small, the required area is. However, the time that a vehicle occupies the designated parking space at the railway station varies per means of transport. When the area is occupied for a long period of time (e.g. parking of private vehicles), other vehicles are not able to make use of the same area. However, a short occupation time (e.g. public transport stop) allows other vehicles, with the same characteristics, to use the same designated area. To express this, the design frequency is introduced as the second component of the access/egress transport footprint. This value expresses the number of vehicles that can use the same parking space during a peak period. A peak period is considered because the largest share of travellers generally make use of the railway station during this period. In general, two peak periods can be distinguished: a morning peak (07:00 – 09:00) and an evening peak (16:00 – 18:00). Van Hagen and Exel (2012) found that the share of travellers in the two distinguishable peak periods strongly differ per station. Dependent per railway station, the busiest moment can either be the morning peak or evening peak. For this research, it is assumed that access/egress facilities should be designed based on the number of departures and arrivals in the busiest peak period to provide enough capacity. Summarizing, the design frequencies represent the average number of departures and arrivals in a period of two hours which are assumed to be normative for the determination of the total required land use.

For private and shared vehicles that require a parking facility at the railway station area (i.e. bicycles, e-scooters and cars), design frequencies are based on the home-end and activity-end potential of the service. These potentials were determined in the second part of the literature review and used for the construction of the trip-end matrices in paragraph 3.3. For ride services, design frequencies are based on the potential at both trip-ends as well, together with the expected operating frequency.

Table 4.10 shows a scheme with the expected arrivals and departures of access/egress vehicles during the two peak periods for each considered means of access/egress transport. Because of uncertainties in departures, arrivals and residence times, the values represent averages. This scheme will be used to elaborate on the determination of the design frequencies in the remainder of this paragraph. First, two examples are given.

Table 4.10 Expected departures and arrivals for the determination of design frequencies

Means of access/egress transport	**Morning peak** (07:00 – 09:00)	**Evening peak** (16:00 – 18:00)
Private bicycle Private e-scooter	-1^{AE}, $+1^{HE}$	-1^{HE}, $+1^{AE}$
Shared free-floating vehicle Shared P2P vehicle	$+1^{HE}$, -1^{AE}	$+1^{AE}$, -1^{HE}
Shared roundtrip vehicle	-1^{AE}	$+1^{AE}$
Private car	$+1^{HE}$	-1^{HE}
Individual traditional ride service	-6^{AE}	-6^{AE}
Collective traditional ride service	$+12^{HE}$, -12^{AE}	$+12^{AE}$, -12^{HE}
Individual on-demand ride service	$+24^{HE}$, -24^{AE}	$+24^{AE}$, -24^{HE}
Collective on-demand ride service	$+24^{HE}$, -24^{AE}	$+24^{AE}$, -24^{HE}

+ : number of arriving vehicles with home-end (HE) or activity-end (AE) traveller(s).
– : number of departing vehicles with home-end (HE) or activity-end (AE) traveller(s).

Example 1. During a peak period of two hours it is expected that a shared free-floating or P2P vehicle is parked by a home-end traveller ($+1^{HE}$) at the railway station area and thereafter taken by an activity-end traveller (-1^{AE}). This results in a design frequency of two.

Example 2. During a peak period of two hours it is expected that 12 collective traditional ride services vehicles arrive with home-end travellers (+12^{HE}) and depart with activity-end travellers (-12^{AE}). In other words, every 10 minutes a vehicle arrives and depart. This results in a design frequency of 24.

As mentioned, the design frequencies for private and shared vehicles are based on the home-end and activity-end potential of the service. When a vehicle has potential at both trip-ends, an arriving and departing traveller are expected to use a vehicle that occupies the same parking space. Therefore, private bicycles, private e-scooters, shared free-floating vehicles and shared P2P vehicles, are assigned a design frequency of two. However, this is only valid under the assumption that:

- during the morning peak:
  - Activity-end travellers with private bicycles and private e-scooters take their vehicle before home-end travellers park their vehicle.
  - Home-end travellers with shared free-floating vehicles and shared P2P vehicles park a vehicle before activity-end travellers take a vehicle.

- during the evening peak:
  - Home-end travellers with private bicycles and private e-scooters take their vehicle before activity-end travellers park their vehicle.
  - Activity-end travellers with shared free-floating vehicles and shared P2P vehicles park a vehicle before home-end travellers take a vehicle.

The other shared business model, roundtrip vehicle sharing, only has potential at the activity-end of the trip. In other words, it is assumed that the space assigned to vehicles of this service, cannot be used by home-end travellers. Therefore, vehicles of this service are assigned a design frequency of one. The same argumentation holds for private cars, although these vehicles have only potential at the home-end.

Because pedestrians and travellers who bring their vehicle on-board do not require any access/egress facility at the railway station area, a design frequency is not applicable to these users.

For ride services, design frequencies are determined based on the (expected) operating frequency and the potential at each trip-end. Parking spaces designated for individual traditional ride service vehicles are expected to be used by travellers every 20 minutes during a peak period. These rides are not reserved in advance and are the only ride service with potential at a single trip-end. The collective variant, represented by buses, operates according to fixed timetables. Assuming that a bus platform is occupied every ten minutes during a peak period, collective traditional ride services are assigned a design frequency of 24. This value also accounts for the fact that buses both have home-end and activity-end potential, meaning that travellers both exit and access the bus when stopping at the railway station. Because on-demand ride services are able to arrive and depart at prearranged times, facilities can be used more efficiently. It is therefore assumed that these ride services have a design frequency of 48, twice as much as collective traditional ride services. This means that vehicles of on-demand ride services arrive and depart every five minutes with potential at both trip-ends. However, further research is required to determine the feasible frequency at which these ride services are able to operate and the possibility to provide the service for both trip-ends by one vehicle. An overview of the determined design frequencies is depicted in Table 4.11.

Table 4.11 Overview of the design frequencies

Means of access/egress transport	Design frequency [vehicles/peak period]
Both home-end and activity-end potential - private bicycle - private e-scooter - shared free-floating vehicle (bicycle, e-scooter and car) - shared P2P vehicle (bicycle, e-scooter and car)	**2**
Either home-end or activity-end potential - shared roundtrip vehicle (bicycle, e-scooter and car) - private car	**1**
Waking Private on-board vehicle	**NA**
Individual traditional ride service	**6**
Collective traditional ride service	**24**
Individual on-demand ride service	**48**
Collective on-demand ride service	**48**

4.5 Occupancy rate

The third and last component of the access/egress transport footprint is the occupancy rate. This value represents the average number of travellers that are transported by one vehicle. Means of transport that are associated with a high storage area do not by definition occupy more land per traveller transported. Pictures that visualise this have become famous due to the clear message that the pictures convoys (Figure 4.8). The figure illustrates the amount of space that is required by different transport means to transport the same number of travellers.

Figure 4.8 The same number of travellers using different means of transport (Cycling Promotion Fund, 2016)

For this research, occupancy rates are collected from existing literature. For vehicles with a capacity of one, the occupancy rate is one as well, since vehicles cannot be driven empty. These are, for this research specifically, services that rely on the use of a bicycle, e-scooter and on-board vehicle.

The European Environment Agency (2015) did research on the occupancy rates of passenger vehicles over the last years. In their key message they mention the falling car occupancy rates since the 1980s. This trend has developed as a result of the greater individualisation of the society, reflected by the increase in car ownership and shrinking household sizes. For the Netherlands, the researchers found an occupancy rate of 1.42. This value lies close to the European average of 1.45 passengers per vehicle. It should be mentioned that these values are general averages and may therefore differ from values for access/egress trips. A report published by the IEA (1997), shows the relation between occupancy rates and trip purpose. Travel and leisure trips are associated with more passengers per vehicle (1.6-2.0) compared to trips made for commuting purposes (1.1-1.2). Because peak periods, the considered timeframe for the determination of the design frequencies, can be characterised by a large share of commuting trips, lower occupancy rates for access/egress trips are expected (Van Hagen & Exel, 2012). Therefore, access/egress services that include a passenger car are assigned an occupancy rate of 1.2 in the remainder of this research.

Occupancy rates for public transport services are discussed in the same research of the European Environment Agency (2015). According to the researchers, data for these services is scarce and trends are inconclusive. The researchers estimate the average number of travellers on buses in the Netherlands to be 25 travellers per vehicle. As the authors describe, values are strongly dependent on the characteristics of the vehicle and the service that is provided (e.g. fares, frequency, accessibility). The bus that was taken as reference for the determination of the storage area in paragraph 4.3, approximately has 30-45 seats available (RET, 2018). An occupancy rate, slightly lower than the number of seats available is assumed to be a reasonable value. Therefore an occupancy rate of 25 passengers per vehicle will be used in the remainder of this report for collective traditional ride services.

In addition to the collective ride service provided by traditional buses, collective on-demand services provide transport for a larger group of travellers. Because these services are relatively new, average occupancy rates are unknown. A *Mercedes-Benz Sprinter* was used as design vehicle for the determination of the storage area for collective on-demand ride services. This vehicle has a capacity of eight travellers per vehicle (Mercedes-Benz, 2018). Because these rides can be booked in advance, it is expected that these minibuses will travel when the demand equals the capacity, especially during peak hours. Therefore, collective on-demand ride services are assigned an occupancy rate of eight.

Table 4.12 summarises the findings of this paragraph in which the occupancy rates for all relevant means of transport are depicted, including the consulted source or estimation method.

Table 4.12 Overview of the occupancy rates

Means of access/egress transport	**Occupancy rate** [travellers/vehicle]	**Source/estimation method**
Car	**1.2**	European Environment Agency (2015)
Bicycle	**1**	Capacity
E-scooter	**1**	Capacity
On-board vehicle	**1**	Capacity
Individual traditional ride services	**1.2**	Occupancy rate passenger car
Collective traditional ride services	**25**	European Environment Agency (2015)
Individual on-demand ride services	**1.2**	Occupancy rate passenger car
Collective on-demand ride services	**8**	Capacity design vehicle

4.6 Footprint

The access/egress transport footprints can be determined for all considered means of access/egress transport with the following formula:

$$Access/egress\ transport\ footprint = \frac{storage\ area}{design\ frequency * occupancy\ rate}$$

Table 4.13 shows the footprints and Figure 4.9 illustrates how the values are in relation to each other. A complete overview of all values that have been determined in this Chapter is given in Appendix F.

Table 4.13 Overview of the footprints

Means of access/egress transport	**Footprint** [m^2/traveller]
Walking	**0.00**
Private bicycle	**0.30**
Shared bicycle[1]	**0.40**
Private e-scooter	**0.10**
Shared e-scooter[1]	**0.13**
Private on-board vehicle	**0.00**
Private car	**17.50**
Shared car[1]	**7.50**
Individual traditional ride service	**3.89**
Collective traditional ride service	**0.43**
Individual on-demand ride service	**0.49**
Collective on-demand ride service	**0.34**

[1] Average of the three vehicle sharing services.

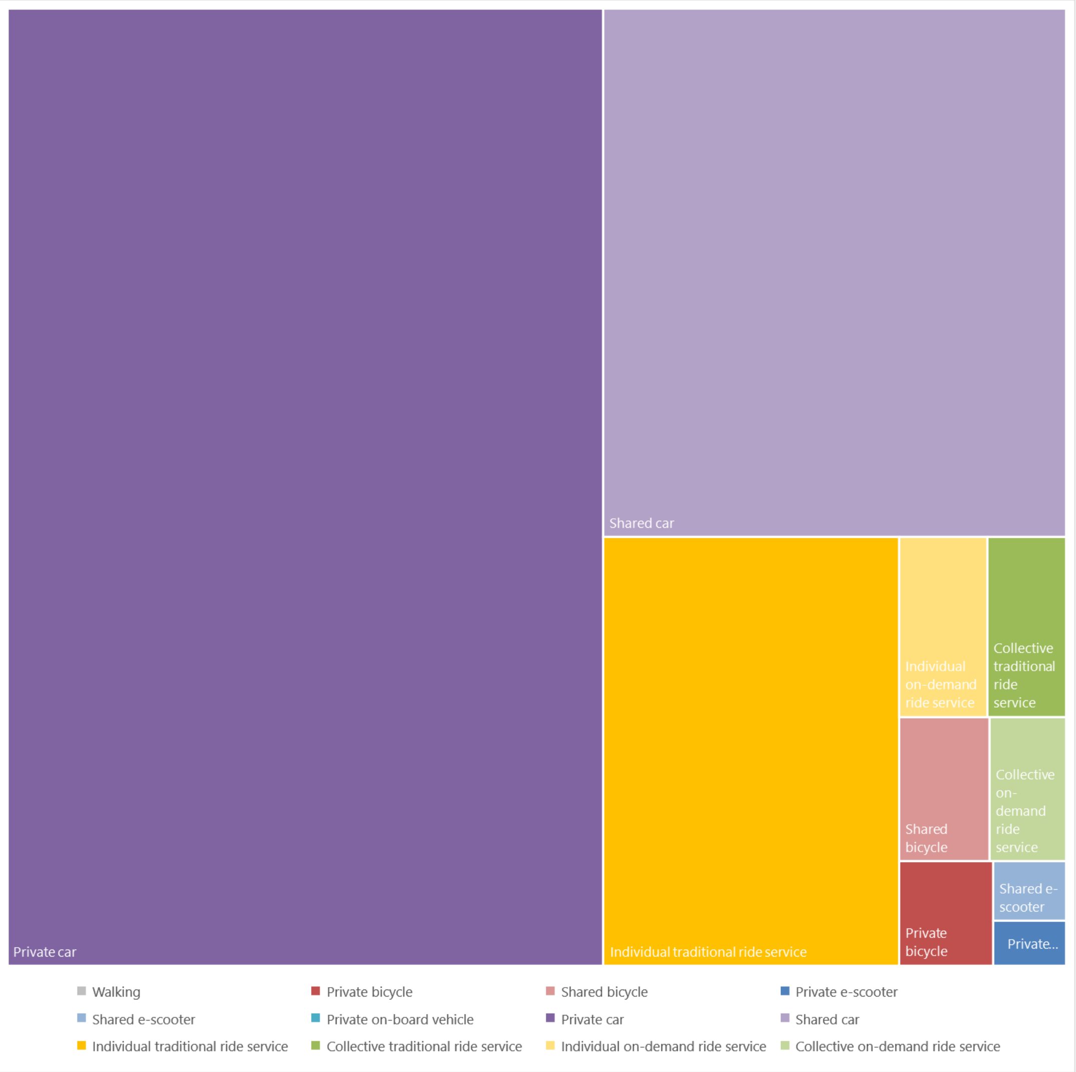


Figure 4.9 Visual comparison of the footprints

The footprints emphasise how (in)efficient means of access/egress transport are regarding the required land use per traveller. The private car, shared car and individual traditional ride services form the top three and all require more than one square meter per traveller. Interesting is that all these services rely on the use of a passenger car. Also the service with the fourth largest footprint, individual on-demand ride services, relies on the use of a passenger car, but its footprint matches the other (lower) values. Figure 4.9 shows that one traveller using a private car, requires more area than when all other means of transport are used by one traveller each. Although a shared car requires less than half the amount of area that is required for a private car, the footprint is still significantly higher than for the other means of access/egress transport. The e-scooter, both private and shared, requires relatively little space. The vehicle is small and can be stored efficiently due to its foldable design. However, walking and private on-board vehicles are the most efficient regarding the required area, since these means of access/egress transport were not associated with an access/egress facility to park or stop at the railway station area. The footprints of other means of transport that require space are within the range of 0.34 – 0.49m²/traveller.

4.7 Conclusion

For all considered means of access/egress transport, the so-called access/egress transport footprint was determined. This indicator consists of three components: (1) storage area, (2) design frequency and (3) occupancy rate, and was given the following definition:

> *'The required area per traveller for a means of access/egress transport to park or stop at the railway station area based on the number of departures and arrivals during a peak period.'*

Storage areas were determined based on existing design vehicles and design guidelines. For new means of access/egress transport, the dimensions of existing vehicles from practice were used as reference. For the determination of the storage areas, not only the dimension of the parking space (i.e. direct land use), but also indirect land use sections such as parking lanes (adjacent to the parking space) and platforms were considered. Other areas such as driving lanes (to reach the parking lanes) and possible construction elements of the facility were not considered. The second component of the footprint, the design frequency, illustrates how often the same parking space is used during a peak period. This is the period in which the largest share of travellers make use of the railway station and assumed to be normative for the provision of access/egress facilities. Generally, this is either the morning peak (07:00 – 09:00) or evening peak (16:00 – 18:00), dependent per railway station. Each means of transport is assigned a design frequency, dependent on its home-end and activity-end potential and/or the expected operating frequency. The third, and last, component of the footprint is the occupancy rate. These values were collected from literature, if available, or estimated when not based on the characteristics of the vehicle.

An overview of the values for all components that have been determined in this chapter is given in Table 4.14. The footprints are depicted in the last column and calculated with the following formula:

$$Access/egress\ transport\ footprint = \frac{storage\ area}{design\ frequency * occupancy\ rate}$$

Table 4.14 Overview of the footprints and all three components

Access/egress modes	Storage area [m²]	Design frequency [vehicles/peak period]	Occupancy rate [travellers/vehicle]	Footprint [m²/traveller]
Walking	0	NA	NA	**0.00**
Private bicycle	0.6	2	1	**0.30**
Shared bicycle[1]	0.6	1.7	1	**0.40**
Private e-scooter	0.2	2	1	**0.10**
Shared e-scooter[1]	0.2	1.7	1	**0.13**
Private on-board vehicle	0	NA	1	**0.00**
Private car	21	1	1.2	**17.50**
Shared car[1]	14	1.7	1.2	**7.50**
Individual traditional ride service	28	6	1.2	**3.89**
Collective traditional ride service	260	24	25	**0.43**
Individual on-demand ride service	28	48	1.2	**0.49**
Collective on-demand ride service	130	48	8	**0.34**

[1] Average of the three vehicle sharing services: roundtrip, one-way and peer-to-peer.

These numbers show that means of access/egress transport that rely on the use of a car, requires the largest amount of area per traveller. The vehicle with the lowest footprint is the e-scooter due to its compact use and foldable design. Because walking and on-board vehicles were not associated with an access/egress facility to park or stop at the railway station area, these means of transport are associated with a footprint of zero.

In the next chapter, a mode choice experiment is set up and conducted to observe current and future mode choice decisions by travellers.

5 ACCESS/EGRESS MODE CHOICE EXPERIMENT

5.1 Introduction

In this chapter, the mode choice experiment for this research is introduced. At the end of this chapter an answer can be given to the fifth sub-question of this research, which was defined as:

> **5. What is the expected modal split in the predefined development paths for access/egress transport?**

The next paragraph (5.2) introduces the case study for the mode choice experiment. Hereafter (paragraph 5.3), the survey is explained in further detail over various subparagraphs. Paragraph 5.4 elaborates on the outcomes of the survey, and the chapter ends with a concluding paragraph (5.5).

5.2 Station Almere Centrum – case study location

One specific railway station is necessary to collect data on modal choice decisions for the predefined scenarios constructed in Chapter 3. Because each railway station is unique in terms of access/egress transport, a general survey is not applicable. In theory, all existing railway stations in the Netherlands can be selected to conduct the survey. However, there are some factors (e.g. number of travellers, the distribution of travellers over the day, the station function, the available means of access/egress transport, (re)development plans) to consider when selecting a railway station.

For this research, railway station Almere Centrum was selected as case study location based on the factors mentioned above. A considerable number of travellers (25,888) make use of the railway station on an average weekday which makes it possible to collect a sufficient sample (NS, 2018a). Besides, the share of home-end and activity-end travellers is evenly distributed, and travellers are able to choose from different means of access/egress transport at Almere Centrum. Last but not least, there are ideas to renovate the station and its surrounding area by 2022, and perhaps this research can contribute to these (re)development plans (Omroep Flevoland, 2018). Figure 5.1 gives an overview of the railway station and its surrounding, including the available access/egress facilities at the railway station area. A larger map and more detailed information on the access/egress facilities is provided in Appendix G.1.

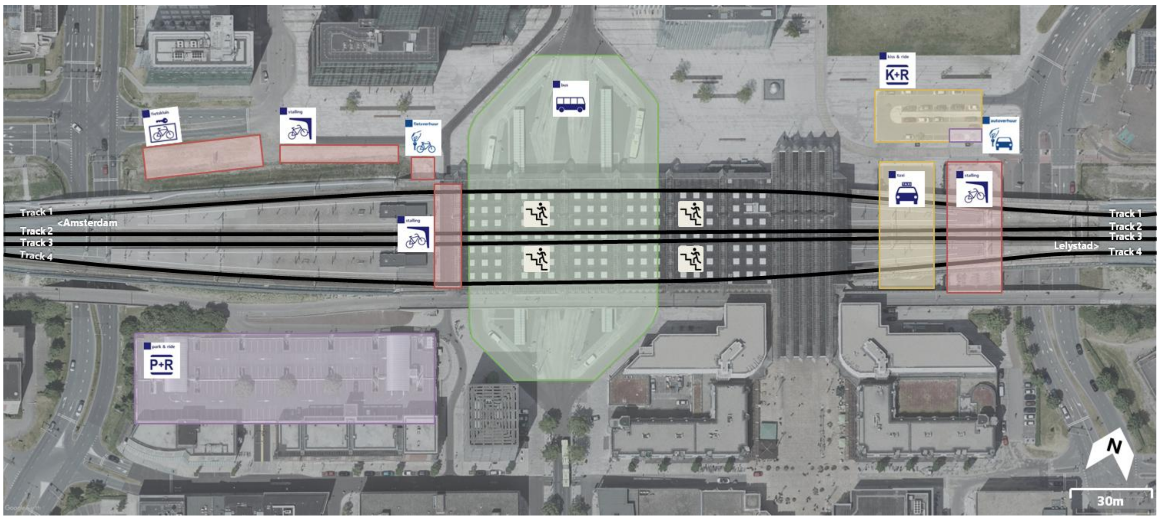


Figure 5.1 Map of railway station Almere Centrum and its access/egress facilities

Specific data for this railway station was requested from *NS Stations* and attached to this report in Appendix G.2 (NS Stations, 2018). The data reveals that approximately 12,800 of the 25,888 travellers are unique travellers, which illustrates that the majority of the travellers uses the station at least two times per day. An analysis of the distribution of travellers over the day was performed and attached to this report in Appendix G.3. The analysis shows that an average weekday morning peak (07:00 – 09:00) accounts for the largest share (18.2%) of travellers. During the evening, travellers are more evenly distributed and an evening peak is not as present (13.5% between 16:00 – 18:00) as can be observed for the morning. During the weekends, no peaks can be observed at all. From these observations, it can be concluded that a weekday morning peak is the representative timeframe for which access/egress facilities at Almere Centrum should be designed.

The data from *NS Stations* also shows that Almere Centrum is used for slightly more home-end trips (58%) than activity-end trips (42%). The most important destinations for people who start their train journey at railway station Almere Centrum are Amsterdam Centraal (18%) and Lelystad Centrum (10%). The modal split percentages for both trip stages are depicted in Figure 5.2 and origin from the dataset of *NS Stations* too.

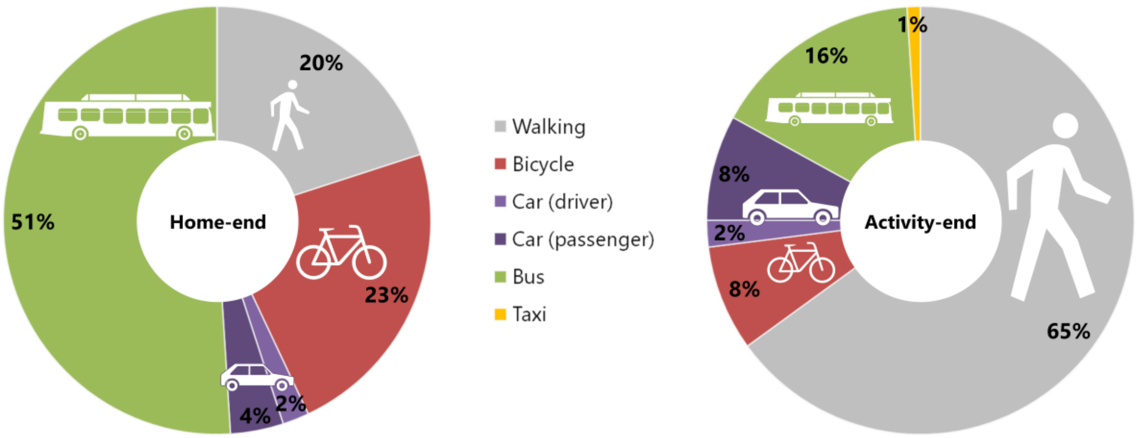


Figure 5.2 Modal split of railway station Almere Centrum according to the data from *NS Stations*

The introduction of this report already elaborated on the average modal split of the 20 busiest railway stations in the Netherlands (Figure 1.2). Compared with the modal split of railway station Almere Centrum, some interesting differences can be observed. The bicycle share for home-end trips at Almere Centrum is significantly lower (23% versus 43%). Additionally, the car is used for only 6% of the home-end trips, which is relatively low compared to the car share for home-end trips to and from the 20 busiest railway stations (15%). The public transport share, on the other hand, is considerably higher at this trip-end for Almere Centrum (51% versus 19%). These differences can be the result of the extensive bus network in Almere and other railway station specific factors which are different from the 20 busiest railway stations. For activity-end trips, walking is even more popular among travellers at Almere Centrum (65% versus 45%). Although high public transport shares are observable for home-end trips at Almere Centrum, the share at the activity-end is relatively low (16%). Activities are probably less accessible by public transport or at a short distance from the railway station. This would also clarify the high share of walking at this trip-end.

The remaining data from *NS Stations* gives information on the ages and trip purposes of travellers at railway station Almere Centrum. All data that was provided by *NS Stations* will be used to analyse the data that will be collected by the survey of this research.

5.3 Survey

5.3.1 Method

Although an extensive list of factors on access/egress mode choice was found during the literature review, the survey of this research will not specify attributes. Using attributes and varying with attribute levels would make the research too extensive and does not fit in the available amount of time. Moreover, this research aims to assess the railway station area regarding the required land use for access/egress facilities and is not solely focused on mode choice decisions. Because attributes will be absent, mode choice decisions of respondents are dependent on the available information and expectations regarding the service provided by the different means of access/egress transport.

Because travellers at railway stations do not have the time to complete a survey on site, the survey was made online. This allows travellers to complete the survey at, for them, a suitable moment. Google Forms is a free online tool and was used to construct the survey. The tool has all the features that are required for this survey, including survey logic and image choice. Survey logic makes it possible to redirect respondents to a specific question based on a given answer. Image choice makes it possible to show figures as multiple choice options instead of text only. The digital survey was made accessible for travellers via a link and QR code, depicted on the flyers that were distributed at Almere Centrum. An example of the flyer that was designed for this survey is attached to this report in Appendix H.

5.3.2 Design

Because surveys are often experienced as dull, the design of the survey plays a crucial role to get enough and reliable responses. The basic principle for the construction of the survey was to make the survey easy and clear to understand. Besides, respondents should be able to complete the survey within a limited amount of time. Since most of the travellers are familiar with the Dutch language, the survey was designed in Dutch. During the construction process, feedback was asked from various persons with different backgrounds to improve the quality of the survey and to eliminate vagueness and uncertainties. Appendix I contains the survey that was constructed for this research. The remainder of this subparagraph briefly explains all parts of the survey.

Introduction

The introduction of the survey describes the background and purpose of the experiment. The format and the expected amount of time that it takes to complete the survey are also communicated to inform respondents on what they can expect. The contact details of the researcher are provided at the end of the introduction to allow respondents to seek contact when they have any questions or comments.

Part 1 – Station function

Because access/egress mode choice strongly depends on the availability of transport means, the first part of the survey aims to capture the station function of Almere Centrum for each respondent. Besides, respondents are asked to select the date and time on which the trip was made. This information can later be used to identify irregular mode choice decisions in case of extraordinary events (e.g. disrupted transport services, extreme weather conditions). Based on the respondent's answer to the station function, a respondent is redirected to the survey that applies to him or her, which can be either the home-end or activity-end survey. Respondents who do not use the train or those who transfer between trains are being thanked for their cooperation but precluded of the remaining questions.

Part 2 – Current mode choice

In the second part of the survey, respondents are asked to specify the means of transport they used for the trip to/from the railway station. Furthermore, respondents are asked to specify the distance of their home-end or activity-end trip. Because the distance was found to influence access/egress mode choice by many researchers during the literature review, the factor is included in the survey.

Part 3 – Future mode choice

The third part asks respondents to choose a means of access/egress transport in each of the four scenarios that were constructed in Chapter 3. Each means of access/egress transport is explained briefly at the beginning of this section. Still, this information is also provided at each question for the means of transport where respondents can choose from. If respondents indicate to prefer a shared vehicle in scenario 2 and/or 4, an additional question is asked to discover the preferred form of sharing. Home-end travellers are asked to choose between free-floating and P2P vehicle sharing. Although all three business models were assumed to have a potential for activity-end trips, activity-end travellers must choose between roundtrip and free-floating vehicle sharing. Because P2P and roundtrip vehicle sharing provide the same service from an activity-end traveller perspective, both services are united in the survey.

Part 4 – Final questions

In the fourth and last part of the survey, respondents are asked to answer four general questions about their gender, age, driver's license possession and trip purpose. All these factors were found to influence access/egress mode choice during the literature review and are easy to analyse in this survey. Moreover, *NS Stations* provided data on the respondents' age and trip purpose, which allows the researcher to make comparisons. For the other features of which data is missing, other sources will be consulted to make comparisons.

Thank you!

When all questions are answered, respondents are thanked for their time and effort. Again the contact details of the researcher are provided in case respondents come up with any questions or comments during the survey.

5.3.3 Practical information

The survey was conducted in week 47 of 2018 from Monday 19 November until Friday 23 November. During these five days, flyers were distributed among travellers at Almere Centrum during the morning peak (07:00 – 09:00) and evening peak (16:00 – 18:00). No extraordinary events (e.g. disrupted transport services, extreme weather conditions) occurred during these days. Although the weather conditions in November are different from other months, general mode choice decisions are expected to be captured by this survey. The surveyor, also the author of this report, was present during all peak hours on all weekdays. On Tuesday and Friday, an extra surveyor provided assistance. Because multiple entrances and exits are present at railway station Almere Centrum, the surveyor(s) changed location(s) during the week. This also reduced the chance of asking travellers a second time. Because it was not allowed to be active on the platforms or block the transfer of travellers, flyers were distributed at a sufficient distance from the gates, entrances and elevators. For recognition, the surveyors wore reflective orange vests with the TU Delft logo on the back and a badge with the same logo and name of the department on the front. Travellers were asked to fill in the graduation survey online via the link on the flyer. Making travellers aware that the survey was for graduation purposes increased the response rate. Emphasising that the survey could be filled in online also led to a higher response, as travellers were able to choose their own suitable moment.

The number of respondents that are required to have a representative sample size can be calculated with the following formula:

$$Sample\ size = \frac{\frac{z^2 * p(1-p)}{e^2}}{1 + \frac{z^2 * p(1-p)}{e^2 N}} = \frac{\frac{1.96^2 * 0.5 * (1-0.5)}{0.05^2}}{1 + \frac{1.96^2 * 0.5 * (1-0.5)}{0.05^2 * 4{,}712}} = 355$$

with:

- z = z-score (1.96 for 95% confidence level)
- p = standard of deviation (percentage in decimal form, 50% = 0.5)
- e = margin of error (percentage in decimal form, 5% = 0.05)
- N = population size (average number of weekday morning peak travellers = 4,712, 18.2% of 25,888)

For the majority of the variables (z-score, standard of deviation and margin of error), standard values can be used. However, the population size refers to the number of people that are being researched. For this research, weekday morning peak travellers are among the group of interest. According to the formula for the desired sample size, 355 respondents are required to have a representative sample.

5.4 Results

In total, 1,955 flyers were distributed among travellers at railway station Almere Centrum. At the end of the week, on Sunday 25th of November 2018 at 23.59, the survey was closed and all 442 responses were exported. An analysis of the results was conducted to improve the quality of the sample. 23 respondents answered that they either transferred between trains or did not use the train at all. These travellers do not fit within the scope of this research. Three other respondents answered that their access/egress mode was a train, which indicates that these respondents did not understand the question and purpose of the research. Another observation which illustrated that travellers did not understand the aim of the survey is related to the distance of travellers' home-end or activity-end trip. Fifteen respondents answered that they walked a distance larger than 10km to/from the railway station. It is expected that these respondents referred to their total trip distance. Because of this, it is imaginable that these respondents answered the mode choice questions also from a 'total trip' perspective instead of an access/egress perspective. All 41 surveys of the abovementioned respondents were removed from the final sample. The remaining 401 surveys were used for further analyses. Because a minimum of 355 respondents was required, it can be concluded that the achieved sample represents the total population of interest.

5.4.1 Descriptive statistics

Descriptive statistics describe the basic features of a dataset. By means of descriptive statistics, the collected data from the survey can be analysed and compared with other data from among others *NS Stations*. However, it should be mentioned that flyers for the survey of this research were distributed during weekday peak hours only, while *NS Stations* gathered general data from travellers at Almere Centrum. For the features that were not researched by *NS Stations*, other sources are consulted to compare the data.

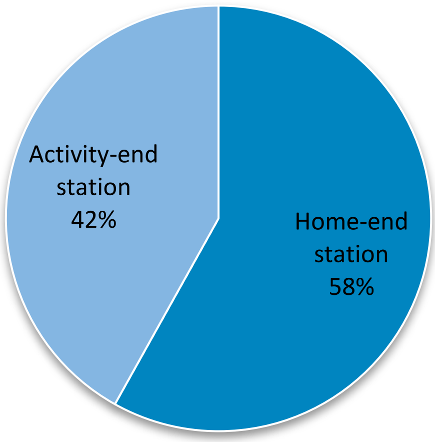


Figure 5.3 Station function of railway station Almere Centrum

Figure 5.3 shows the station function of Almere Centrum according to the findings of the survey. These numbers illustrate that railway station Almere Centrum is used more as a departure station (58%, 233 respondents) than arrival station (42%, 168 respondents). The same percentages were also found by *NS Stations* which has already been discussed in the second paragraph of this chapter.

The survey of this research also collected data on gender, age, trip purpose and driver's licence possession. These results are depicted in Figure 5.4. The distribution of men and women is 55% versus 45% respectively. *NS Stations* did not provide data on the gender of the respondents. However, the open source dataset of the *CBS* on passenger mobility in 2017, shows the same ratio of men/women for travellers making a trip by train (Centraal Bureau voor de Statistiek, 2018b).

Regarding the age of the respondents, it can be observed that more travellers aged 45-64 are among the respondents of this survey than of *NS Stations'* (36% versus 26%). The age category 20-24 on the other hand, is less represented (17% versus 24%). Differences for other age categories are within a range of 5%. Because the data from *NS Stations* originates from surveys as well, it is not by definition true that values collected via the survey in this research are wrong. Differences can be a result of the time of day at which age cohorts travel because flyers to access the survey were distributed during peak hours only.

The trip purpose was also researched in both the survey of this research and by *NS Stations*. Differences can be observed for the three distinguished travel motives. Because flyers for the survey were distributed during weekday peak hours, respondents travelling for commuting/business (72% versus 54%) and school/study (21% versus 13%) purposes are overrepresented. People travelling for social/recreational purposes are expected to use the railway station especially outside the peak hours and during the weekends. This also explains the lower share found in this research (7%), relative to the value found by *NS Stations* (33%).

Of all respondents that completed the survey for this research, 80% indicated to be in possession of a car drivers license. As for the gender, *NS Stations* did not provide data on this determinant. General data on the total number of drivers licenses in the Netherlands, together with the total number of inhabitants, indicate that 64% of the people are in possession of a drivers license (Centraal Bureau voor de Statistiek, 2018c). The high share found in this research illustrates that the possession of a driver's license does not by definition means that this group prefers a car instead of the train.

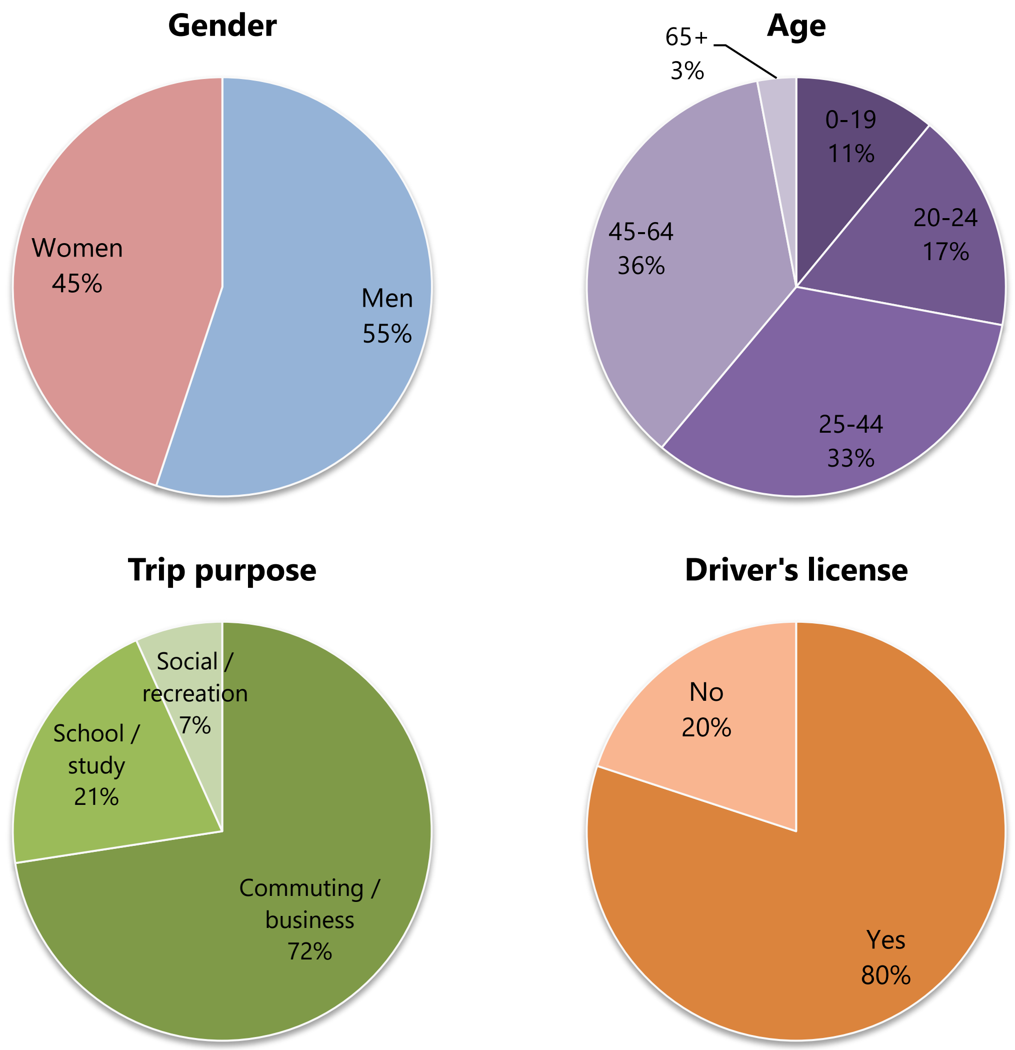


Figure 5.4 Statistics from survey data on various mode choice factors

5.4.2 Modal split

All modal split data that is collected by the survey, for the current situation and all constructed scenarios, are added to the report in Appendix J.1. In this subparagraph, the results are analysed.

Current situation

The second part of the survey asked travellers for their current means of access/egress transport. Additionally, respondents were asked to give an indication of the distance of this trip to/from the railway station. The results of both are depicted in Figure 5.5 and Figure 5.6 respectively.

Respondents that answered 'other' on the question about their current transport mode had to specify their means of transport. Three respondents chose this option and indicated to use a scooter (2x) or a moped for their home-end trip. For activity-end trips initially, seven respondents chose the option 'other'. However, after analysing the replies, it was found that six of them travelled by car as a passenger. As a result of a wrong consideration during the construction phase of the survey, this option was not available for respondents that made an activity-end trip. Because the assumption was that travellers do not have access to a car at this trip-end, the car options were excluded. However, only the car (driver) option had to be excluded and not the car (passenger) variant. The results were adapted manually to correct for this, and the six responses were assigned to the option 'car (passenger)'. The remaining respondent indicated that he or she used a scooter.

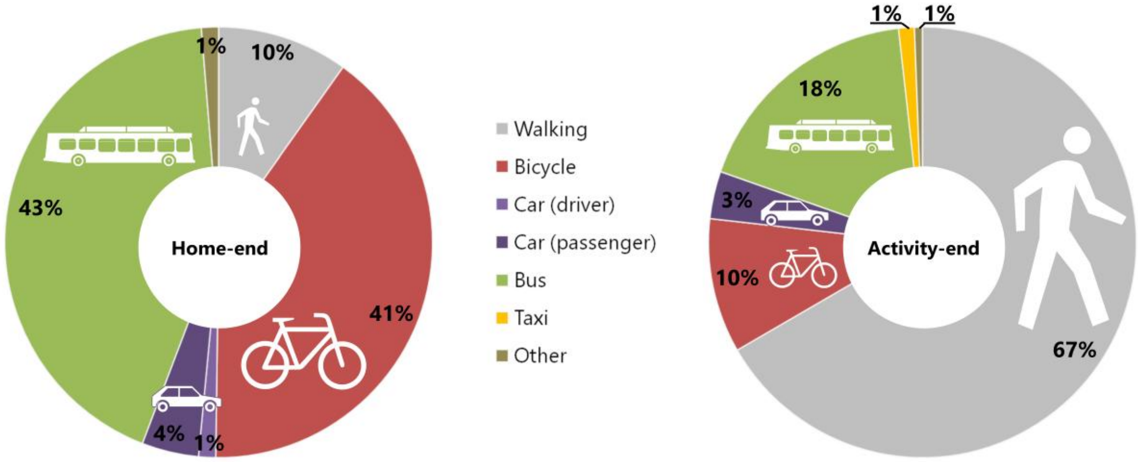


Figure 5.5 Modal split of station Almere Centrum for home-end and activity-end trips

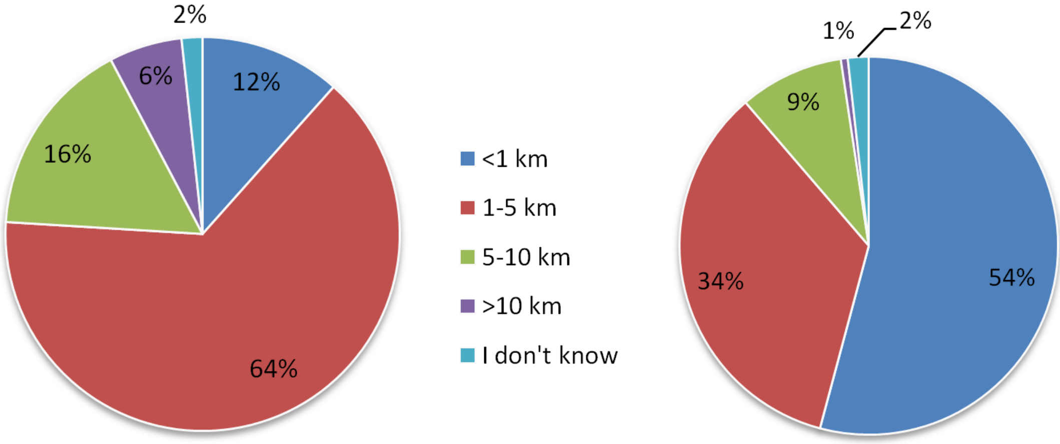


Figure 5.6 Home-end distances (left) and activity-end distances (right) for railway station Almere Centrum

Data on the modal split for railway station Almere Centrum is also part of the data from *NS Stations*. These numbers were already discussed in paragraph 5.2 and depicted in Figure 5.2. Information on the access/egress distance, on the other hand, is not provided by *NS Stations* and therefore not comparable. However, the data on the access/egress distances allows the researcher to elaborate on the modal split data.

It can be observed that activity-end trips are characterised by short distances with a maximum of 1km (54%). This also explains the large share (67%) of travellers that walk from the railway station to their activity and the other way around. For home-end trips, most of the trips fall within the range of 1-5km (64%). As a result, other means of transport such as the bus (43%) and the bicycle (41%) are more frequently used at this trip-end. Regarding the data from *NS Stations*, lower shares of walking (10% versus 20%) and bus (43% versus 51%) are observed for home-end trips. However, the share of people cycling is considerably higher (41% versus 23%). For activity-end trips, the data is more comparable. Only the car is used to a much lesser extent (3% versus 10%) according to the data from the survey in this research. Again, an explanation for the differences can be the considered periods in which both surveys were conducted. For this research, flyers to fill in the survey were distributed during peak hours only. In addition, because the survey held by *NS Station* dates from 2016, travellers might have changed their means of transport since.

Home-end trips

It was already observed that in the current situation, the majority of the home-end trips are made by bicycle (41%) and bus (43%). In each of the four scenarios that are constructed in Chapter 3, interesting findings can be observed regarding the access/egress mode choice. For each of the four scenarios, a Sankey diagram is constructed, based on the outcomes of the survey (Figure 5.7). The left side of each Sankey diagram shows the current means of access/egress transport of home-end travellers. The right side of the diagrams show the preferred means of access/egress transport in the respective scenarios for these travellers, based on the home-end scenario matrix depicted in Figure 3.4. All diagrams are also added separately to this report in Appendix J.2 with larger dimensions.

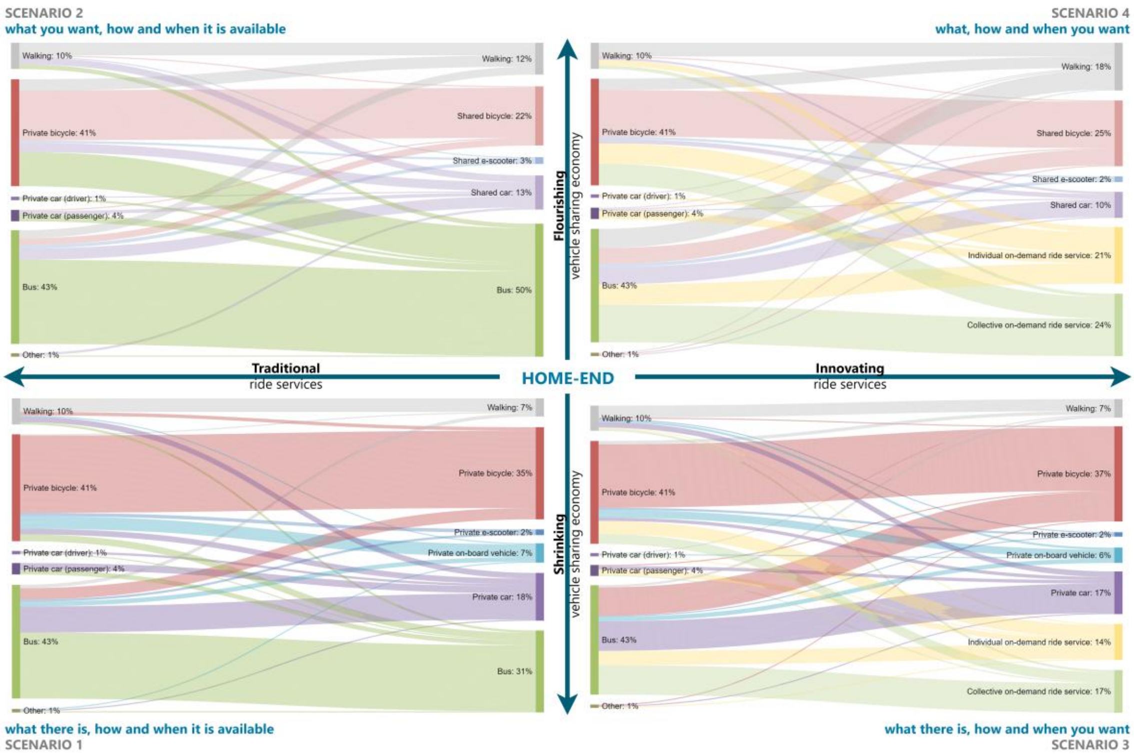


Figure 5.7 Sankey diagrams for home-end trips

In general, it can be observed that the bus and private bicycle remain a high share in the scenarios where these means of transport remain available. In scenarios where these services are not available, the preference of travellers is divided over all means of access/egress transport available. Some interesting observations for home-end trips solely are further discussed below. The data to elaborate on these observations is added to this report in Appendix K.1.

Car popularity

First of all, the car is found to be a popular transport mode in each of the four scenarios, regardless of the type of car available (private or shared). Although the car is currently used for only 5% of the home-end trips (driver + passenger), the car share in each of the four scenarios is 18%, 13%, 17% and 10% respectively (Figure 5.7). The data reveals that 32% of the home-end travellers, which equals 74 respondents, prefer to use the car in one or more scenarios. The numbers illustrate that especially younger (0-24, 57%) women (62%) travelling for school/study purposes (51%) prefer to use a car in at least one of the scenarios. As expected, the home-end distances are larger for this group than for the average home-end traveller. More trips with a length of 5-10km and longer than 10km are represented in this dataset. Still remarkable is the relatively high share of trips by car which are shorter than 1km (9%).

Another interesting observation regarding the popularity of the car is found when analysing the characteristics of travellers who choose a private car when available (scenario 1 and 3). Among this group, the percentage of women (72%) is even higher than observed during the previously discussed observation. Travellers aged 0-24 account for almost three quarters (72%) of this group, while the average is 27%. In line with this result, the number of travellers without a driver's license is also higher and accounts for 40%, which is 20% higher than the average. This illustrates the inexperience of driving a car among a group who prefers to use one.

Both observations show the preference towards the car for specific users of which an explanation is hard to give. Teenagers who do not work yet might get enthusiastic about the idea of travelling by car in the future. However, this does not explain the high share of women among travellers who prefer a car.

Bus users

The traditional bus remains a popular means of transport in the scenarios where the service is available. In scenario 1 and 2, respectively 31% and 50% of the travellers have a preference for the bus. Additionally, a quarter of the travellers (57 respondents) prefer the bus in both of the scenarios. 82% of this group, already uses the bus in the current situation. Data on the characteristics of these travellers do not show extreme differences regarding the average home-end traveller. Still, a majority of them travels for commuting/business purposes (81%) and falls within the age range of 25-44 and 45-64 (both 39%).

Activity-end trips

As for home-end trips, Sankey diagrams are constructed for activity-end trips and depicted in Figure 5.8. The right side of the diagrams show the preferred means of access/egress transport in the respective scenarios for these travellers, based on the activity-end scenario matrix depicted in Figure 3.5. All diagrams are also added in Appendix J.2 with larger dimensions.

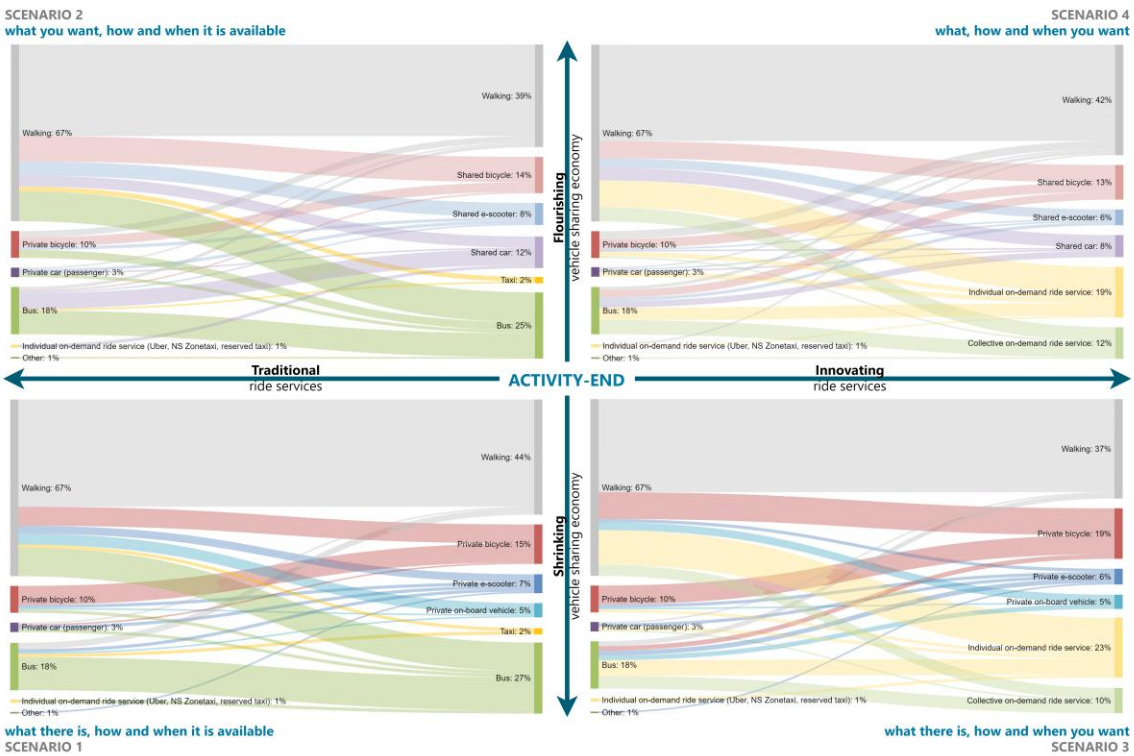


Figure 5.8 Sankey diagrams for activity-end trips

In general, it can be observed that walking remains a high share among activity-end travellers. However, in each scenario, the share decreases considerably. Some interesting observations for activity-end trips solely are further discussed below. The data to elaborate on these observations is added to this report in Appendix K.2.

Ex pedestrians

The share of travellers that walk at the activity-end of the trip reduces in each of the four scenarios (44%, 39%, 37% and 42%) relative to the current situation (Figure 5.8). The data illustrates that although 67% of the activity-end trips are made by foot, 20% of the travellers actually never prefer to walk. This group of travellers prefer not to walk although 82% of them has to walk less than 1km. The characteristics of the travellers among this group are not considerably different from the average activity-end traveller.

Pedestri(F)ans

Besides the group of travellers who never prefer to walk, there is a large share of activity-end travellers (30%) who indicate to have a preference for walking in each of the four scenarios. Most of them (94%) do already travel by foot in the current situation. Again, the majority of the trips (71%) are less than 1km. However, 27% of this group walks a distance of 1-5km. Characteristic differences are present among this group relative to the average activity-end traveller. The share of men among this group is 65% and also travellers aged 25-44 (45%) are present in larger numbers. This illustrates that middle-aged men travelling for commuting/business purposes (86%) are more willing to walk, regardless of the available transport modes and services.

Access/egress trips in general

In addition to the home-end and activity-end observations, general observations are discussed in the remainder of this subparagraph. Especially interesting are the relatively new transport modes and services that are included and the characteristics of travellers who prefer to make use of them. Six themes will be further discussed. The data to elaborate on these observations is added to this report in Appendix L. At the end of this subparagraph, a visual summary of the observations is made by means of an infographic.

Sharing is hot

Different types of shared vehicles are included in the scenario matrices and the outcomes of the survey show that there is potential for all of them. In order to find out what type of travellers do have a preference for sharing, travellers who prefer any type of shared vehicle (bicycle, e-scooter or car) when available (scenario 2 and 4) are further analysed. 21% of the travellers indicate to choose a shared vehicle in both scenarios. The results show that slightly more men (58%) than women (42%) are among this group relative to the average traveller. Another interesting observation is the increased share of travellers aged 25-44 (35%) and 45-64 (40%). Regarding the trip purpose, 78% of the travellers in this group indicate to travel for business/commuting purposes.

During the survey, travellers were also asked to choose their preferred form of sharing, if travellers indicated to have a preference regarding any type of shared vehicle in scenario 2 and/or 4. For home-end trips, travellers were able to choose between the sharing forms free-floating and P2P. For activity-end trips, the available forms were roundtrip and free-floating. The results, part of Appendix J.1, show that in both the sharing scenarios, at both trip-ends, the shares are almost equally divided. For home-end trips, free-floating sharing (52%) has a slightly greater preference over P2P sharing (48%). For activity-end trips, 53% of the travellers prefer a free-floating vehicle and 47% a roundtrip.

.. or not

The Sankey diagrams already illustrate the unattractiveness of shared vehicles relative to private vehicles. This observation is especially visible for home-end trips in the second scenario where the share of bus and walking increases as a result of the unavailability of private vehicles. To analyse this in further detail, the characteristics of travellers who prefer a private vehicle in scenario 1, but subsequently no shared vehicle in scenario 2, are examined. This group also accounts for 21% of the travellers, which was found to be the share of travellers who prefer to share a vehicle as well. Among the group who do not prefer to share a vehicle, the majority of the travellers are women (52%), while the average was 'only' 45%. In line with the unexpected findings on the previous theme, the share of younger travellers aged 0-19 increased by 5% to a total of 16%. Looking at the trip purpose of the travellers among this group shows larger shares for school/study (25%) and social/recreation (12%) trips. These findings are in line with the findings on the ages as young travellers are expected to travel especially for these purposes. Presumably, these travellers are not so willing to share a vehicle and prefer to have a vehicle for their own.

Flexible rides are hot

The other innovative transport services, part of the scenario matrices, are the on-demand rides. As for shared vehicles, travellers who prefer any form of on-demand ride services (individual or collective) when available (scenario 3 and 4) are further analysed. First of all, this group is slightly larger (23%) than the groups who were pro- and anti-vehicle sharing. As expected, the largest share (46%), uses the traditional bus as current means of transport. On-demand ride services, both individual and collective, can be seen as a flexible upgrade compared to traditional forms such as the bus. Again, it is interesting to see that older people are more willing to make use of innovative services. The share of travellers aged 45-64 increases by 13% to a total share of 49%, at the expense of groups aged 20-24 (-5%) and 25-44 (-10%). An explanation for this can be the accessibility of the bus, which is perceived differently between elderly and youngsters. An on-demand ride service no longer has the issues of accessibility.

.. or not

Besides travellers who are in favour of on-demand ride services, travellers with an aversion towards these type of rides are further analysed. The travellers who prefer a traditional ride service in scenario 1, but subsequently no on-demand ride service in scenario 3 are examined. This group is only half the share (12%) of the group of travellers who would prefer an on-demand service when available. Again, the majority of the travellers (74%) already travels by bus in the current situation. The characteristics of these travellers show that especially teenagers aged 20-24 (30%, +13%) travelling for school/study purposes (36%, +15%) are among this group with an aversion towards on-demand ride services. Regarding driver's license possession, a relatively small share indicates to be in possession of a driver's license (66%). Probably, the current bus service is perceived good enough, and changes to the service are not expected to be appreciated.

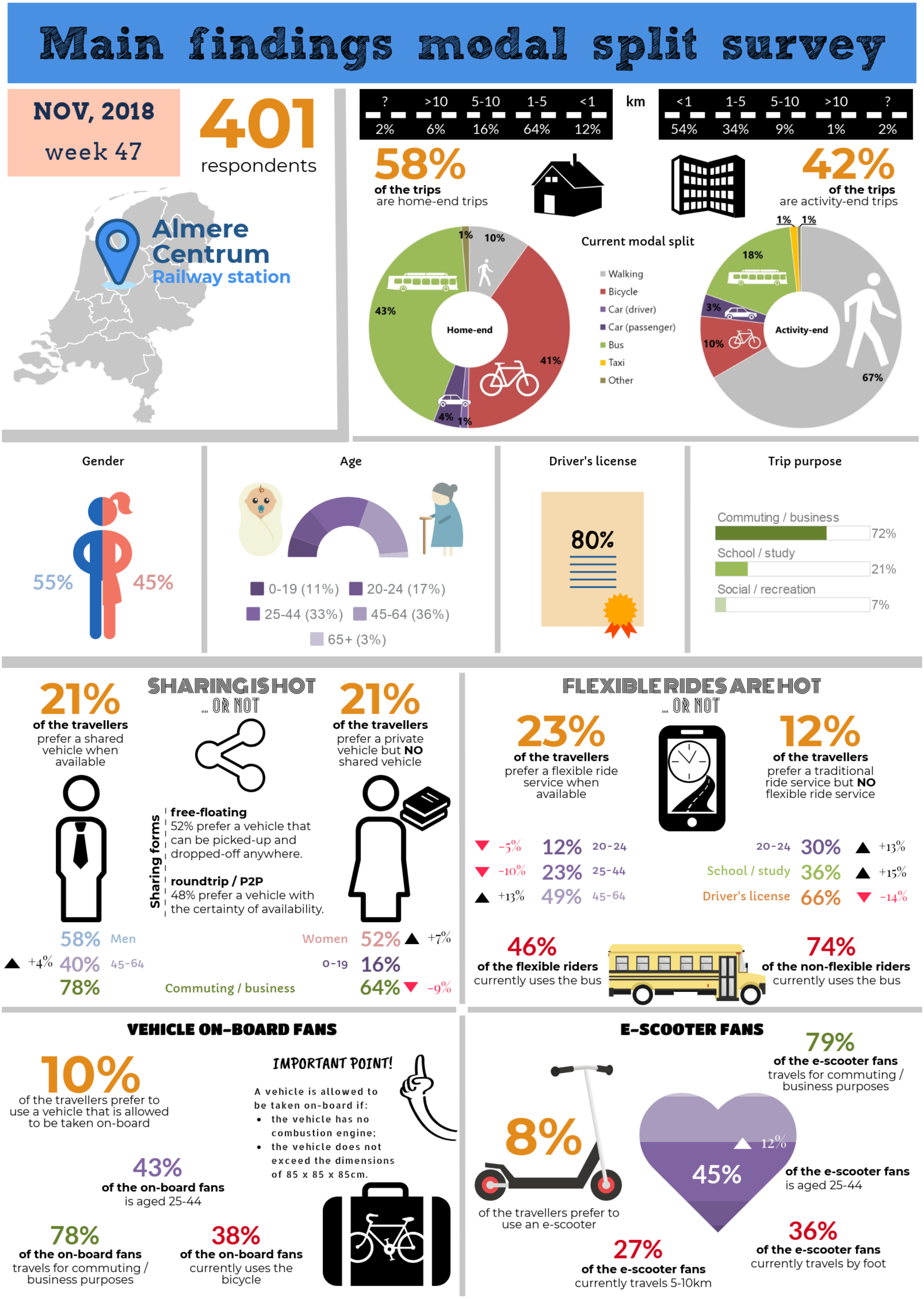
On-board fans

The survey that is performed also allowed travellers to choose for bringing a vehicle on-board in the train in scenarios 1 and 3. 10% of the travellers indicated to prefer this option in at least one of the scenarios. This option was found popular among current cyclists (38%), who probably already bring their vehicle on-board, in the form of a foldable bicycle. This specific type of bicycle was not part of the answer options, and existing users are categorised as general cyclists. The data shows that especially travellers aged 25-44 (43%, +9%), travelling for commuting/business purposes (78%, +5%), are among this group.

E-scooter fans

The e-scooter was part of each scenario in different forms, either private or shared. The data shows that a relatively low share (8%) of the travellers indicated to prefer an e-scooter in at least one scenario. Again travellers aged 25-44 (45%, +12%), travelling for commuting/business purposes (79%, +6%), are largely represented. Relative to the average traveller, more women (48%) are found to be interested in using an e-scooter in at least one scenario. Another interesting observation is the access/egress distance of e-scooter fans. Especially trips between 5-10km (27%, +14%) are popular among e-scooter fans compared to the average traveller, while trips between 1-5km (33%, -19%) are less represented. Still, it should be taken into account that only 8% of all travellers indicate to use an e-scooter in at least one scenario, which is relatively low.

The infographic on the next page visualises the observations that have been discussed for access/egress trips in general.


Main findings modal split survey
NOV, 2018
week 47
401
respondents
Almere
Centrum
Railway station
? >10 5-10 1-5 <1
2% 6% 16% 64% 12%
km
<1 1-5 5-10 >10 ?
54% 34% 9% 1% 2%
58%
of the trips
are home-end trips
42%
of the trips
are activity-end trips
Current modal split
Walking
Bicycle
Car (driver)
Car (passenger)
Bus
Taxi
Other
Home-end
1% 10% 43% 41% 4% 1%
Activity-end
1% 1% 18% 3% 10% 67%
Gender
55% 45%
Age
0-19 (11%) 20-24 (17%)
25-44 (33%) 45-64 (36%)
65+ (3%)
Driver's license
80%
Trip purpose
Commuting / business 72%
School / study 21%
Social / recreation 7%
SHARING IS HOT
... OR NOT
21%
of the travellers
prefer a shared vehicle when available
21%
of the travellers
prefer a private vehicle but NO shared vehicle
Sharing forms
free-floating
52% prefer a vehicle that can be picked-up and dropped-off anywhere.
roundtrip / P2P
48% prefer a vehicle with the certainty of availability.
58% Men
+4% 40% 45-64
78%
Commuting / business
Women 52% +7%
0-19 16%
64% -9%
FLEXIBLE RIDES ARE HOT
... OR NOT
23%
of the travellers
prefer a flexible ride service when available
12%
of the travellers
prefer a traditional ride service but NO flexible ride service
-5% 12% 20-24
-10% 23% 25-44
+13% 49% 45-64
20-24 30% +13%
School / study 36% +15%
Driver's license 66% -14%
46%
of the flexible riders
currently uses the bus
74%
of the non-flexible riders
currently uses the bus
VEHICLE ON-BOARD FANS
10%
of the travellers prefer to use a vehicle that is allowed to be taken on-board
IMPORTANT POINT!
A vehicle is allowed to be taken on-board if:
• the vehicle has no combustion engine;
• the vehicle does not exceed the dimensions of 85 x 85 x 85cm.
43%
of the on-board fans
is aged 25-44
78%
of the on-board fans
travels for commuting / business purposes
38%
of the on-board fans
currently uses the bicycle
E-SCOOTER FANS
79%
of the e-scooter fans
travels for commuting / business purposes
8%
of the travellers prefer to use an e-scooter
12%
45%
of the e-scooter fans
is aged 25-44
27%
of the e-scooter fans
currently travels 5-10km
36%
of the e-scooter fans
currently travels by foot

5.5 Conclusion

The aim of this chapter was to set up and conduct an access/egress mode choice experiment to observe current and future mode choice decisions. For this experiment, the Almere Centrum railway station in the Netherlands was selected as case study location. This station is used by 25,888 travellers on an average weekday, especially during the morning peak (18.2%) and the evening peak (13.5%).

Flyers to access the online survey were distributed on site for one week during the peak hours. In total, 442 surveys were completed by the train travellers of Almere Centrum. After filtering the outliers, 401 surveys remained useful for further analyses. Some basic features of the dataset were analysed and compared with other data from among others *NS Stations*. The modal split data that was collected is depicted in Table 5.1 (home-end trips) and Table 5.2 (activity-end trips). These numbers were also visualised by means of Sankey diagrams in this chapter to illustrate the modal split transition. Because no attributes were specified in the survey, the observed mode choice in each scenario represents the preferred means of access/egress transport of travellers.

Table 5.1 Modal splits for home-end trips

Means of access/egress transport [HOME-END]	**Current Situation**	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**
Walking	10%	7%	12%	7%	18%
Private bicycle	41%	35%		37%	
Shared bicycle			22%		25%
Private e-scooter		2%		2%	
Shared e-scooter			3%		2%
Private on-board vehicle		7%		6%	
Private car	5%	18%		17%	
Shared car			13%		10%
Individual traditional ride service					
Collective traditional ride service	43%	31%	50%		
Individual on-demand ride service	0%			14%	21%
Collective on-demand ride service				17%	24%
Other	1%				
	100%	**100%**	**100%**	**100%**	**100%**

Table 5.2 Modal splits for activity-end trips

Means of access/egress transport [ACTIVITY-END]	**Current Situation**	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**
Walking	67%	44%	39%	37%	42%
Private bicycle	10%	15%		19%	
Shared bicycle	0%		14%		13%
Private e-scooter		7%		6%	
Shared e-scooter			8%		6%
Private on-board vehicle		5%		5%	
Private car	3%				
Shared car	0%		12%		8%
Individual traditional ride service	0%	2%	2%		
Collective traditional ride service	18%	27%	25%		
Individual on-demand ride service	1%			23%	19%
Collective on-demand ride service				10%	12%
Other	1%				
	100%	**100%**	**100%**	**100%**	**100%**

Data on the current modal split of home-end trips shows large shares for the bus (43%) and the bicycle (41%). For activity-end trips, these modes are only used by respectively 18% and 10% of the travellers, after walking (67%). In line with these findings, the majority of activity-end trips (54%) are of 1km or less. The distance of home-end trips is on average a little longer, 64% of the trips are within a range of 1-5km. Regarding the preferred means of access/egress transport in the constructed scenarios, the following observations were made:

Home-end trips

- Although the car is currently used for only 5% of the home-end trips, the transport mode is popular in each of the four scenarios (18%, 13%, 17% and 10%). Especially among women, aged 0-24, travelling for school/study purposes. Even trips shorter than 1km will be made by this group.
- The traditional bus remains popular, especially among travellers aged 25-64, travelling for commuting/business purposes, who already make use of the bus. A quarter of the respondents currently takes the bus and has a preference for this ride service.

Activity-end trips

- Although walking accounts for the largest share (67%) of current activity-end trips, the share reduces significantly in each of the four scenarios (44%, 39%, 37% and 42%).
- Characteristics of travellers who currently walk, but who do not prefer to walk, does not significantly differ from the average activity-end traveller. This group represents 20% of the total number of activity-end travellers.
- 30% of the activity-end travellers always prefer to walk. Especially men, aged 25-44, travelling for commuting/business purposes.

Access/egress trips in general

- 21% of the travellers prefer a shared vehicle when available.
    - Especially men, aged 25-64, travelling for commuting/business purposes.
- In general, the preference of travellers towards the different sharing forms is equally divided. 52% prefer a vehicle that can be picked up and dropped off anywhere, while 48% prefer a vehicle with the certainty of availability.
- 21% of the travellers prefer a private vehicle, but no shared vehicle.
    - Especially younger women, travelling for school/study and social/recreation purposes.
- 23% of the travellers prefer a flexible ride service when available.
    - Especially travellers aged 45-64.
- 12% of the travellers prefer a traditional ride service, but no flexible ride service.
    - Especially younger women, travelling for school/study purposes.
- 10% of the travellers prefer to use a vehicle that is allowed to be taken on-board.
    - Especially middle-aged travellers, travelling for commuting/business purposes who currently cycle.
- 8% of the travellers prefer to use an e-scooter.
    - Especially middle-aged women, travelling for commuting/business purposes.

In the next chapter, the modal split data that was collected in this chapter is used in combination with the developed footprint indicator to assess the required land use at railway station areas.

6 SPATIAL ASSESSMENT OF ACCESS/EGRESS FACILITIES

6.1 Introduction

In this chapter, multiple sections of this research come together to determine and assess the total required land use for access/egress facilities. This chapter aims to give an answer to the sixth sub-question, which was defined as:

6. **How does the expected modal split influences the total required land use for access/egress facilities at the railway station area?**

In the next paragraph (6.2), the procedure to determine the total required land use for access/egress facilities is addressed. Hereafter (paragraph 6.3), the values are determined and analysed for the current situation and the four scenarios. Additionally, the outcomes are compared with the land use of existing facilities at the Almere Centrum. Paragraph 6.4 elaborates on the (re)development possibilities for access/egress facilities based on the findings of this research. As for all chapters, a conclusion is given in the last paragraph (6.5).

6.2 Estimation of the total required land use

The total required land use for access/egress facilities is not to be mixed up with the areas that were determined in Chapter 4. The storage areas elaborated on the area that is required for a means of access/egress transport to park or stop at the railway station area. The values that are determined in the remainder of this chapter, describe the total amount of area that is required for access/egress facilities taking into account all departures and arrivals in the normative peak period. To determine these values, the footprints (Appendix F) that were determined in Chapter 4, and the modal split data (Appendix J.1) that was collected in Chapter 5, are combined.

First, the number of home-end and activity-end travellers during an average weekday morning peak (07:00 – 09:00) are calculated. For railway station Almere Centrum, this was found to be the busiest period in which 18.2% of the travellers make use of the station and for which access/egress facilities should be designed. Because the share of home-end (58%) and activity-end trips (42%) was also researched during the mode choice experiment, the traveller numbers can be calculated for both trip-ends (Table 6.1). Although Almere Centrum had 7% extra travellers in 2017 relative to 2016, a growth in the number of travellers is not taken into account for this research (NS, 2018a). Because this research focuses on a time horizon of 20 years, it is unknown how the number of travellers develop during this considered period.

Table 6.1 Number of travellers for periods and trips of interest

		Number of travellers	
Average weekday		**25,888**	
Weekday morning peak (18.2%)		**4,712**	
• Home-end	(58%)		**2,738**
• Activity-end	(42%)		**1,974**

With the modal split percentages from Chapter 5 and the traveller numbers during the normative peak period from Table 6.1, the following calculations can be made for each means of access/egress transport:

$$HE\ [travellers] = HE[\%] * 2{,}738$$
$$AE\ [travellers] = AE[\%] * 1{,}974$$

Summing up the traveller numbers for both trip-ends gives the total number of travellers that make use of the respective means of access/egress transport. With these numbers and the footprints from Chapter 4, the total required land use for access/egress facilities can be determined. In formulas this can be written as follows:

$$Total\ [travellers] = HE\ [travellers] + AE\ [travellers]$$
$$Total\ required\ land\ use = footprint * total\ [travellers]$$

6.3 Total required land use

The total required land use for access/egress facilities is calculated according to the method described in the previous paragraph. Just as the footprints, the total required land use includes the parking spaces, parking lanes (adjacent to the parking spaces) and possible platforms. Appendix M contains an overview of the calculations and outcomes for the current situation and the four scenarios that were constructed in Chapter 3. First, the current situation will be discussed.

Current situation

The current situation is an interesting one to analyse, as comparisons can be made with the land use of existing facilities. Before this is done, some remarks are made regarding the determination of the required land use for access/egress facilities in the current situation.

Land use assigned to a car (passenger)

Regarding the conducted survey, travellers were asked to specify their role when travelling by car in the current situation. This could either be as a car driver or as a car passenger. When the car driver picks up or drops off the car passenger at the railway station, the service can be characterised as individual on-demand ride service regarding the land use of the vehicle. The vehicle only stops for a short period of time at a designated facility (e.g. K+R). However, it is also possible that the car passenger was not picked up or dropped off, but both the car driver and car passenger entered or exited the car at the railway station area. In this situation, the car has to be parked at a designated car facility (e.g. P+R) and the footprint for the private car should be applied. For home-end trips, it is unknown whether a car passenger is picked up or dropped off, or travelling together with the car driver by train. Therefore, 50% of the car passengers are assigned to the first category and the other 50% to the second category. Consequently, cars assigned to P+R facilities have higher occupancy rates than determined in paragraph 4.5 because relatively little car drivers were captured with the mode choice experiment. For activity-end trips on the other hand, private cars were not assumed to be available at this trip-end. Since no car drivers were among this group, all activity-end car passengers are assigned the footprint of individual on-demand ride services.

Other

Travellers who used a vehicle in the current situation that was not an answer option in the survey were able to choose the option ‘other’. This option was chosen by 1% of the home-end travellers and 1% of the activity-end travellers. All of them used a scooter or moped to/from the railway station. Because these means of transport are not considered in this research, no footprint can be assigned to these travellers. As a result, the required area that is calculated for the current situation is lower. However, due to the relatively low share of scooters and mopeds, the difference is minimal.

Having made these remarks it can be concluded that the current situation requires 2,772m² (Figure 6.1). Although only 2% of the travellers need a space to park their private car, 59%, or 1,645m², of the total land use is required for this group (Appendix M). The land use shares for the other means of transport that require access/egress facilities are better in proportion with the share of travellers that make use of them. The bus, for example, is used by 32% of the travellers and requires 24%, or 662m², of the total required land use. An advantage of the high walking share in the current situation (34%) is that these travellers do not require any area regarding access/egress facilities.

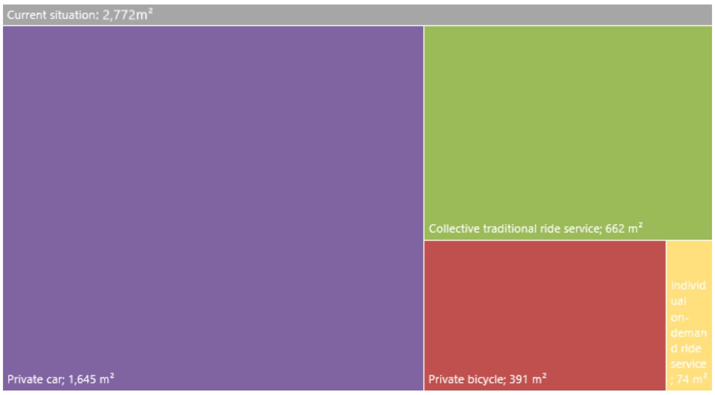


Figure 6.1 Required land use for access/egress facilities in the current situation

The required land use for access/egress facilities can be compared with the land use of existing facilities (Table 6.2). The area of each facility is measured online in Google Maps and represents the total area of the facility as depicted in Figure 6.2. In theory, the calculated values for the required land use are minimum values and existing facilities should be at least this size to provide enough capacity.

Table 6.2 Comparison of the required and existing land use for access/egress facilities

Access/egress facility	Required land use[1]	Existing facilities[2]
Bicycle racks and lockers (private bicycle)	391 m^2	1,780 m^2
Bicycle rental (shared bicycle)	0 m^2	45 m^2
Parking garage (private car)	1,645 m^2	7,300 m^2
Car rental (shared car)	0 m^2	35 m^2
Taxi stands (individual traditional ride service)	0 m^2	960 m^2
Bus station (collective traditional ride service)	662 m^2	7,750 m^2
Kiss and Ride (individual on-demand ride service)	74 m^2	725 m^2
	2,772 m^2	**18,595 m^2**

[1] Including parking spaces, parking lanes (adjacent to the parking spaces) and possible platforms.

[2] Total area of facility which also includes other infrastructure such as driving lanes to reach the parking lanes and possible construction elements of the facility.

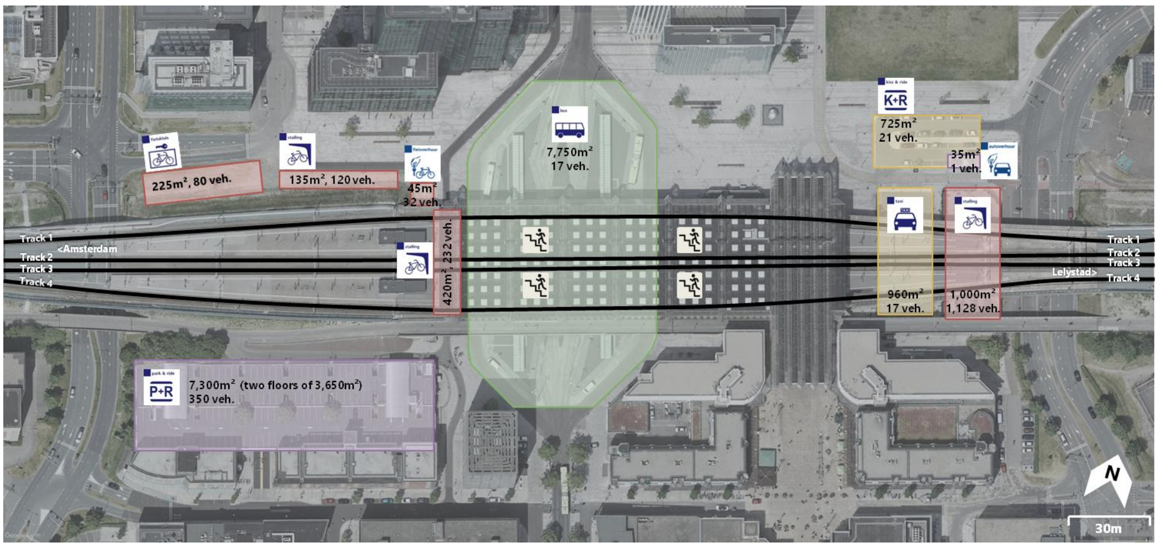


Figure 6.2 Map of railway station Almere Centrum and the areas and capacities of access/egress facilities

The values in Table 6.2 show that the existing facilities are considerably larger than required according to the outcomes of this research. To explain these differences, detailed information on the capacities, storage areas and designs of existing facilities have been added to this report in Appendix G.1. These will be used to elaborate on the existing access/egress facilities.

Private bicycle facilities
The four existing private bicycle facilities at Almere Centrum have a total area of 1,780m² with a total capacity of 1,508 parking spaces. According to the outcomes of this research, only 391m² is required to provide parking spaces for 1,304 travellers (Appendix M). As for all facilities, the required area only includes the parking spaces and adjacent parking lanes, while the existing area represents the total area of the facility. In here, the driving lanes to reach the parking lanes and construction elements of the facility are also included. Moreover, the majority of the bicycle facilities at Almere Centrum (e.g. bicycle racks, on-street parking, lockers) have a higher storage area compared to the double-sided floor rack with extension rail that was considered as reference facility in paragraph 4.3. Additionally, private bicycles were assigned a design frequency of two, indicating that one parking space can be used by two travellers during a peak period. This is probably overestimated since the share between home-end and activity-end travellers is not equally divided as can be observed from the modal split results of the survey.

Bicycle rental
None of the respondents indicated to use a shared bicycle in the current situation. In practice, 45m² is available for 32 shared bicycles that are parked in regular bicycle racks. This means that each bicycle occupies 1.4m² (= 45m² / 32), instead of the 0.6m² that was considered in this research for a double-sided floor rack with extensions rail.

Parking garage
The nearest parking garage to railway station Almere Centrum has a capacity of 350 parking spaces divided over two floors of 3,650m². The total area (7,300m²) is amply sufficient for the 1,645m² that is required. Although driving lanes and construction elements were not considered for the determination of total required land use, the area per vehicle (7,300m² / 350 = 21m²) for the existing facility is equal to the considered storage area in paragraph 4.3. Because the considered and existing facility both rely on perpendicular car parking, the existing facility is probably designed smaller than the standards prescribe. Because the facility does not have an advantageous tariff for train travellers, the facility is used relatively little, although there is enough space available.

Car rental
None of the respondents indicated to use a shared car in the current situation. In practice, one shared car is available and occupies 35m². Although this area also includes shares of the parking lanes and platforms at the K+R facility, the parking space is overdimensioned for a shared vehicle considering its small dimensions.

Taxi stands
As for bicycle and car rental, none of the respondents used a non-reserved taxi. Because the taxi stands are built around the foundation piles of the rail viaduct, the area per taxi stand of 57m² (= 960m² / 17) is considerably larger than the storage area considered in this research (28m²). Moreover, the taxi stands have a parallel design and a large share of the existing facility consists of driving lanes, while for this research, a perpendicular design was considered and driving lanes were not included.

Bus station
The bus station accounts for the largest area of all existing facilities (7,750m²), while only 662m² is required according to outcomes of this research. There are various explanations for this. First of

all, the bus station is dimensioned larger than required with large platforms in between the different bus stops. Besides, the area also includes entrance gates and stairs to the train platforms. Regarding the design frequency, it was assumed in this research that each bus platform is occupied every ten minutes. However, at Almere Centrum, the same bus uses two platforms for embarking and disembarking which requires additional area. It should also be mentioned that not all existing platforms are used and occupancy rates might deviate from the considered value in paragraph 4.5.

Kiss and Ride

The Kiss and Ride (K+R) facility at Almere Centrum has a total area of 725m² with a capacity of 21 parking spaces. This means that each vehicle is assigned 35m² (= 725m² / 21), which is a little bit more than the storage area for individual on-demand ride services (28m²). This is expected to be the result of the parking lanes and the platform in the middle of the facility that are included in the total area of the existing facility. Although the facility was found to be used relatively much, the required area according to the outcomes of this research is considerably lower than the existing area. Because vehicles at Almere Centrum are allowed to park for fifteen minutes and this research considered a design frequency of 48 (i.e. each five minutes a vehicle that picks up and drops off (a) traveller(s)). However, in practice, vehicles are allowed to park for fifteen minutes at the P+R facility and usually either pick up or drops off (a) traveller(s).

The remainder of this paragraph elaborates on the required area for access/egress facilities in the four constructed scenarios. It should be mentioned that these areas assume that facilities are designed according to the values determined in Chapter 4 for the storage areas, design frequencies and occupancy rates. Two figures are created to visualise the results. Figure 6.3 shows how the required land use is divided among the scenarios. Figure 6.4 also distinguishes the scenarios but emphasises the required land use per means of access/egress transport.

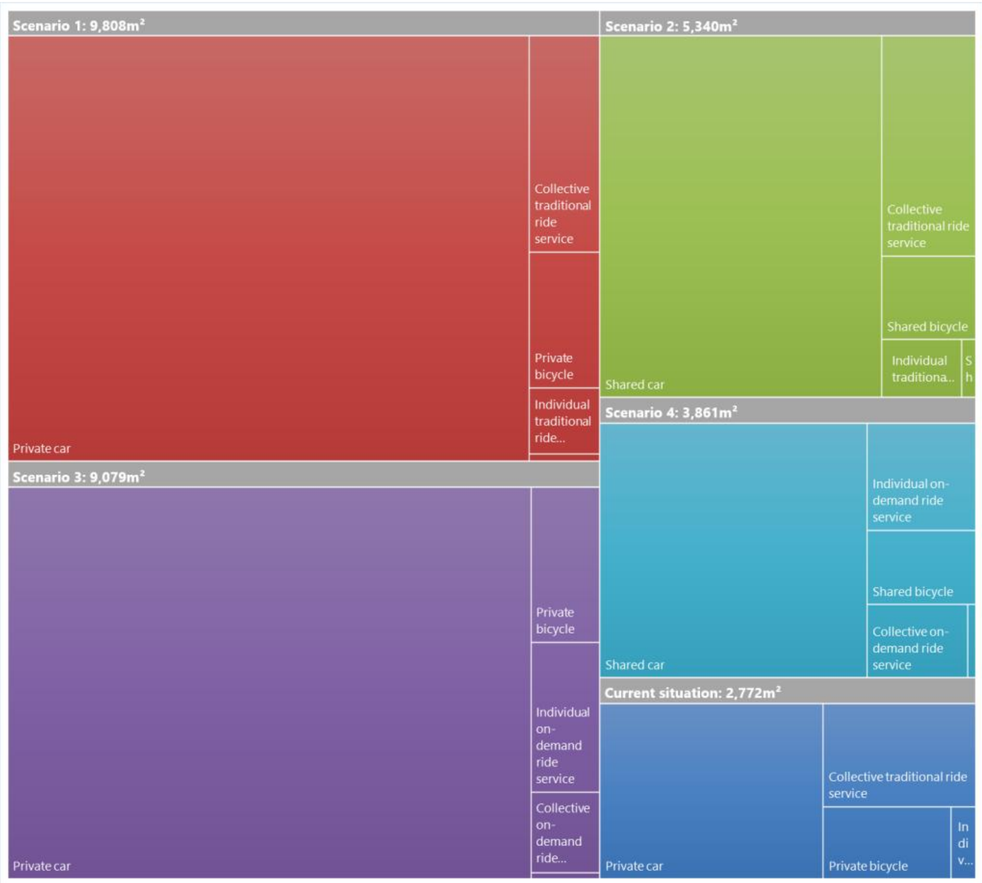


Figure 6.3 Required land use per scenario

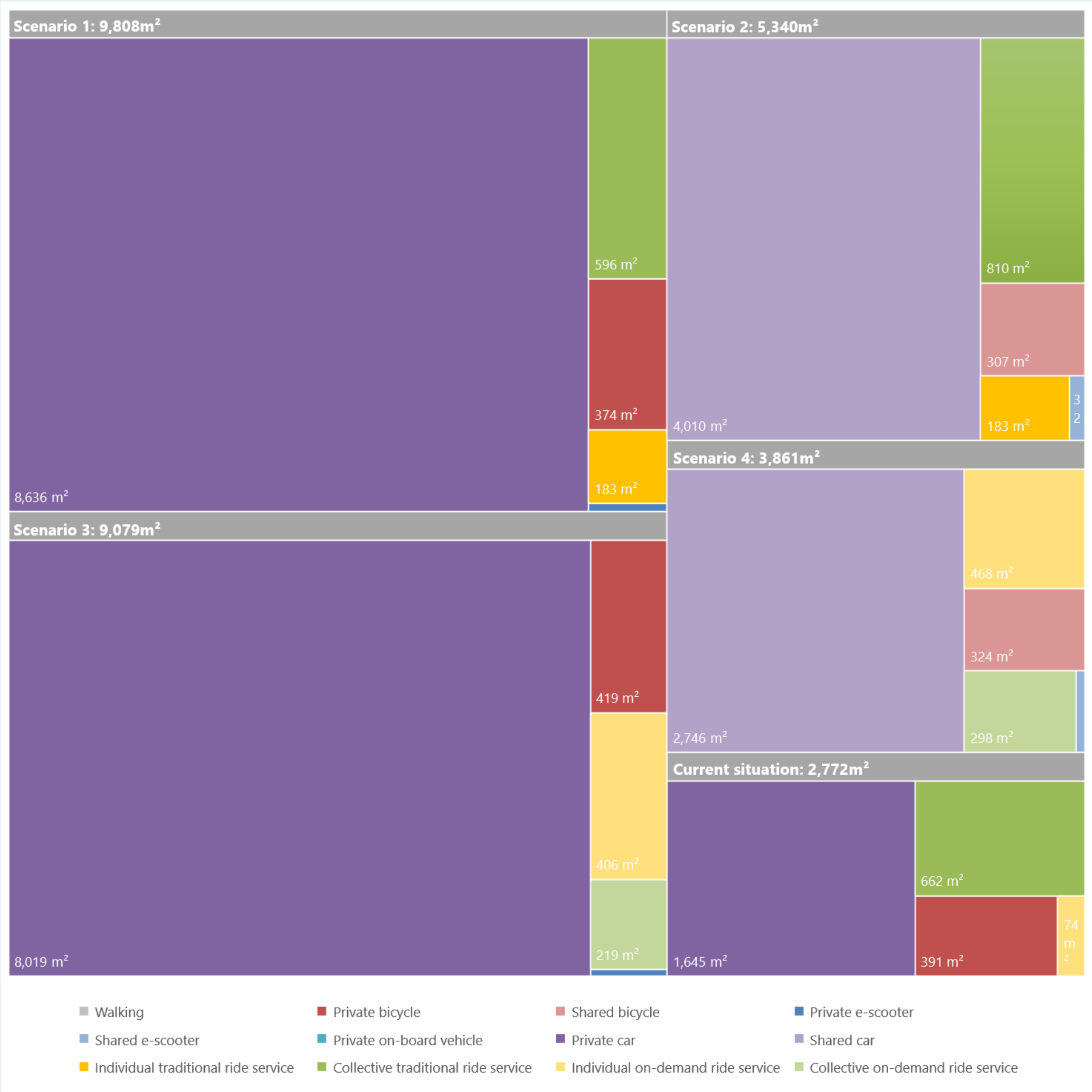


Figure 6.4 Required land use per means of access/egress transport

Scenario 1

The scenario in which only private vehicles and traditional ride services are provided requires the largest area (9,808m²) of all four scenarios. 88% of the required land use is needed to facilitate all travellers that prefer a private car, of which the share is only 10%. This is more than the area of the existing parking garage (7,300m²).

Scenario 2

The second scenario, in which private vehicles are replaced by shared vehicles, requires 5,340m². Although the footprint of shared cars (7.50m²/traveller) is considerably lower than of private cars (17.50m²/traveller), still 75% of the required area is needed to facilitate shared cars. For other shared vehicles (e.g. bicycle and e-scooter), the footprints were found to be higher compared to the private form. As a result, the required land use for bicycles in scenario 2, relative to scenario 1, is slightly lower (307m² versus 374m²), although the share of travellers decreased from 26% to 19%. Besides the car, collective traditional ride services require a large area (810m²) which accounts for 15% of the total required area. However this means of transport is also used by 40% of the total amount of travellers.

Scenario 3

Different from scenario 1, flexible rides instead of traditional rides are offered in this scenario. In total, 9,079m² is required to facilitate all means of access/egress transport. Due to the availability and preference for the private car (10%), a large area (88%) is required to facilitate these vehicles. The bicycle requires the largest area (419m²) in this scenario relative to the other scenarios and the current situation. Regarding ride services, the division of land use between the individual and collective forms are different for on-demand rides relative to traditional ones. In this scenario, 406m² is required for individual on-demand rides while 183m² was required for individual traditional rides in scenario 1. For the collective forms this division is 219m² and 596m² respectively.

Scenario 4

The scenario in which only shared vehicles and flexible ride services are provided requires the least amount of area (3,861m²) of all other scenarios. In line with the observations done before, the car requires the largest share of area (71%). However, the share of travellers that prefer the car (9%) is the lowest for all scenarios. This also explains why this scenario is the most advantageous of all other scenarios regarding the required land use. Regarding other shared vehicles, the values are comparable of those from scenario 2. For both on-demand ride services, extra land is required relative to scenario 3 for both the individual (468m²) and collective (298m²) form. The individual form requires 12% of all land that is required in this scenario.

6.4 (Re)development possibilities

The previous paragraph determined and analysed the required land use for access/egress facilities in different scenarios. According to the outcomes, railway station areas should be designed differently in each scenario. The remainder of this subparagraph elaborates on the (re)development possibilities for railway station areas, based on the two driving forces that were chosen for the construction of the scenario matrix.

Vehicle sharing economy: Private vehicles → Shared vehicles

When shared vehicles are more frequently used in the future, some access/egress facilities are expected to require adjustments. Dependent on the dimensions of the shared car fleet, parking spaces are expected to reduce in size. Because the dimensions these parking areas are normative for the design of a parking facility, the area dedicated to the car is crucial for the total capacity. Although lane markings of parking spaces can easily be changed, obstacles such as walls and pillars, which are used for parking garages, limit the freedom to redesign the area in the future.

For the bicycle and e-scooter, facilities are not expected to require any significant adjustments. Because both vehicles rely on facilities that can easily be moved such as racks and lockers, designated areas can easily be rearranged. Because both the private and shared forms require the same type of facilities, facilities maintain their value regardless if the shared forms become a success or not. Moreover, additional area is required when the roundtrip service becomes a success as this business model was assigned the highest footprint relative to the private and other shared forms.

Regarding, ride service facilities, it is expected that additional space is required for collective traditional ride services (e.g. bus stations) as a result of travellers who are not willing to share a vehicle. However, if private vehicles remain available alongside shared vehicles, minimal changes are expected to be required.

Ride service industry: Traditional ride services → On-demand ride services

When rides are being offered according to an on-demand service, significant changes are expected to be needed regarding facilities at the railway station area.

First of all, the required area for individual ride services is expected to increase as a result of the on-demand services. The facilities of both traditional and on-demand services, taxi stands and K+R respectively, were found to have similar characteristics with the same storage areas. It is therefore expected that existing facilities remain useful in the future. However, larger and efficiently designed facilities are expected to be needed when on-demand ride services become more frequently used.

Secondly, bus stations are expected to disappear or require adjustments when on-demand ride services are offered. Because collective on-demand ride services were expected to rely on other type of vehicles relative to the traditional form, existing bus stations are expected to be inefficient for ride services with minibuses. Because the footprint of the on-demand form is slightly lower, it is expected that the current areas of traditional bus stations are sufficient for minibus stations when considering an equal modal split.

In general, individual ride services are expected to require more area at the railway station area while collective rides are expected to require less when on-demand ride services are being offered in the future.

6.5 Conclusion

This chapter aimed to determine and analyse the required land use for access/egress facilities at the railway station area. First, the modal split percentages (Chapter 5) were converted to passenger numbers in the morning peak, which was defined as the normative period for which access/egress facilities at the railway station area should be designed. Subsequently, these numbers were used in combination with the footprints (Chapter 4) to determine the total required area for access/egress facilities per means of access/egress transport.

According to this research, 2,772m² is required for access/egress facilities at railway station Almere Centrum in the current situation, based on the number of travellers in the busiest peak period, the morning peak. This value includes the area of parking spaces, driving lanes (adjacent to the parking spaces) and possible platforms which were also considered for the determination of the storage areas for the footprint. Although this is assumed to be a minimum value, the existing areas of access/egress facilities at Almere Centrum were found to be considerably larger and occupy in total 18,595m². This area also includes parking lanes and possible construction elements of the facilities. Moreover, an analysis on the land use of existing facilities illustrated that facilities are currently overdimensioned and designed according to different values than considered for the footprint indicator of this research.

The four scenarios were assigned a required land use of 9,808m², 5,340m², 9,079m² and 3,861m² for access/egress facilities respectively. Because the car was found to be a preferred means of transport in combination with its high footprint, a significant amount of area is required to facilitate these travellers. Moreover, because walking is not as preferred in the scenarios as chosen in the current situation, extra land use is required to facilitate the means of access/egress transport to which these people shift.

According to the outcomes, railway station areas should be designed differently in each scenario. Based on the two driving forces that were chosen for the construction of the scenario matrix, the following (re)development possibilities were observed:

When the vehicle sharing economy develops:

- Car parking facilities require a different design as the dimensions of shared vehicles are expected to be smaller.

- Facilities for bicycles and e-scooters remain needed and keep their value as both private and shared forms require the same type of facilities.
- It is expected that additional area for collective traditional ride services is required when the use of private vehicles is discouraged to stimulate sharing.

When the ride service industry develops:

- Existing individual traditional ride facilities (e.g. taxi stands and K+R) remain useful for individual on-demand ride services and are expected to require more space.
- Traditional bus stations are expected to disappear or require adjustments and minibus stations are required for the collective on-demand ride services. Because minibus stations require less space for the same demand, collective ride service facilities are not expected to require a larger area.

In the next chapter, the research is concluded and recommendations are given for both science and practice. Moreover, a discussion aims to reflect on some of the research processes.

7 CONCLUSIONS AND RECOMMENDATIONS

7.1 Introduction

In this final chapter, conclusions are drawn from the research. First (paragraph 7.2), general conclusions are provided and an answer is given to the main research question of this research. In paragraph 7.3, some of the research processes are discussed and critically reflected. The final paragraph (7.4) of this chapter aims to give recommendations for both science and practice, based on the findings of this research.

7.2 Conclusions

This section provides conclusions to the various subtopics of access/egress transport that have been addressed in this research. The aim of this research was to create knowledge and set guidelines for the (re)development of railway station areas regarding the required land use for access/egress facilities as a result of access/egress transportation developments. In order to answer the main research question, six sub-questions were identified. All six sub-questions have been answered during this research. The conclusions written at the end of each paragraph aimed to summarize each chapter and answered the respective sub-question(s). In this section, all answers are united to address the main research question.

1. Which factors influence the mode choice of travellers travelling to/from the railway station?

The first part of the literature review showed that a combination of multiple factors influence the access/egress mode choice of travellers. It was found that factors can be assigned to one of the following six categories: (1) **characteristics of the traveller**, (2) **psychological factors**, (3) **characteristics of the access/egress trip**, (4) **characteristics of the access/egress modes**, (5) **characteristics of the built environment** and (6) **main stage factors**. Besides, the review illustrated that the influence of each factor strongly depends on the type of study and its considered scope (e.g. trip stages, means of access/egress transport and transit nodes).

2. What are the impacts and potentials of trends and developments for access/egress transport to/from railway stations in the next 20 years?

The remainder of the literature review elaborated on trends and developments that are likely to influence access/egress transport in the future. The demand for access/egress transport is expected to be influenced by among others demographic shifts, urbanisation and climate change. The **impact** of these trends can be captured by the extent to which access/egress mode choice factors are influenced. However, as a result of these trends, in combination with technological developments, new and innovating means of transport emerge. Shared mobility, autonomous mobility and electric mobility thereby play an important role and have the **potential** to change the supply of access/egress transport in the future. In 20 years, shared mobility, in particular, is expected to significantly change access/egress trips by means of the following services: (1) **carsharing**, (2) **bikesharing**, (3) **e-scooter sharing**, (4) **individual on-demand ride services** and (5) **collective on-demand ride services**.

3. Which future development paths for access/egress transport can be distinguished in 20 years?

The success of the access/egress services among the shared mobility concept is expected to be dependent on two main driving forces. On the one hand, the degree to which the vehicle sharing economy develops, and on the other hand, the degree to which ride services are offered. A combination of high and low penetrations of both the driving forces resulted in four distinguishable scenarios: (1) **Privately owned vehicles and traditional ride services**, (2) **Shared vehicles and traditional ride services**, (3) **Privately owned vehicles and on-demand ride services** and (4) **Shared vehicles and on-demand ride services**.

4. How can the required area for access/egress facilities at the railway station be determined and how does this value differ per means of transport?

For all considered means of access/egress transport, the so-called **access/egress transport footprint** was determined (Chapter 4). This indicator consists of three components: (1) **storage area**, (2) **design frequency** and (3) **occupancy rate**, and was given the following definition:

> *'The required area per traveller for a means of access/egress transport to park or stop at the railway station area based on the number of departures and arrivals during a peak period.'*

The following footprints were determined: walking (**0m²**), private on-board vehicle (**0m²**), private e-scooter (**0.10m²**), shared e-scooter (**0.13m²**), private bicycle (**0.30m²**), collective on-demand ride service (**0.34m²**), shared bicycle (**0.40m²**), collective traditional ride service (**0.43m²**), individual on-demand ride service (**0.49m²**), individual traditional ride service (**3.89m²**), shared car (**7.50m²**) and private car (**17.50m²**).

5. What is the expected modal split in the predefined development paths for access/egress transport?

An access/egress mode choice experiment was conducted at the Almere Centrum railway station in the Netherlands to observe current and future mode choice decisions. Travellers were asked for their preferred means of access/egress transport in each of the four constructed scenarios. **Sankey diagrams** were created to visualise the mode choice decisions of 401 respondents. These illustrated that current home-end trips are mainly made by bus (43%) and bicycle (41%). However, the modal splits in each of the four scenarios shift and illustrate that especially the car is a preferred means of transport in each scenario (18%, 13%, 17% and 10%) while the current share is relatively low (5%). At the activity-end, most of the travellers currently walk (67%). However, this share decreases considerably in each of the four scenarios (44%, 39%, 37% and 42%) at the expense of other means of transport. In general, the modal splits illustrated that travellers have a preference towards traditional means of transport (e.g. private vehicles and traditional ride services) relative to innovative services such as shared vehicles and on-demand ride services.

6. How does the expected modal split influences the total required land use for access/egress facilities at the railway station area?

The modal split percentages and the access/egress transport footprint were united in Chapter 6 to determine the total required area for access/egress facilities at the railway station area. According to this research, **2,772m²** is required for access/egress facilities at railway station Almere Centrum in the current situation, based on the number of travellers in the busiest peak period, the morning peak. This value includes the area of parking spaces, driving lanes (adjacent to the parking spaces) and possible platforms which were also considered for the determination of the storage areas for the footprint. According to the preferred means of access/egress transport in each of the four scenarios, respectively **9,808m²**, **5,340m²**, **9,079m²** and **3,861m²** is required for access/egress facilities. The preference for the car and the disapprove towards walking in the scenarios are the two main explanations for the differences relative to the current situation.

Taking into consideration these findings, the following can be concluded regarding the main research question, which was defined as:

'How should railway station areas in the Netherlands be (re)developed regarding the required land use for access/egress facilities as a result of access/egress transportation developments on a time horizon up to 20 years?'

First of all, it is important to consider which means of transport are desired for access/egress trips to/from a specific railway station. For Almere Centrum the outcomes showed that large car parking facilities should be provided in each of the four scenarios. However, it is questionable whether car use to/from railway stations should be stimulated, especially when the railway station is located in the city centre. In these areas space is scarce and cars were found to be the most inefficient means of access/egress transport regarding land use. However, access/egress mode choice can be controlled for by various factors as was observed for Almere Centrum.

Secondly, this research illustrated that access/egress facilities require a different amount of land in each scenario. However, it was also found that many facilities have similar characteristics and can be used by multiple means of access/egress transport regardless of the scenario that develops. This multi-purpose function is depicted in Table 7.1 based on the findings of this research.

Table 7.1 Multi-purpose function of access/egress facilities

Access/egress facility		Means of access/egress transport
Parking area (cars)	P+R	Private cars
		Shared cars
Parking area (small vehicles)	Bicycle racks	Private bicycles
		Shared bicycles
	E-scooter lockers	Private e-scooters
		Shared e-scooters
Waiting area (cars)	K+R	Individual traditional ride services
		Individual on-demand ride services
Bus station	Large platforms	Collective traditional ride services
Minibus station	Small platforms	Collective on-demand ride services

It was found that car parking facilities require a different design regarding the dimensions of parking spaces when the sharing economy develops. Facilities for bicycles and e-scooters keep their value as both private and shared forms require the same type of facilities. Moreover, facilities for these vehicles (e.g. lockers and bicycle racks) can easily be used interchangeably on the same area. This makes it possible to expand/decrease the number of parking spaces for both means of transport dependent on the scenario and modal split that develops without reconstructing the area. For ride services on the other hand, both the individual forms of traditional and on-demand ride services require the same type of facility. When the ride service industry develops, additional land is expected to be required. For the collective variant, the vehicles of the traditional and on-demand service have different characteristics which makes it plausible that other facilities are required. However, because the on-demand service required less space for the same demand, facilities are not expected to require a larger area.

7.3 Discussion

During this research, various assumptions and choices have been made. Results and conclusions that originated from this research are dependent on those decisions. In this paragraph, the following six topics are critically evaluated: research scope, trends and developments, scenarios, footprint indicator, mode choice experiment and spatial assessment.

Research scope

For this research, a scope was necessary to make the research manageable in the amount of time and with the resources available. In paragraph 1.3.1, it was determined that this study solely focuses on the Netherlands, railway stations and a time horizon of 20 years for the (re)development of railway stations. As a result, the findings of this research do have some limitations.

Differences between countries

Because this research focused on the Netherlands solely, means of access/egress transport that are (expected to be) frequently used for access/egress trips in the Netherlands were considered only. The literature review addressed access/egress transport from a global point of view and illustrated that, coherent to the country, different means of access/egress transport play a dominant role. Moreover, the literature review illustrated that access/egress mode choice is dependent on many different factors of which the majority are country dependent as well. Consequently, the findings that are done in this research are especially relevant for the Dutch context. However, the methodology that was used in this research can also be applied for studies that focus on other countries where different means of access/egress transport are used and where factors influence mode choice decisions differently.

Differences per transit node

Since most of the multimodal main stages in the Netherlands are carried out by train (61%), this research focused on access/egress trips to/from railway stations railway stations solely. Other transit nodes such as bus stations, tram stations and metro stations have different characteristics where, according to the findings in paragraph 2.2.2, other mode choice decisions are made. However, the footprints that were developed in this research can also be used for other transit nodes where similar means of access/egress transport are (expected to be) used to provide access/egress facilities. The findings that were done based on the mode choice experiment, on the other hand, are expected to be especially relevant for railway stations. Because the characteristics of railway stations differ mutually as well, it is expected that the findings are different per railway station as well. This will be further discussed at the discussion on the mode choice experiment where a specific railway station was selected for the case study.

Time horizon

This research considered a time horizon of 20 years to elaborate on the developments that are expected to affect access/egress transport within that respective period. However, a shorter or longer time horizon logically influences the developments that are relevant to consider. This is further discussed in the next section on trends and developments.

Trends and developments

In this research, trends were discussed at an abstract level. The effects of some worldwide trends on access/egress transport, both the demand and supply side, were elaborated. However, access/egress transport is expected to be affected by many more trends than discussed in this research. Additionally, the impacts regarding the demand for access/egress transport are more extensive and complex than described in Chapter 3. Regarding the supply of access/egress transport, three major game changers (shared mobility, autonomous mobility and electric mobility) were addressed. Only services originating from the shared mobility concept were considered for the remainder of the research. These services were expected to have the most significant impact on access/egress trips, and therefore the required land use for access/egress facilities, in the considered time horizon of 20 years. Consequently, this research provided a single-sided vision on the (re)development of railway station areas and did not considered the effects of developments other than shared mobility.

Scenarios

The scenario matrix that was constructed in Chapter 3 distinguished four unique development paths. A clear distinction was made between the type of vehicles (private or shared) and the type of ride services (traditional or flexible) that were expected to dominate in each scenario. In practice, access/egress transport is not assumed to evolve according to one single scenario. The future will lie somewhere in the middle of the four scenarios in which the various means of access/egress transport are used interchangeably.

Furthermore, only a limited number of access/egress modes were considered for the construction of the scenario matrix. First of all, the outcomes of the literature review were used to elaborate on which transport means to include. Secondly, considerations had to be made to make the scenarios not too extensive. The considered business models for shared vehicles and the potential the shared mobility services were based on available information, expectations and discussions. However, additional services might play a role that were not included or potentials turn out to be different than considered in this research.

As a result of both trade-offs, mode choice decisions that are made according to this scenario matrix are research specific and will be different when other scenarios are considered.

Footprint indicator

The access/egress transport footprint was developed for this research specifically. Because no previous work was found to use as reference, the indicator had to be developed from scratch and has its limitations. The three components of the indicator are evaluated.

Storage area

Two components of the storage area were distinguished: the area of the parking space where the vehicle parks or stops (i.e. direct land use) and indirect land use sections such as parking lanes (adjacent to the parking space) and platforms. Other areas such as driving lanes (to reach the parking lanes) and possible construction elements of the facility were not considered. Additionally, means of access/egress transport that were not associated with a designated area to park or stop at the railway station area (walking and on-demand vehicles) were assigned a storage area of $0m^2$. However, these transport means also require space to move around the railway station area. Consequently, the determined storage areas in this research are lower than means of access/egress transport require and occupy in practice.

The storage areas were determined based on existing design vehicles and design guidelines. However, this information was not available for all means of access/egress transport considered in this research. For these vehicles, storage areas were determined based on vehicles from practice. Because various type of vehicles and facilities exist, the determined storage areas in this research are dependent on the considered type of vehicle and facility. For this research, the majority of the storage areas were chosen based on the most efficient design of a facility. Consequently, the determined storage areas in this research are generally lower than means of access/egress transport occupy in practice.

Design frequency

The design frequency was introduced to account for the (in)efficient use of the parking spaces by access/egress vehicles. The period at which the largest share of travellers make use of the railway stations, either the morning- or evening peak, was considered for the determination of the design frequencies. It was assumed that access/egress facilities should be designed based on the number of departures and arrivals in the busiest peak period to provide enough capacity.

For ride services, this assumption holds that facilities are designed for the number of travellers in the busiest peak period. It is plausible that this calculated area is sufficient for all other departures and arrivals of ride service vehicles because fewer travellers make use of these rides outside the busiest peak period.

For private and shared vehicles, this assumption holds that travellers who depart from or arrive at the railway station area outside the busiest peak period are not taken into account for the required land use. Although the design frequencies are averages, it is expected that not all the departures and arrivals outside the busiest peak period are compensated for by the considered design frequencies. In general, because of uncertainties in departures, arrivals and residence times, the design frequencies are probably overestimated for private and shared vehicles. For the footprints, this means that additional area is expected to be required to facilitate travellers outside the busiest peak period as well.

The design frequencies were determined for each means of access/egress transport based on the expected home-end and activity-end potential and/or the expected operating design frequency. Vehicles with a design frequency of two (private bicycle, private e-scooter, shared free-floating vehicles and shared P2P vehicles) were assumed to be used as much by home-end travellers as by activity-end travellers. However, available modal split data showed that the modal splits vary considerably for both trip-ends (Figure 1.2). As a result, design frequencies for these means of transport are probably overestimated. Consequently, these vehicles are expected to require more area at the railway station area than determined in this research. Moreover, the order in which home-end and activity-end travellers arrive and depart was assumed to be efficient to achieve a design frequency of two. It is expected that home-end travellers arrive at the railway station first in the morning and activity-end travellers arrive first at the activity-end station in the evening peak. It is therefore expected that the design frequencies of private bicycles and private e-scooters are overestimated and additional area is required.

Occupancy rate

Because literature on occupancy rates of vehicles for access/egress trips specifically was unavailable, general values were used as reference. Consequently, the considered occupancy rates for access/egress vehicle with a capacity larger than one can deviate from occupancy rates in practice. Especially for collective ride services that are able to transport many travellers at once, occupancy rates are difficult to estimate and do strongly depend on the considered service and vehicle. Because collective traditional ride service vehicles have the largest capacity, the assigned occupancy rate is expected to be the least accurate.

Mode choice experiment

First of all, the mode choice experiment of this research was conducted among travellers at railway station Almere Centrum. At the beginning of this discussion, it was already mentioned that access/egress transport differs per country and transit node. Van Hagen and Exel (2012) illustrated that the access/egress modal split strongly depends on the type of railway station that is considered. This can also be clarified by the findings on access/egress mode choice factors. For example, the characteristics of travellers that make use of Almere Centrum might deviate from other railway stations. Moreover, the characteristics of the access/egress trips (e.g. trip purpose and distance) and the characteristics of the built environment are expected to be different per railway station. As a result, it is expected that the (findings based on the) outcomes of the survey are especially relevant for railway station Almere Centrum. However, the results might serve as reference for railway stations with similar characteristics as Almere Centrum.

Secondly, the survey that was conducted did not specify attributes for the considered means of access/egress transport. As a result, the preferred means of access/egress transport were captured in each of the four scenarios. The preference of travellers is expected to deviate from actual mode choice decisions when attributes such as costs are taken into account. This was also observed for the current modal split of travellers at Almere Centrum, which significantly differed from the scenario modal split percentages. Consequently, the results and conclusions that were drawn from these modal splits are based on preferences and expected to be different in practice.

Spatial assessment

For the determination of the total required land use for access/egress facilities, many of the abovementioned limitations apply as well. The areas include only parking spaces, parking lanes (adjacent to the parking spaces) and platforms which were also considered for the determination of the storage areas. For the total required land use in the current situation, assumptions were made regarding the land use assigned to a car (passenger) and no land use was assigned to travellers who used a scooter or moped. Moreover, the required areas in the scenarios are based on the modal split data of the survey which are preferred means of access/egress transport in each of the four scenarios.

Last, calculations were made based on the number of travellers at an average weekday morning peak at Almere Centrum. A growth, or decrease, in traveller numbers was not considered because it was unknown how the traveller demand will change over the considered time horizon of 20 years. Additionally, because the number of travellers at an average weekday morning peak were considered, the total required areas do not include a safety margin and do not account for special occurrences in which larger traveller demands might occur.

7.4 Recommendations

7.4.1 Recommendations for science

This section contains recommendations for future research. These arose from findings and issues during the research.

- The discussion on the research scope limitations illustrated that further research is required for similar studies in other countries and for other transit nodes. The results of this research are expected to be strongly dependent on the defined research scope and therefore especially relevant for railway stations in the Netherlands. However, the methodology that was used in this research can also be applied for studies that focus on other countries and transit nodes where different means of access/egress transport are (expected to be) frequently used and where factors influence mode choice decisions differently.

- Although many researchers studied mode choice factors in general, the number of studies on multimodal transport and access/egress transport is relatively scarce. Because the literature study of this research only reviewed a limited number of studies, more research is required to understand and predict access/egress mode choice decisions. More research can be done on the influence of different factors on access/egress mode choice decisions to validate the framework (Figure 2.3) that was developed in paragraph 2.2.2 and to extend the infographic (Figure 2.4) from paragraph 2.2.3.

- Further research is required to observe ongoing trends and to determine the impact of these trends on access/egress transport in the future. Moreover, as a result of the considered time horizon and aim of the study, this research solely focused on services originating from the shared mobility concept. Therefore, further research is required to study the effects of other developments such as autonomous and electric mobility.

Electrified vehicles are already relevant as charging stations are required at railway station areas. On a longer term, automated vehicles are expected to require designated facilities. All findings together can contribute to understand and predict how the access/egress sector evolves in the coming years.

- The scenario matrix that was constructed in this research can be extended for a more realistic approach of the future situation. Not only different trends and development can be included, also additional means of access/egress transport can be taken into account. Moreover, additional research is required to predict how the different business models for shared vehicles develop and determine the potential of services in each scenario.

- The discussion already emphasised that the developed footprint indicator has its limitations and can be further improved.
    - For a wider applicability of the footprint indicator, storage areas for additional type of vehicles and facilities should be determined.
    - The indirect land use of transport means at the railway station area should be estimated to determine the required land use more accurately.
    - It is recommended to study how facilities for relatively new means of access/egress transport such as shared cars, e-scooters and minibuses should be designed and what the corresponding storage areas are.

    - Further research is required to determine the principles for which access/egress facilities should be designed. It is assumed that a distinction can be made between a normative period for ride services that stop for a short period of time, and for vehicles that park at the railway station area for a longer period.
    - Additional research is also required to determine realistic design frequencies for all means of access/egress transport, taking into account the unequal distribution of arrivals and departures.
    - When vehicles are able to make use of each others' facilities, design frequencies increase and less area is expected to be required at the railway station area. Further research should be done to research the potential of multi-purpose facilities. For example, areas designated for private cars are usually empty during the night and areas designated for roundtrip vehicles during the day. Moreover as free-floating and P2P vehicles are expected to occupy facilities only for a short period of time relative to private vehicles, further research should be done into the potential of this area that is empty during the day.

    - Further research is required to determine occupancy rates for access/egress trips specifically.

- Further research is required to observe mode choice decisions by travellers for various type of railway stations. It is recommended to design a general survey of which the results can be assigned to specific railway stations based on the answers of the respondents. This would improve the general applicability of the data and takes away the disadvantages of setting up and conducting a railway station specific survey.

- Additional work is needed to observe realistic mode choice decisions in future scenarios because this research only captured the preference of travellers. This can be done by specifying attributes and varying with attribute levels for means of access/egress transport that are considered in the research.

7.4.2 Recommendations for practice

This subparagraph provides recommendations for practice. Some categories are distinguished to give specific suggestions to some relevant parties.

General recommendations for the practice in general

- It was found that access/egress mode choice factors have a significant influence on mode choice decisions by travellers. As a result, decision makers are able to steer access/egress transport. It is recommended to provide access/egress facilities for desired means of access/egress transport near the entrance of the railway station. Moreover, a compensation (e.g. in terms of money, vouchers or a point system) could be used to influence travellers.

- When land is scarce, and the use of cars is undesired, attractive parking facilities for these vehicles such as P+R should not be provided. Cars have a high footprint which means that these vehicles require a large area regarding the number of travellers that can be facilitated relative to other means of access/egress transport.

- It is recommended to stimulate free-floating vehicle sharing and P2P vehicle sharing. Both services have a low footprint which means that these vehicles require a small area regarding the number of travellers that can be facilitated. Moreover, these vehicles occupy facilities at the railway station area only for a short period of time relative to private and roundtrip vehicles.

- Regarding car parking facilities, it is recommended to select and construct the area in such a way that the total area can be redesigned with smaller parking spaces when shared vehicles are more frequently used.

- It is recommended to provide facilities for bicycles and e-scooters at the railway station area regardless if the shared forms become a success or not. Both vehicles are efficient means of access/egress transport regarding the required land use and facilities such as bicycle racks and lockers can easily be moved if the area needs to be redesigned.

- Under the condition that passenger cars are desirable for stops at the railway station, it is recommended to provide enough area for individual on-demand ride services such as K+R facilities. Because individual traditional ride services (i.e. non reserved taxis) require the same type of facility for taxi stands, it is recommended to combine both facilities. It is expected that facilities can be designed larger and more efficiently. However, as non-reserved taxis have a higher footprint it is desirable to only have on-demand services that make use of the facility.

- In line with the recommendation for science, the design of future minibus stations should be further researched to elaborate on the future of bus stations. When traditional buses remain used, designated bus stations with longer platforms are required. Although minibuses can make use of the same facility, the design is not made for minibuses. It is therefore recommended to consider a reference design vehicle for the collective on-demand ride services and come up with an efficient design. Perhaps a variant is possible which can transform existing bus stations into minibus stations.

- Regarding access/egress facilities in general, many different facilities have been elaborated in this research. However, it was found that facilities can have a multi-purpose function regarding the means of access/egress transport that can make use of it. For designing facilities, this multi-purpose function should be taken into account instead of designing separate facilities as is done at for example Almere Centrum for individual ride services.

Recommendations for NS and/or subdivisions of NS

- The existing regulations of NS regarding hand luggage dates from 2015 and allows travellers to take a vehicle on the train (free of charge) if the vehicle has no combustion engine and if the vehicle does not exceed the dimensions of 85 x 85 x 85cm (NS, 2015). With the ongoing developments, more vehicles are entering the market that meet these restrictions. However, it is questionable whether these vehicles are still allowed to be taken on the train in the future when trains become busier and more travellers want to use an on-board vehicle. It is recommended for the NS to come up with specific regulations towards on-board vehicles to prevent unfavourable consequences to happen. For example when travellers buy an on-board vehicle which is allowed to be taken on-board in the current situation but not in the future.

- Current surveys distinguish the usual means of access/egress transport as answer options to research mode choice. For surveys in the future, it is recommended to make a distinction between car travellers that make use of long term (P+R) or short term (K+R) facilities. This makes the data that is collected through the survey more valuable regarding the required land use at the railway station area. In line with this argument, on-board vehicles should be included as an option as well. Currently, travellers with, for example, a foldable bicycle are assigned to the category cyclists although they do not park their bicycle at the railway station area. Lastly, an option scooter/moped should be included. This would decrease the number of travellers that choose 'other' and provides more information on the area that is needed.

BIBLIOGRAPHY

Alonso González, M., Van Oort, N., Cats, O., & Hoogendoorn, S. (2017). Urban Demand Responsive Transport in the Mobility as a Service Ecosystem: Its Role and Potential Market Share. *Thredbo 15: Competition and Ownership in Land Passenger Transport, 60*.

Arentze, T. A., & Molin, E. J. E. (2013). Travelers' preferences in multimodal networks: Design and results of a comprehensive series of choice experiments. *Transportation Research Part A: Policy and Practice, 58*, 15-28. doi:https://doi.org/10.1016/j.tra.2013.10.005

Bach, B., De Groot, R., & Van Hal, E. (2006). *Urban design and traffic: a selection from Bach's toolbox*. Ede: CROW.

Ben-Akiva, M., McFadden, D., Gärling, T., Gopinath, D., Walker, J., Bolduc, D., . . . Rao, V. (1999). Extended Framework for Modeling Choice Behavior. *Marketing Letters, 10*(3), 187-203. doi:https://doi.org/10.1023/A:1008046730291

Brouwer, I., & Huijsmans, M. (2011). *Visie op het omgevingsdomein*. Retrieved from www.spoorbeeld.nl

Bureau Spoorbouwmeester. (2012). *Het Stationsconcept. Visie en toepassing*. Retrieved from www.spoorbeeld.nl

car2go. (2018a). Factsheet car2go [Press release]

car2go. (2018b). Meet the car2go fleet. Retrieved from https://www.car2go.com/IT/en/nuoveauto/

Centraal Bureau voor de Statistiek. (2016). *PBL/CBS Regionale bevolkings- en huishoudensprognose 2016-2040: sterke regionale verschillen*. Retrieved from https://www.cbs.nl/nl-nl/achtergrond/2016/37/pbl-cbs-regionale-prognose-2016-2040

Centraal Bureau voor de Statistiek. (2017a). *Bevolkingsprognose 2017-2060: 18,4 miljoen inwoners in 2060*. Retrieved from https://www.cbs.nl/nl-nl/achtergrond/2017/51/18-4-miljoen-inwoners-in-2060

Centraal Bureau voor de Statistiek. (2017b). Forecast: 18.4 million inhabitants in 2060. Retrieved from https://www.cbs.nl/en-gb/news/2017/51/forecast-18-4-million-inhabitants-in-2060

Centraal Bureau voor de Statistiek. (2017c). Regionale kerncijfers Nederland; Nabijheid voorzieningen, afstand tot treinstation. Retrieved 15-06-2018 https://opendata.cbs.nl/statline/#/CBS/nl/dataset/70072ned/table?ts=1529154928097

Centraal Bureau voor de Statistiek. (2018a). Levensverwachting; geslacht, leeftijd (per jaar en periode van vijf jaren). Retrieved 15-08-2018 https://opendata.cbs.nl/#/CBS/nl/dataset/37360ned/table?ts=1534327106168

Centraal Bureau voor de Statistiek. (2018b). Personenmobiliteit in Nederland; persoonskenmerken en vervoerwijzen, regio. Retrieved 11-12-2018 https://opendata.cbs.nl/statline/#/CBS/nl/dataset/83499NED/table?ts=1544532869801

Centraal Bureau voor de Statistiek. (2018c). *Trends in Nederland 2018*. Retrieved from https://www.cbs.nl/nl-nl/publicatie/2018/26/trends-in-nederland-2018

Cervero, R. (2001). *Walk-and-Ride: Factors Influencing Pedestrian Access to Transit* (Vol. 3).

Cervero, R., & Kockelman, K. (1997). Travel demand and the 3Ds: Density, diversity, and design. *Transportation Research Part D: Transport and Environment, 2*(3), 199-219. doi:https://doi.org/10.1016/S1361-9209(97)00009-6

Cervero, R., & Murakami, J. (2008). *Rail + Property Development: A model of sustainable transit finance and urbanism*.

Chakour, V., & Eluru, N. (2013). *Analyzing commuter train user behavior: A decision framework for access mode and station choice* (Vol. 41).

Chan, N. D., & Shaheen, S. (2012). *Ridesharing in North America: Past, Present, and Future* (Vol. 32).

Creemers, L., Bellemans, T., Janssens, D., Wets, G., & Cools, M. (2014). *Analyzing access, egress, and main transport mode of public transit journeys: evidence from the Flemish national household travel survey*.

CROW-KpVV. (2017). Ruim 5.700 nieuwe deelauto's. Retrieved from https://kpvvdashboard-4.blogspot.com/

CROW. (2005a). *Toegankelijkheid collectief personenvervoer - Bussen*.
CROW. (2005b). *Toegankelijkheid collectief personenvervoer - Taxi's*.
CROW. (2012). *ASVV 2012 - Aanbevelingen voor verkeersvoorzieningen binnen de bebouwde kom*. Ede: CROW.
CROW. (2014). KpVV dahboard duurzame en slimme mobiliteit, Prestaties van vervoerwijzen. Retrieved from https://kpvvdashboard-20.blogspot.com/
Cycling Promotion Fund. (2016). A comparison of space used by bus, bike, and car. Retrieved from http://sensibletransportation.org/wideningwontwork.org/news/bus-bike-car-comparison-cycling-promotion-fund/index.html
Das, H. S., Tan, C. W., & Yatim, A. H. M. (2017). Fuel cell hybrid electric vehicles: A review on power conditioning units and topologies. *Renewable and Sustainable Energy Reviews, 76*, 268-291. doi:https://doi.org/10.1016/j.rser.2017.03.056
De Witte, A., Hollevoet, J., Dobruszkes, F., Hubert, M., & Macharis, C. (2013). Linking modal choice to motility: A comprehensive review. *Transportation Research Part A: Policy and Practice, 49*, 329-341. doi:https://doi.org/10.1016/j.tra.2013.01.009
Debrezion, G., Pels, E., & Rietveld, P. (2009). Modelling the joint access mode and railway station choice. *Transportation Research Part E: Logistics and Transportation Review, 45*(1), 270-283. doi:https://doi.org/10.1016/j.tre.2008.07.001
ECORYS. (2014). *Beoordeling van gevolgen van veranderingen in de posities van relevante partijen op stations*. Retrieved from https://www.ecorys.nl/rapportenfactsheets/eigendomsverhoudingen-stations
European Commission. (2018). Foresight | Knowledge for policy. Retrieved from https://ec.europa.eu/knowledge4policy/foresight_en
European Environment Agency. (2015). Occupancy rate of passenger vehicles. Retrieved from https://www.eea.europa.eu/data-and-maps/indicators/occupancy-rates-of-passenger-vehicles/occupancy-rates-of-passenger-vehicles
European Foresight Platform. (2014). Megatrend / Trend / Driver / Issue. Retrieved from http://www.foresight-platform.eu/community/forlearn/how-to-do-foresight/methods/analysis/megatrend-trend-driver-issue/
Ewing, R., & Cervero, R. (2010). Travel and the Built Environment. *Journal of the American Planning Association, 76*(3), 265-294. doi:https://doi.org/10.1080/01944361003766766
Falco BV. (2018). FIETSPARKEERSYSTEMEN met FietsParKeur. In.
Fraiberger, S., & Sundararajan, A. (2015). *Peer-to-Peer Rental Markets in the Sharing Economy*.
Franckx, L., & Mayeres, I. (2015). *Future trends in mobility: challanges for transport planning tools and related decision-making on mobility product and service development*. Retrieved from http://www.mind-sets.eu/news-and-events/downloads-and-deliverables/
Frost & Sullivan (Producer). (2010). World's Top Global Mega Trends To 2020 and Implications to Business, Society and Cultures.
Gemeente Amsterdam. (2017). *Meerjarenplan Fiets 2017 - 2022*. Retrieved from https://www.amsterdam.nl/parkeren-verkeer/fiets/meerjarenplan-fiets/
Givoni, M., & Rietveld, P. (2007). The access journey to the railway station and its role in passengers' satisfaction with rail travel. *Transport Policy, 14*(5), 357-365. doi:https://doi.org/10.1016/j.tranpol.2007.04.004
Goel, R., & Tiwari, G. (2016). Access–egress and other travel characteristics of metro users in Delhi and its satellite cities. *IATSS Research, 39*(2), 164-172. doi:https://doi.org/10.1016/j.iatssr.2015.10.001
Google Maps (Cartographer). (2018). Station Almere Centrum: Popular times. Retrieved from https://www.google.nl/maps/place/Almere+Centrum/@52.3752478,5.2171329,17z/data=!3m1!4b1!4m5!3m4!1s0x47c6171fc2f158dd:0xdf3c42df3ec04984!8m2!3d52.3752478!4d5.2193216
Halldórsdóttir, K., Nielsen, O. A., & Prato, C. G. (2017). Home-end and activity-end preferences for access to and egress from train stations in the Copenhagen region. *International Journal*

of Sustainable Transportation, 11(10), 776-786. doi:https://doi.org/10.1080/15568318.2017.1317888
IEA. (1997). *Indicators of energy use and efficiency*. International Energy Agency. Paris, France.
Jiang, Y., Christopher Zegras, P., & Mehndiratta, S. (2012). Walk the line: station context, corridor type and bus rapid transit walk access in Jinan, China. *Journal of Transport Geography, 20*(1), 1-14. doi:https://doi.org/10.1016/j.jtrangeo.2011.09.007
Kennisinstituut voor Mobiliteitsbeleid. (2014). *Mobilitetisbeeld 2014*. Retrieved from https://www.kimnet.nl/mobiliteitsbeeld
Kennisinstituut voor Mobiliteitsbeleid. (2017). *Mobiliteitsbeeld 2017*. Retrieved from https://www.kimnet.nl/mobiliteitsbeeld
Kim, S., Ulfarsson, G. F., & Todd Hennessy, J. (2007). Analysis of light rail rider travel behavior: Impacts of individual, built environment, and crime characteristics on transit access. *Transportation Research Part A: Policy and Practice, 41*(6), 511-522. doi:https://doi.org/10.1016/j.tra.2006.11.001
Krygsman, S., Dijst, M., & Arentze, T. (2004). Multimodal public transport: an analysis of travel time elements and the interconnectivity ratio. *Transport Policy, 11*(3), 265-275. doi:https://doi.org/10.1016/j.tranpol.2003.12.001
Lindstöm Olsson, A.-L. (2003). *Factors that influence choice of travel mode in major urban areas: The attractiveness of Park & Ride*. KTH Royal Institute of Technology, Stockholm.
Martin, E., & Shaheen, S. (2011). The Impact of Carsharing on Public Transit and Non-Motorized Travel: An Exploration of North American Carsharing Survey Data. *Energies, 4*(11), 2094.
Martin, E., & Shaheen, S. (2016). *Impacts of Car2go on Vehicle Ownership, Modal Shift, Vehicle Miles Traveled, and Greenhouse Gas Emissions: An Analysis of Five North American Cities*. Retrieved from http://innovativemobility.org/wp-content/uploads/2016/07/Impactsofcar2go_FiveCities_2016.pdf
Martin, E., Shaheen, S., & Lidicker, J. (2010). Impact of Carsharing on Household Vehicle Holdings:Results from North American Shared-Use Vehicle Survey. *Transportation Research Record, 2143*(1), 150-158. doi:https://doi.org/10.3141/2143-19
Mercedes-Benz. (2018). Technical data. Retrieved from https://www.mercedes-benz.nl/vans/nl/sprinter/tourer/technical-data
Mi. (2018). Mi Electric Scooter. Retrieved from https://www.mi.com/global/mi-electric-scooter/specs/
Milakis, D., Snelder, M., Van Arem, B., Van Wee, B., & Homem de Almeida Correia, G. (2017). Development and transport implications of automated vehicles in the Netherlands: Scenarios for 2030 and 2050. *European Journal of Transport and Infrastructure Research, 17(1)*, 63-85.
Mo, B., Shen, Y., & Zhao, J. (2018). *Impact of Built Environment on First- and Last-Mile Travel Mode Choice*.
Molin, E. J. E., & Timmermans, H. J. P. (2010). Context Dependent Stated Choice Experiments: The Case of Train Egress Mode Choice. *Journal of Choice Modelling, 3*(3), 39-56. doi:https://doi.org/10.1016/S1755-5345(13)70013-7
Munshi, T. (2016). Built environment and mode choice relationship for commute travel in the city of Rajkot, India. *Transportation Research Part D: Transport and Environment, 44*, 239-253. doi:https://doi.org/10.1016/j.trd.2015.12.005
National Academies of Sciences, Engineering, & and Medicine. (2016). *Shared Mobility and the Transformation of Public Transit*. Washington, DC: The National Academies Press.
Normcommissie 351 041 "Parkeergarages". (2013). NEN 2443 (nl): Parkeren en stallen van personenauto's op terreinen en in garages. In.
NS. (2015). *Algemene Voorwaarden voor het vervoer van Reizigers en Handbagage van de Nederlandse Spoorwegen (AVR-NS)*. Retrieved from https://www.ns.nl/voorwaarden.html
NS. (2018a). Grootste, kleinste en snelst groeiende stations [Press release]. Retrieved from https://nieuws.ns.nl/grootste-kleinste-en-snelst-groeiende-stations/

NS. (2018b). NS Zonetaxi. Retrieved from https://www.ns.nl/en/door-to-door/consumers/ns-zonetaxi.html
NS. (2018c). Using the OV-fiets. Retrieved from https://www.ns.nl/en/door-to-door/ov-fiets
NS Stations (2018, 7 November 2018). [Station Almere Centrum: data].
NS Zakelijk. (2015). Nieuwsbrief februari 2015. *NS Zakelijk*. Retrieved from http://2organize.tripolis.com/public/preview?GcrM5LFHzvz*cgrFto4hLKQ3zr_EEQF7EGknuBDxHR3rZD2APzsTZUOyGihdSPIR
Omroep Flevoland. (2018). Station Almere Centrum wordt aantrekkelijker [Press release]. Retrieved from https://www.omroepflevoland.nl/nieuws/165663/station-almere-centrum-wordt-aantrekkelijker
Ortuzar, J. D., & Willumsen, L. G. (2011). *Modelling Transport, 4th Edition*. West Sussex, United Kingdom: John Wiley & Sons, Ltd.
Park, K., Ewing, R., Scheer, B. C., & Tian, G. (2018). The impacts of built environment characteristics of rail station areas on household travel behavior. *Cities, 74*, 277-283. doi:https://doi.org/10.1016/j.cities.2017.12.015
Projectteam Basisstation. (2005). *Basisstation 2005*. Retrieved from https://www.stations.nl/beleid
ProRail, & NS. (2010). *Samen bouwen aan betere stations; Uitwerking afspraken evaluatie spoorwetgeving*. Retrieved from https://acc.stations.nl/beleid
Puello, L. L., & Geurs, K. (2015). Modelling observed and unobserved factors in cycling to railway stations: application to transit-oriented-developments in the Netherlands. *European Journal of Transport and Infrastructure Research, 15*(1), 27-50.
PwC. (2018). Megatrends: 5 global shifts changing the way we live and do business. Retrieved from https://www.pwc.co.uk/issues/megatrends.html
Racca, D. P., & Ratledge, E. C. (2004). *Project Report for "Factors that affect and/or can alter mode choice"*. Retrieved from http://udspace.udel.edu/handle/19716/1101
Rayle, L., Dai, D., Chan, N., Cervero, R., & Shaheen, S. (2016). Just a better taxi? A survey-based comparison of taxis, transit, and ridesourcing services in San Francisco. *Transport Policy, 45*, 168-178. doi:https://doi.org/10.1016/j.tranpol.2015.10.004
Rees, W. E. (1992). Ecological footprints and appropriated carrying capacity: what urban economics leaves out. *Environment and Urbanization, 4*(2), 121-130. doi:10.1177/095624789200400212
RET. (2018). Materieel - bus. Retrieved from https://corporate.ret.nl/over-ret/materieel/bus
Rijksdienst voor Ondernemend Nederland. (2018). *Elektrisch vervoer in Nederland: Highlights 2017*.
SAE International. (2018). Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles. In: SAE International.
Shaheen, S., & Chan, N. (2016). *Mobility and the Sharing Economy: Potential to Facilitate the First- and Last-Mile Public Transit Connections* (Vol. 42).
Shaheen, S., Chan, N., Bansal, A., & Cohen, A. (2015). *Shared Mobility: A Sustainability & Technologies Workshop: Definitions, Industry Developments, and Early Understanding*. Retrieved from https://trid.trb.org/view/1375066
Shaheen, S., Cohen, A., & Jaffee, M. (2018). *Innovative Mobility: Carsharing Outlook*. Retrieved from https://escholarship.org/uc/item/1mw8n13h
Shelat, S., Huisman, R., & Van Oort, N. (2018). Analysing the trip and user characteristics of the combined bicycle and transit mode. *Research in Transportation Economics*. doi:https://doi.org/10.1016/j.retrec.2018.07.017
Shladover, S. E. (Producer). (2018). Practical Challenges to Deploying Highly Automated Vehicles.
Stichting FietsParKeur. (2004). *Normstellend document fietsparkeersystemen*. Retrieved from http://www.fietsparkeur.nl/
Tran, M. T., Zhang, J., & Fujiwara, A. (2014). Can We Reduce the Access by Motorcycles to Mass Transit Systems in Future Hanoi? *Procedia - Social and Behavioral Sciences, 138*, 623-631. doi:https://doi.org/10.1016/j.sbspro.2014.07.248

Treinreiziger.nl. (2016). NS Zonetaxi steeds vaker gebruikt. Retrieved from https://www.treinreiziger.nl/ns-zonetaxi-steeds-vaker-gebruikt/

TwentsFlex. (2018). *TwentsFlex Rijssen-Holten, je rit op bestelling*. Retrieved from https://www.twents.nl/twentsflex/over-twentsflex

Van Binsbergen, A., & Hoogendoorn, S. (2016). De toekomst van stedelijke mobiliteit. *NM Magazine, 11*.

Van Goeverden, K., & Homem de Almeida Correia, G. (2017). *Potential of peer-to-peer bike sharing for relieving bike parking capacity shortage at train stations: an explorative analysis for the Netherlands*. Paper presented at the Colloquium Vervoersplanologisch Speurwerk, Gent.

Van Hagen, M., & Exel, M. (2012). *De reiziger centraal. De reiziger kiest de weg van de minste weerstand*. Retrieved from https://www.spoorbeeld.nl/

Van Mil, J. F. P., Leferink, T. S., Annema, J. A., & Van Oort, N. (2018). *Insights into factors affecting the combined bicycle-transit mode*. Paper presented at the CASPT, Brisbane, Australia.

Van Vuuren, D. P., Boot, P., Ros, J., Hof, A., & Den Elzen, M. (2016). *Wat betekent het Parijsakkoord voor het Nederlandse langetermijn-klimaatbeleid?* Den Haag: PBL.

Wen, C.-H., Wang, W.-C., & Fu, C. (2012). Latent class nested logit model for analyzing high-speed rail access mode choice. *Transportation Research Part E: Logistics and Transportation Review, 48*(2), 545-554. doi:https://doi.org/10.1016/j.tre.2011.09.002

Wiercx, M., Huisman, R., Van Oort, N., & Van Arem, B. (2019). *Operations of zero-emission buses: impacts of charging methods and mechanisms on costs and the level of service*. Paper presented at the Transportation Research Board 98th Annual Meeting, Washington, D.C.

Yap, M. D., Correia, G., & Van Arem, B. (2016). Preferences of travellers for using automated vehicles as last mile public transport of multimodal train trips. *Transportation Research Part A: Policy and Practice, 94*, 1-16. doi:https://doi.org/10.1016/j.tra.2016.09.003

Zhao, F., Li, M.-T., Chow, L.-F., Gan, A., & David Shen, L. (2002). *FSUTMS Mode Choice Modeling: Factors Affecting Transit Use and Access*.

APPENDICES

A MODE CHOICE FACTORS

Travel mode level of service

Transit travel time (including transfer time, wait time, etc. walk time)
Highway travel time
Out of vehicle travel time
Presence of a transit, bicycle or walk route
Direct service or not, transfer costs
Hours of operation
Costs, fares
Comfort/security variables
Time of year, season
Total number of bus runs
Average bus runs per stop
Average daily headways
Peak headways
Revenue vehicle hours, revenue vehicle distance
Service offered by park and rides and multi-modal facilities

Land use/urban design

Land use mix, entropy (single family multi, retail, office entertainment, institutional, industrial, manufacturing)
Sidewalks
Population density
Employment density
Parking fees/parking availability
Availability of parking
Average commute time
Housing density
Retail, commercial, service, industrial, employment density
Average parcel size
Pedestrian environment factors

Accessibility

Walk time involved in trip
% of people in an area that are within a certain distance to transit facilities
Time it takes to drive to a park and ride, (distance <= 10 miles)
Regional accessibility
Often arrayed by different types of employment (service, commercial)
Kinds of accessibility

- Modal – degree of connectivity of two places by mode available
- Temporal – variation in time of day
- Legal – legal/regulatory restrictions
- Relative – Ease of travel between two points based on time and cost
- Integral – Ease of travel between one point and many, time and cost
- Place – just spatial separation between two places
- Activity – activities at destinations accounted for explicitly
- Cumulative opportunity index – #opportunities reachable within defined cost or time

Gravity type measures – sum of opportunities weighted by travel time/cost

Transit users' socioeconomic/demographic characteristics

Gender
Age
Ethnicity
Income
Child in the household
Proportion of population 16 yrs and younger
Proportion of population 65 and older
Household structure, household size
Average housing value
Average commercial, industrial, service, non-residential, property value
Vehicle availability, % of household without car
Total number of vehicles per household, #vehicles/licensed driver, #vehicles/worker
Average number of cars owned by households with children
Average number of cars owned by households without children
Race, percentages for white, black, Asian, Hispanic, Foreign
Average workers in household with and without children
Average person in household with and without children
% Households without children
Number of persons in household who can drive
Origin and/or destination

Characteristics of the trip

Trip purpose (work, school, shopping, recreation, or others)
Trip distance
Origin and destination information

B CONSULTED STUDIES LITERATURE REVIEW

Author(s)	Year	Country	Type of transit node	Multimodal stages (HE / MS / AE)[1]			Mode(s)	
Arentze & Molin	2013	Netherlands	Stations	HE	MS	AE	4 modes	Walking, bicycle, bus/tram and PT bike
Cervero	2001	United States	Transit stations	HE		AE	1 mode	Walking
Chakour & Eluru	2013	Canada	Railway stations	HE			4 modes	Drive alone, shared ride, transit and active transportation
Creemers et al.	2014	Belgium	Railway stations BTM stations	HE	MS	AE	3 modes	Car, BTM and slow
Debrezion et al.	2009	Netherlands	Railway stations	HE			4 modes	Car, public transport, bicycle and walking
Givoni & Rietveld	2007	Netherlands	Railway stations	HE		AE	5 modes	BTM, walking, bicycle, car (passenger) and car (driver)
Goel & Tiwari	2016	India	Metro stations	HE		AE	7 modes	Walking, bicycle, cycle rickshaw, auto rickshaw, 2W, car and bus
Halldórsdóttir et al.	2017	Copenhagen	Railway stations	HE		AE	5 modes	Walking, bicycle, car driver, car passenger and bus
Jiang et al.	2010	China	Bus rapid transit (BRT) stations	HE		AE	1 mode	Walking
Kim et al.	2007	United States	Light-rail transit (LRT) systems	HE			4 modes	Drive and park, pick up and drop off, bus and walking
Krygsman et al.	2004	Netherlands	Railway stations	HE	MS		3 modes	Walking, bicycle and other (car driver, passenger, taxi etc.)
Mo et al.	2018	Singapore	Mass rapid transit (MRT) stations	HE		AE	3 modes	Walking, bus and LRT
Molin & Timmermans	2010	Netherlands	Railway stations			AE	7 modes	Public transport, taxi, train taxi, PT bike, bike in train, bike at station and Greenwheels
Puello & Geurs	2015	Netherlands	Railway stations	HE			1 mode	Bicycle
Shelat et al.	2018	Netherlands	Railway stations	HE	MS	AE	1 mode	Bicycle

Tran et al.	2014	Vietnam	Mass transit stations	HE			4 modes	Walking, bicycle, motorcycle (driver) and motorcycle (passenger)
van Mil et al.	2018	Netherlands	Railway stations	HE	MS		1 mode	Bicycle
Wen et al.	2012	Taiwan	High-speed rail (HSR) stations	HE			8 modes	City bus, train, car driver, car passenger, motorcycle driver, motorcycle passenger, taxi and shuttle bus
Yap et al.	2016	Netherlands	Railway stations			AE	4 modes	BTM, bicycle, AV car-sharing and AV automatically driven

[1] Three stages can be distinguished for a multimodal trip: home-end (HE) stage, main stage (MS) and activity-end (AE) stage.

C ACCESS/EGRESS MODE CHOICE FACTORS

Characteristics of the traveller

Factor	Influence	Study
Gender	Men are less willing to take the bus at the activity-end compared to women	Halldórsdóttir et al., 2017
	Females are more likely to use the bus than males	Kim et al., 2007
	Females are more likely to choose the car to/from the station compared to males	Creemers et al., 2014
	Females are less likely to choose slow transport modes to/from the railway station compared to males	Creemers et al., 2014
	Males show a positive influence on the motorcycle (driver) and a negative influence on walking and bicycle	Tran et al., 2014
Age	Increasing age is related to a higher use of the car at the home-end	Givoni & Rietveld, 2007
	Travellers over 65-years old tend to use the car more at the activity-end	Givoni & Rietveld, 2007
	Transit riders younger than 25 have an increasing share for being picked up and dropped off at the station	Kim et al., 2007
	The age group 25-34 is associated with a reduction in the walk share compared to other transport modes	Kim et al., 2007
	The older people are likely to choose walking and motorcycle (driver) as access mode to UMRT stations	Tran et al., 2014
Occupation	Being a student increases the probability of taking the bus at both the home-end and activity-end	Halldórsdóttir et al., 2017
	Having a student card (indication of being a student) reduces the probability of taking the bicycle to the railway station	Puello & Geurs, 2015
	Full-time employees have increasing shares of being picked up and dropped off	Kim et al., 2007
	Full-time students are associated with an increasing bus share and even more so increasing walk share relative to drive and park and pick up and drop off	Kim et al., 2007
Driver's license	Transit riders with valid driver's license are more likely to drive and park and walk instead of being picked up and dropped off or taking the bus	Kim et al., 2007
	Having a driver's license increases the probability of choosing a car to/from the railway station	Creemers et al., 2014
Vehicle ownership / Car availability	Owning a car increases the probability of using the car at the home-end	Halldórsdóttir et al., 2017
	Owning a car increases the probability of using the car as access mode	Debrezion et al., 2009
	Owning a car or motorised two-wheelers (2W) increases the probability to use these respective transport modes for access trips. Owning both modes increases the probability of using 2W as access mode	Goel & Tiwari, 2016
	Owning a motorcycle negatively effects the choice of walking	Tran et al., 2014
	Having a car available decreases the probability of cycling to the railway station	Puello & Geurs, 2015
	Having a private automobile available for the trip is associated with a reduction in the shares of all transport modes compared to drive and park	Kim et al., 2007
Income	Lower incomes are associated with an increase in bus share while higher incomes reduce the bus share compared to the other transport modes	Kim et al., 2007
Race	African-Americans are associated with an increased bus share, and to a lesser extent, increased pick up and drop off share compared to drive-and-park and walking, relative to the other races	Kim et al., 2007
Number of children	Respondents are less likely to use bicycle and motorcycle (driver) if their households have more children	Tran et al., 2014

Number of workers	Number of workers is positively associated with walking mode	Tran et al., 2014
Other motorists	Having another motorist in the household decreases the probability of using the car at the home-end	Halldórsdóttir et al., 2017
Season ticket	Owning a season ticket increases the probability of using the bus at the activity-end	Halldórsdóttir et al., 2017
Type of train user	Second class train travellers on average prefer the use of bicycle or BTM as egress mode while first class train users prefer the use of automated vehicles	Yap et al., 2016
	Travellers who do not travel by rail on a regular basis tend to use the car more often at the home-end and activity-end	Givoni & Rietveld, 2007

Psychological factors

Factor	Influence	Study
Attitude	Travellers' attitudes regarding the sustainability of automated vehicles (AVs) is the most important attitudinal factor for using AVs	Yap et al., 2016
	The attitude towards the station environment shows a positive influence on cycling to the station. The higher the valuation of the environment, the higher the probability of cycling.	Puello & Geurs, 2015
Perception	The perception of trust is found to be the second-most important factor influencing the stated use of automated vehicles	Yap et al., 2016
	The perception of the connectivity of the departure station increases bicycle use	Puello & Geurs, 2015
	The perceived quality of bicycle facilities significantly increases bicycle use	Puello & Geurs, 2015
	The in-vehicle time in an automatically driven AV is perceived more negatively compared to the in-vehicle time of a manually driven AV	Yap et al., 2016
	Travellers perceive the different time attributes that are associated with transport modes differently	Arentze & Molin, 2013
	Perception of travel costs are not uniform among travellers	Arentze & Molin, 2013
Preferences	Travellers have base preferences for service quality attributes based on considerations such as reliability, safety, health, convenience, comfort and image/status which are transport mode specific	Arentze & Molin, 2013

Characteristics of the access/egress trip

Factor	Influence	Study
Distance	When the distance increases, the probability of cycling to the railway station decreases	Puello & Geurs, 2015
	An increasing distance reduces the share of cycling and walking at the home-end while the share of public transport and car increases	Givoni & Rietveld, 2007
	Non-motorised vehicles are used on shorter access distances	Debrezion et al., 2009
	Higher probability of choosing bus when longer access/egress distances are considered	Mo et al., 2018
	The longer the distance to the transit, the lower the willingness to walk to access the station	Kim et al., 2007
	With increasing trip distance the probability of choosing PT over car increases	Goel & Tiwari, 2016
	When the distance increases, the probability of walking decreases while the probability of choosing PT bike increases	Molin & Timmermans, 2010

Trip purpose	Work-related travel purposes increases the probability of choosing automobile modes as egress mode	Molin & Timmermans, 2010
	Different access/egress mode choice preferences are found at both the home-end and activity-end for shopping, leisure and errand purposes	Halldórsdóttir et al., 2017
	Travellers with business purposes seem to use the car more often at the home-end compared to travellers with commuting purposes	Givoni & Rietveld, 2007
	Travellers with leisure purposes seem to use the car more often at the activity-end	Givoni & Rietveld, 2007
Travel party	Travelling with company increases the probability of choosing slow transport modes as bike and walking as egress mode	Molin & Timmermans, 2010
	Travelling with company increases the probability of choosing automobile modes as egress mode	Molin & Timmermans, 2010
	Having a fellow traveller decreases the probability of taking the bus at the home-end and the probability of walking or cycling at the activity-end	Halldórsdóttir et al., 2017
Time of day	Travelling in daylight increases the probability of choosing slow transport modes as bike and walking as egress mode	Molin & Timmermans, 2010
	Higher probability of walking relative to other transport modes when trips are made in the evening or night	Kim et al., 2007
Weather	Dry weather increases the probability of choosing slow transport modes as bike and walking as egress mode	Molin & Timmermans, 2010
Knowledge of the route	Well-known routes increases the probability of choosing slow transport modes as bike and walking as egress mode	Molin & Timmermans, 2010
	Not knowing the route increases the probability of choosing automobile modes as egress mode	Molin & Timmermans, 2010
Amount of luggage	Not carrying heavy luggage increases the probability of choosing slow transport modes as bike and walking as egress mode	Molin & Timmermans, 2010
	Carrying heavy luggage increases the probability of choosing automobile modes as egress mode	Molin & Timmermans, 2010

Characteristics of the access/egress mode

Factor	Influence	Study
Travel time	Improving the walkability (reduction of walk travel time) increases the probability of walking at both the home-end and activity-end	Halldórsdóttir et al., 2017
	Improving the bikeability (reduction of bicycle travel time) increases the probability of cycling at both the home-end and activity-end	Halldórsdóttir et al., 2017
	Improving the bus service (reduction of in-vehicle time) increases the probability of choosing the bus to/from train stations	Halldórsdóttir et al., 2017
	Travel time by transport mode has a negative impact on the mode choice	Chakour & Eluru, 2013
Costs	Reducing the costs of public access modes increases the share of public transport as access mode	Wen et al., 2012
	Raising parking fees will discourage many travellers from driving their cars to the station	Wen et al., 2012
	Travel costs are relevant for multimodal mode choice	Yap et al., 2016
Level of service (LOS) / Qualitative factors	Factors which are less easy (or impossible) to measure influence mode choice. Examples are comfort and convenience, safety, protection and security	Ortuzar & Willumsen, 2011

Characteristics of the built environment

Factor	Influence	Study
Density	A low residential density increases the probability of cycling to the railway station	Puello & Geurs, 2015
	Access trips by foot increases when density increases (especially residential densities)	Cervero, 2001
	A higher density of socioeconomic activities encourages people to walk on the first- and last-mile	Mo et al., 2018
	In areas with a high population density, the probability of walking as access/egress mode increases	Goel & Tiwari, 2016
	Travelling within central areas increase the probability of taking the bus at the home-end and the decreases the probability of cycling at the activity-end	Halldórsdóttir et al., 2017
Diversity	A more mixed-use environment seems to promote walking access, ostensibly because transit riders can chain trip ends by foot in more diverse settings	Cervero, 2001
	Higher entropy index (well-mixed land use) encourages people to walk on the first- and last-mile	Mo et al., 2018
	Travelling within central areas increase the probability of taking the bus at the home-end and the decreases the probability of cycling at the activity-end	Halldórsdóttir et al., 2017
Design (of the surrounding)	Residents are more likely to walk to a station instead of using the car in settings with fairly complete sidewalk networks. Intersection density also promotes walking as access mode to the station.	Cervero, 2001
	Increase in road length density decreases the share of walking while bus share increases on the first- and last-mile	Mo et al., 2018
	Walking is preferable if respondents selected measures of improving sidewalk and pedestrian facilities for better accessibility	Tran et al., 2014
	An environment with shaded corridors increases the willingness to walk and therefore increases the share of walking	Jiang et al., 2012
Design (of the railway station)	Available parking facilities increase the probability of choosing the bicycle at the activity-end, especially when these facilities are covered	Halldórsdóttir et al., 2017
	Parking facilities at the railway station increase the probability of choosing the bicycle to the railway station	Puello & Geurs, 2015
	Parking facilities at the station for competitive means of transport decreased the share of walking to the station.	Cervero, 2001
	Bus availability shows an increase in the share of bus	Kim et al., 2007
	Stations with park and ride lots are associated with a reduction in the bus and walk shares compared to drive and park and pick up and drop off	Kim et al., 2007

Main stage factors

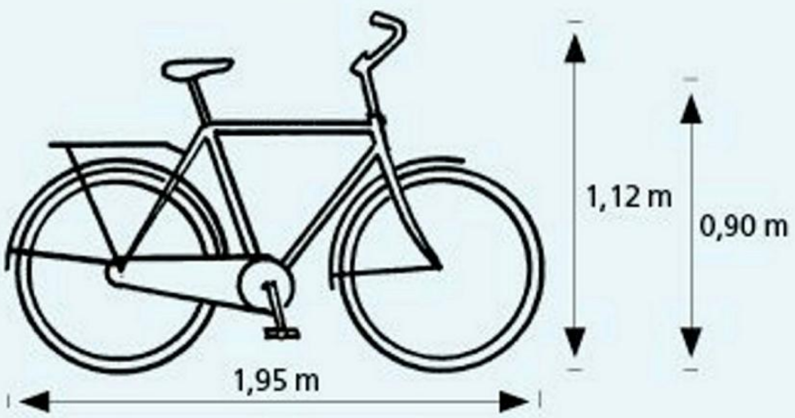
Factor	Influence	Study
Travel time of the train journey / Interconnectivity ratio	Longer travel time of the main journey decreases the probability of taking the bicycle to the railway station	Puello & Geurs, 2015
	The use of the bicycle is associated with longer line-haul stages (resulting in a smaller interconnectivity ratio)	Krygsman et al., 2004
Allowance to bring the bicycle on the train	Paying and imposing restrictions for bringing the bicycle on the train reduces the probability of cycling at the activity-end	Halldórsdóttir et al., 2017

D DESIGN VEHICLES

D.1 Bicycle

	standaardfiets
lengte (m)	1,94
breedte (m)[1)]	0,64
stuurhoogte (m)	1,23
zithoogte (m)	0,90
aantal assen	2
aantal wielen	2
wielbasis (m)	1,11
wieldiameter (m)	0,72
massa leeg (kg)	20
elektrische ondersteuning tot (km/h)	

1) wettelijk maximum is 0,75 m

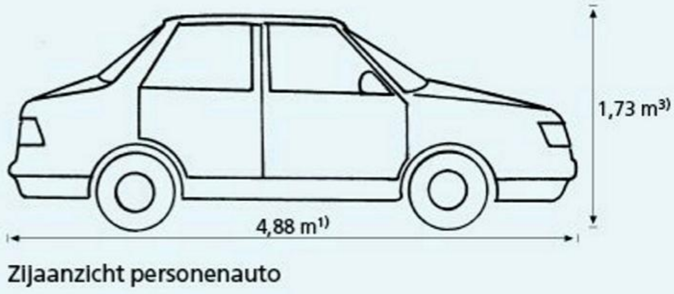


Zijaanzicht standaardfiets

Figure D.1 Dimensions of design vehicle – bicycle (CROW, 2012)

D.2 Car

lengte (m)[1)]	4,88
breedte (m)[2)]	1,83
hoogte (m)[3)]	1,73
bodemvrijheid (m)	0,10
aantal assen	2
aantal wielen	4
wielbasis (m)	2,77
spoorbreedte (m)	1,56
draaicirkel (m)	11,58
massa leeg (kg)	1.491
massa maximaal (kg)[4)]	2.189
vermogen (kW)	110
vermogen (pk)	150
remvertraging	5,2 m/s^2
aandrijving	benzine/diesel/lpg/elektrisch



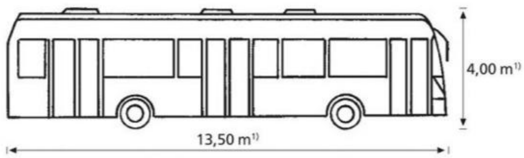
1) de maximale lengte is 12 m
2) de maximale breedte is 2,55 m exclusief spiegels
3) de maximale hoogte is 4 m
4) de maximale masse (inclusief belading) is 3.500 kg

Figure D.2 Dimensions of design vehicle – car (CROW, 2012)

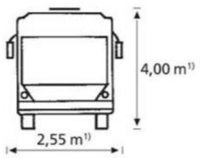
D.3 Bus

	twee assen	drie assen	gelede bus	dubbelgelede bus
lengte (m)[1]	13.50	15.00	18.75	25.00
breedte (m)[1]	2.55	2.55	2.55	2.55
hoogte (m) [1]	4.00	4.00	4.00	4.00
aantal assen	2	3	3 of meer	4
aantal wielen	4	6	6 of meer	8
wielbasis (m)	5.80		5.80 + 7.80[2]	5.80 + 7.15 + 6.45[3]
maximale spoorbreedte (m)	2.04	2.04	2.04	2.04
overhang voor (m)	2.72	2.72	2.72	2.72
overhang achter (m)	3.50			
wettelijke remvertraging (m/s^2)	4.50	4.50	4.50	4.50
massa maximaal (kg)[1]	50.000	50.000	50.000	50.000
aandrijving	diesel	diesel	diesel	diesel

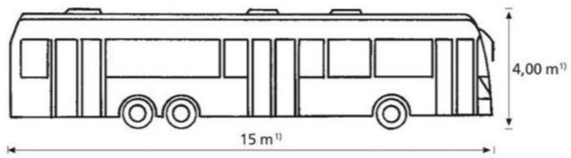
1) wettelijk maximum exclusief spiegels
2) 5.80 m van eerste tot tweede as; 7.80 m van tweede naar de derde as
3) 5.80 m van de eerste tot de tweede as; 7.15 m van de tweede naar de derde as, 6.45 m van de derde naar de vierde as



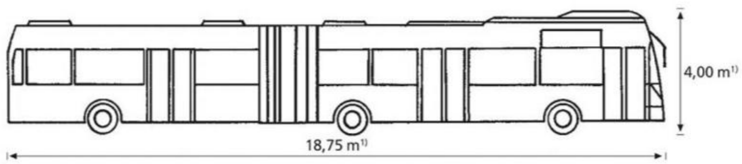
Zijaanzicht autobus met twee assen



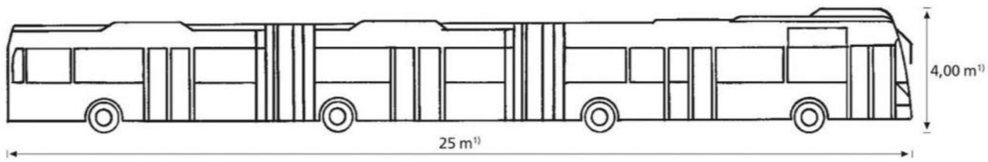
Vooraanzicht autobus



Zijaanzicht autobus met drie assen



Zijaanzicht gelede bus



Zijaanzicht dubbelgelede bus

Figure D.3 Dimensions of design vehicle – bus (CROW, 2012)

E STORAGE AREAS

E.1 Bicycle

For the dimensioning of bicycle facilities, *ProRail* refers to the normative document *Fietsparkeur* (Stichting FietsParKeur, 2004). This document includes detailed quality requirements which bicycle parking systems have to meet. For both secured and unsecured bicycle parking facilities, walking paths should be present along the parking spaces. This path should at least have a width of 2.10m. However, for bicycle parking systems with extension rail, a larger width of at least 3.00m is required. The spacing between bicycles (hart-op-hartafstand in Dutch) for all parking forms should be at least 37.5cm.

The storage areas for four different bicycle parking forms are depicted at the bottom row of Table E.1. The values for each system are calculated by multiplying the depth by the number of running meter per bicycle. The depth is the total depth of a parked bicycle including the share of the parking lane width. The running meter per bicycle for floor racks is half the minimum spacing because bicycles are placed on two levels. Illustrations of the considered parking forms are given on the next pages.

Table E.1 Storage areas for different bicycle parking forms

	High-low system, single-sided	High-low system, double-sided	Floor rack with extension rail, single-sided	Floor rack with extension rail, double-sided
Parking space length [m]	1.90	1.45	1.90	1.45
Parking lane width [m]	2.10	2.10	3.00	3.00
Running meter per bicycle [m]	0.375	0.375	0.1875	0.1875
Depth[1] [m]	2.95	2.50	3.40	2.95
Storage area [m^2]	**1.11**	**0.94**	**0.64**	**0.55**

[1] Depth = parking space length + (parking lane width / 2)

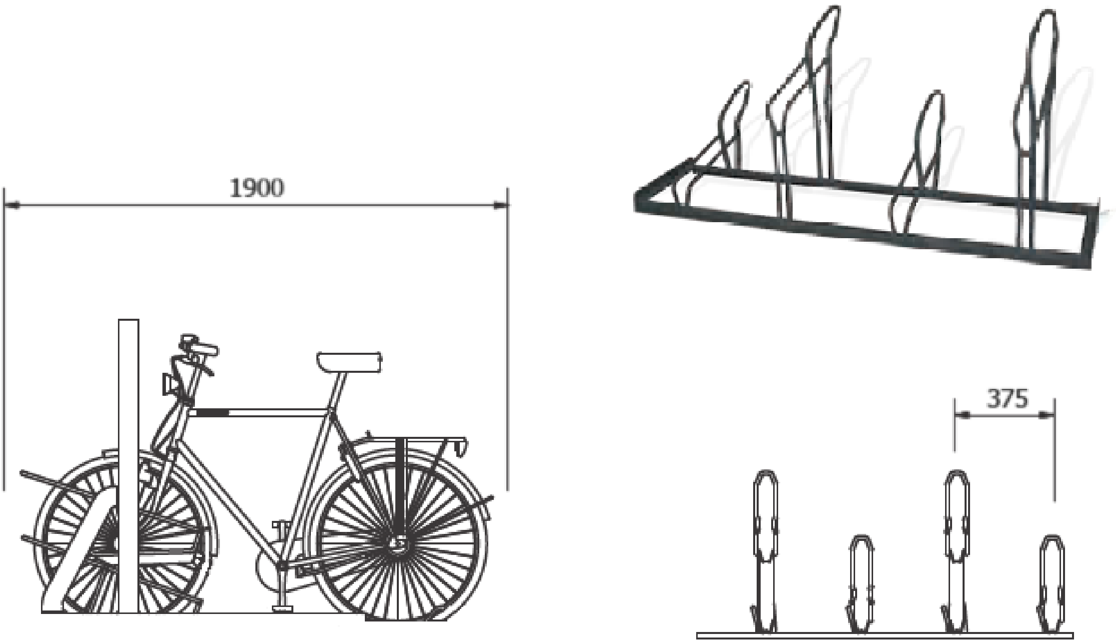


Figure E.1 Dimensions of a high-low bicycle system, single-sided (Falco BV, 2018)

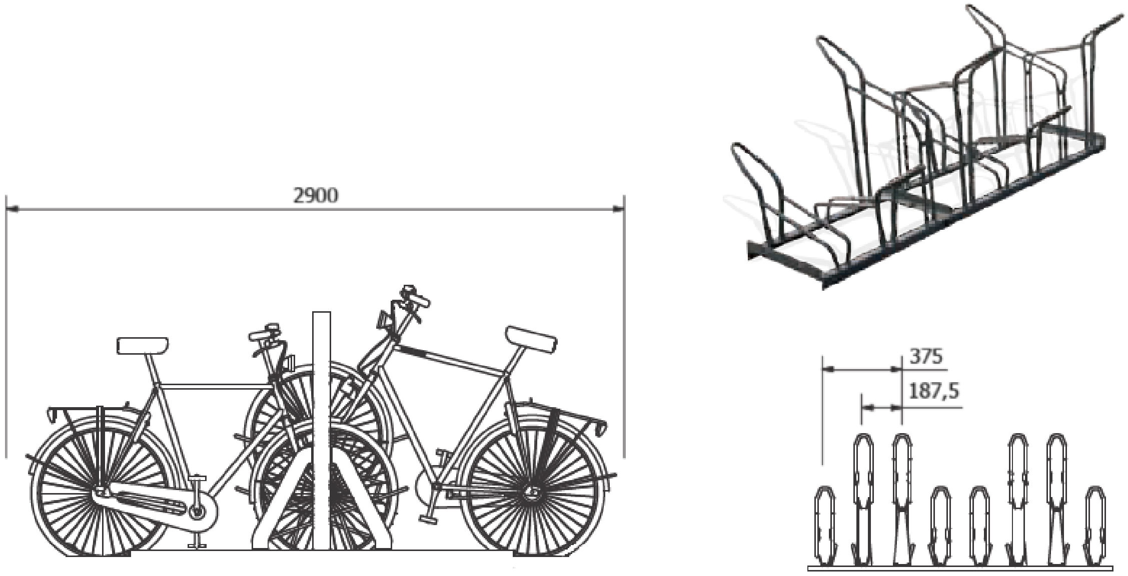


Figure E.2 Dimensions of a high-low bicycle system, double-sided (Falco BV, 2018)

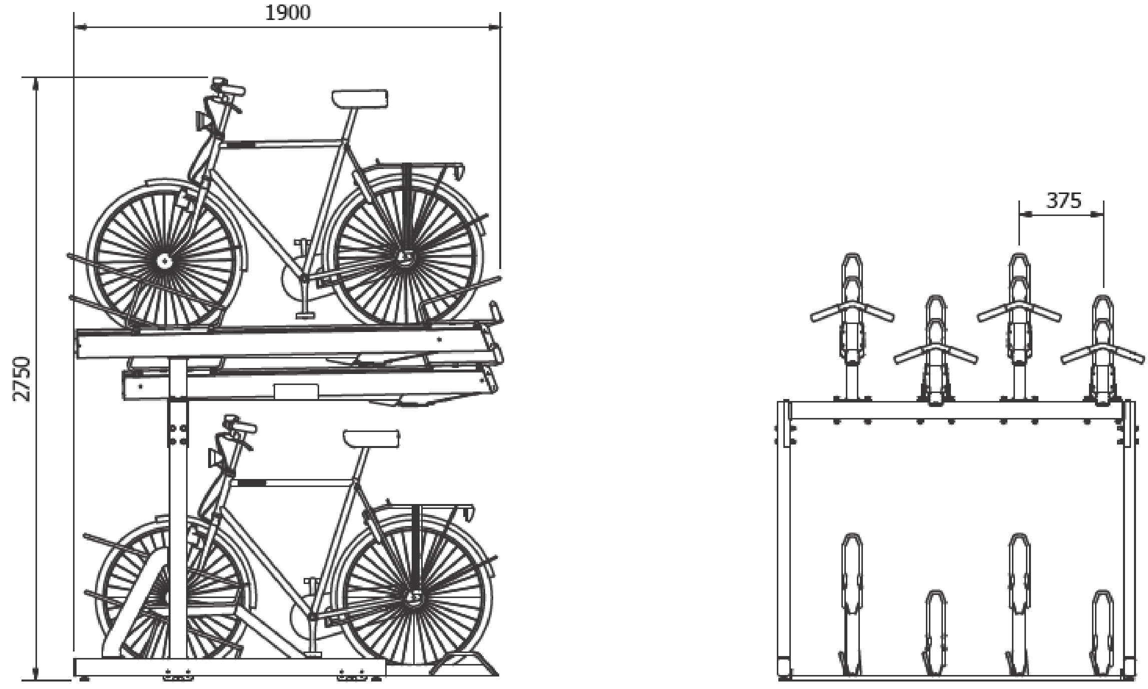


Figure E.3 Dimensions of a floor rack with extension rail, single-sided (Falco BV, 2018)

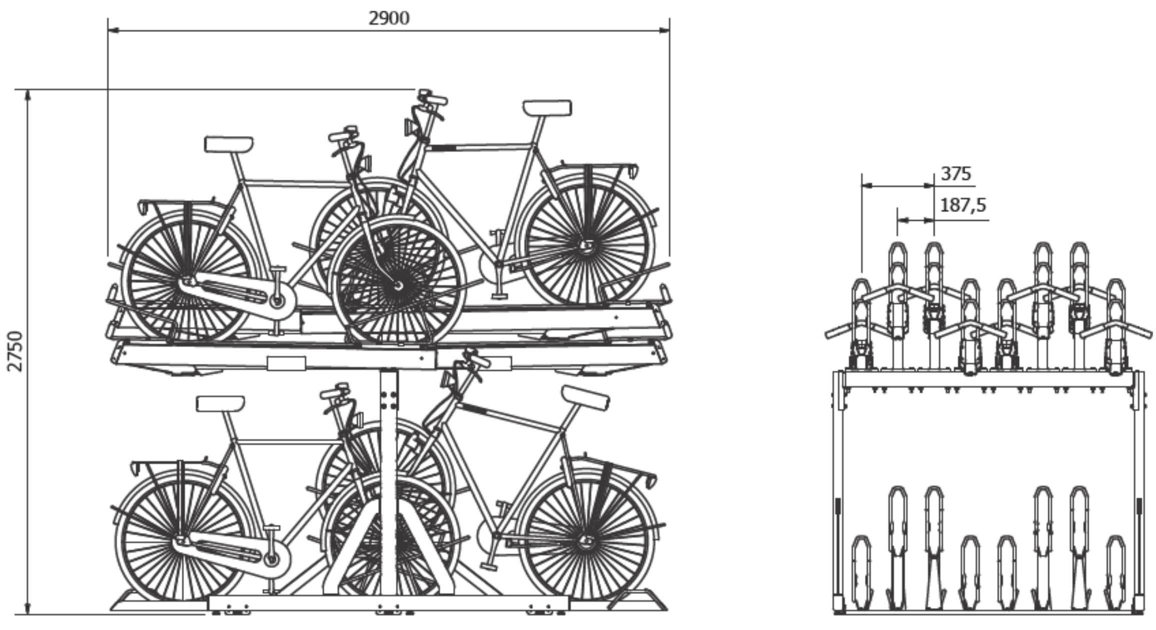


Figure E.4 Dimensions of a floor rack with extension rail, double-sided (Falco BV, 2018)

E.2 Car

The Dutch design standards and recommendations on parking facilities for passenger cars (NEN 2443) contains values for different parking forms and facilities (Normcommissie 351 041 ''Parkeergarages'', 2013). Values for (not intensively used) public facilities are used since P+R facilities at railway stations, where private cars often stand idle for a long time, do not have an intensively used public character. The design values for four different car parking forms are depicted in Table E.2 and can also be found in the illustrations on the next pages to clarify their meaning.

The storage areas are depicted at the bottom row of Table E.2 and depicted in the illustrations for each parking form. The values for each form are calculated by multiplying the depth by the number of running meter per car The depth is the total depth of a parked car including the share of the parking lane width.

Table E.2 Storage areas for different car parking forms

	Perpendicular	Angular (single parking lane)	Angular (double parking lane)	Parallel
Angle (α)	90°	45°	45°	0°
Parking space width [m]	2.40	2.40	2.40	2.00
Parking space length [m]	5.13	NA	NA	6.25
Parking lane width [m]	6.67	3.80	3.80	4.00
Running meter per car [m]	2.40	3.39	3.39	6.25
Depth[1] [m]	8.47	6.85	6.10	4.00
Storage area [m^2]	**20.32**	**23.25**	**20.70**	**25.00**

[1] Depth = parking space depth + (parking lane width / 2)

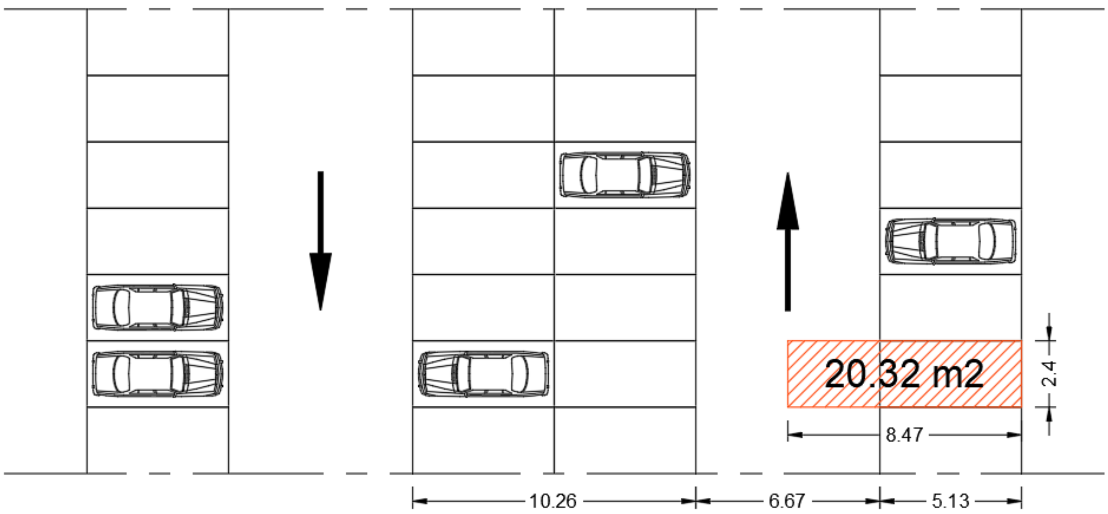


Figure E.5 Car parking - perpendicular (90°)

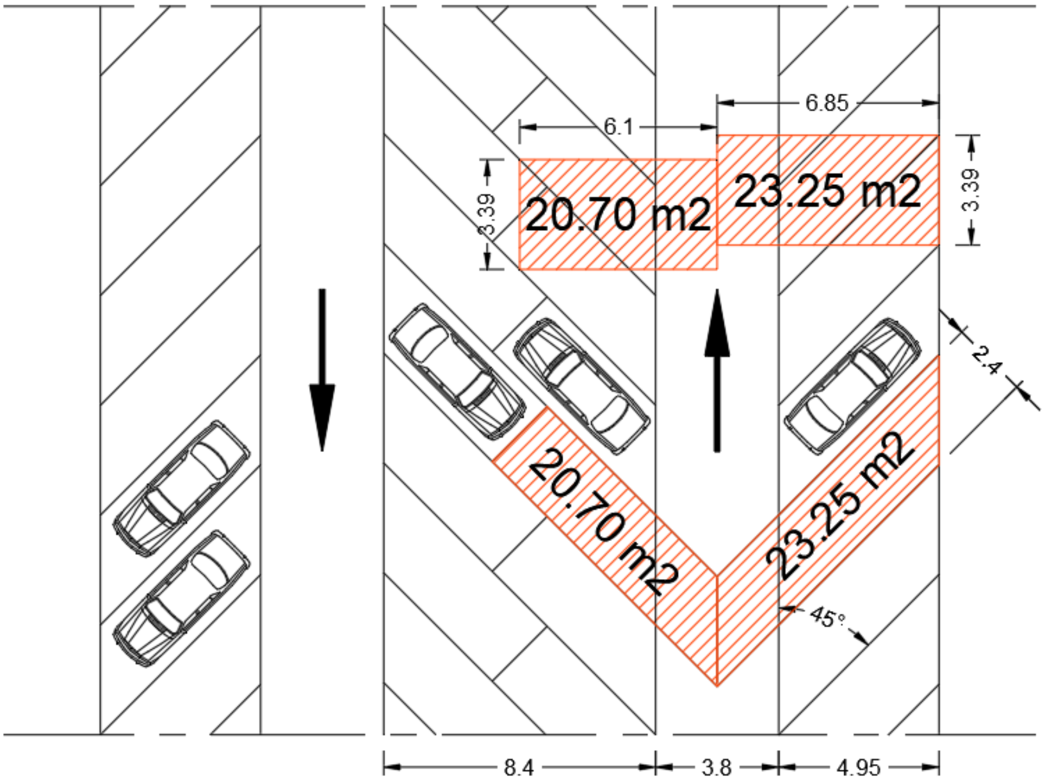


Figure E.6 Car parking - angular (45°), double parking lane (left) and single parking lane (right)

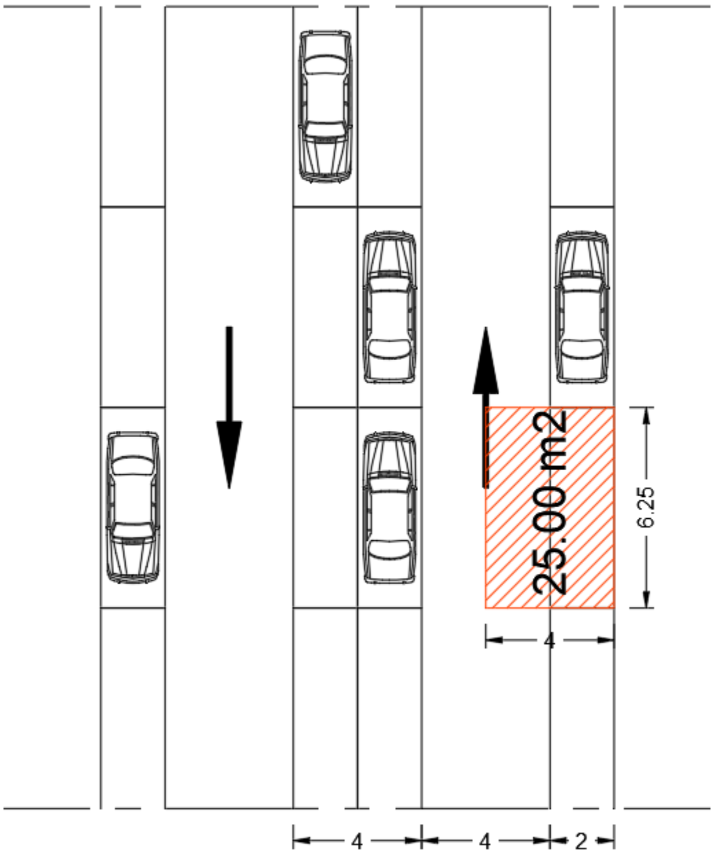


Figure E.7 Car parking - parallel (0°)

E.3 Individual traditional ride service vehicles (taxi stands)

According to the CROW (2005b), it is desirable to comply with the following guidelines for the dimensions of taxi facilities:

1. Taxi stands have a minimum dimension of 6.00 x 2.30m (length x width), including 0.50m to (dis)embark, for parallel forms (Figure E.8).
2. Taxi stands have a minimum dimension of 5.00 x 3.00m (length x width) for perpendicular forms (Figure E.9).

These values do not provide any information regarding the required parking lane dimensions to manoeuvre in and out the taxi stand. Therefore, values that were found for regular car parking facilities are used. For parallel and perpendicular car parking, these widths were 4.00m and 6.67m respectively when spaces are present at both sides of the parking lane. The minimum platform width is included in the figures and has a value of 0.90m.

The storage areas for the two different parking forms are depicted at the bottom row of Table E.3. The values for each form are calculated by multiplying the depth by the number of running meter per car. The depth is the total depth of a parked car including the platform width and the share of the parking lane width.

Table E.3 Storage areas for different taxi stand forms

	Parallel	Perpendicular
Parking space width [m]	2.30	3.00
Parking space length [m]	6.00	5.00
Platform width [m]	0.90	0.90
Parking lane width [m]	4.00	6.67
Running meter per car [m]	6.00	3.00
Depth[1] [m]	5.20	9.24
Storage area [m^2]	**31.20**	**27.70**

[1] Depth = parking space depth + platform width + (parking lane width / 2)

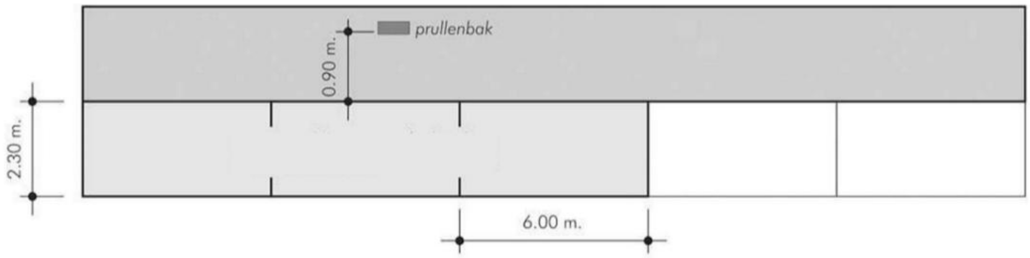


Figure E.8 Taxi stand - parallel (CROW, 2005b)

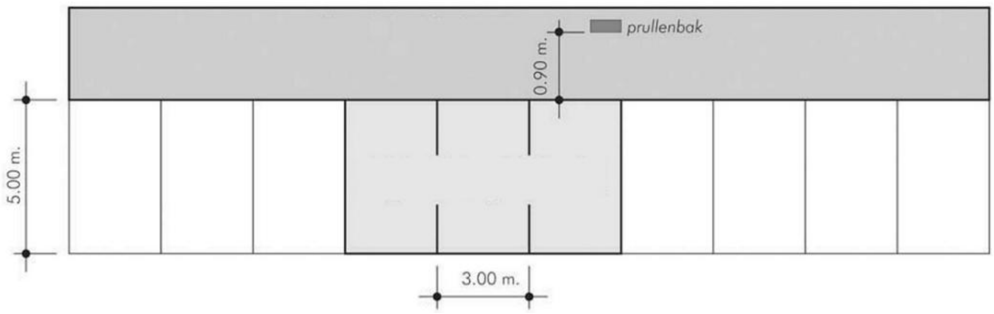


Figure E.9 Taxi stand - perpendicular (CROW, 2005b)

E.4 Collective traditional ride service vehicles (bus stations)

The CROW (2005a) determined maximum dimensions for different type of buses based on the number of axles (Appendix D.3). These regulations state that the maximum width of a bus is 2.55m while the length is restricted to 13.50m for two-axle buses, 15m for a bus with more than two axles and maximum 18.75m for articulated buses. For this research, buses with a standard length of 12m are considered. Logically, the platform length is dependent on the length of the buses that make use of the platforms. The minimum width of the platform is included in the guidelines and should at least be two meters.

Three standard layouts can be distinguished: fishbone layout (visgraatopstelling in Dutch), a parallel structure and the so-called sawtooth layout (zaagtandopstelling in Dutch). The storage areas for the different layouts are depicted at the bottom row of Table E.4. The values are determined from the illustrations depicted below that are constructed by means of the guidelines.

Table E.4 Storage areas for different bus station platform layouts

	Fishbone (90°)	Fishbone (45°)	Parallel	Sawtooth
Bus stop length [m]	13.00	NA	13.00	NA
Bus stop width [m]	3.00	NA	3.00	NA
Platform width [m]	3.20	NA	2.00	NA
Platform length [m]	15.00	NA	13.00	NA
Storage area [m^2]	**288**	**240**	**260**	**247**

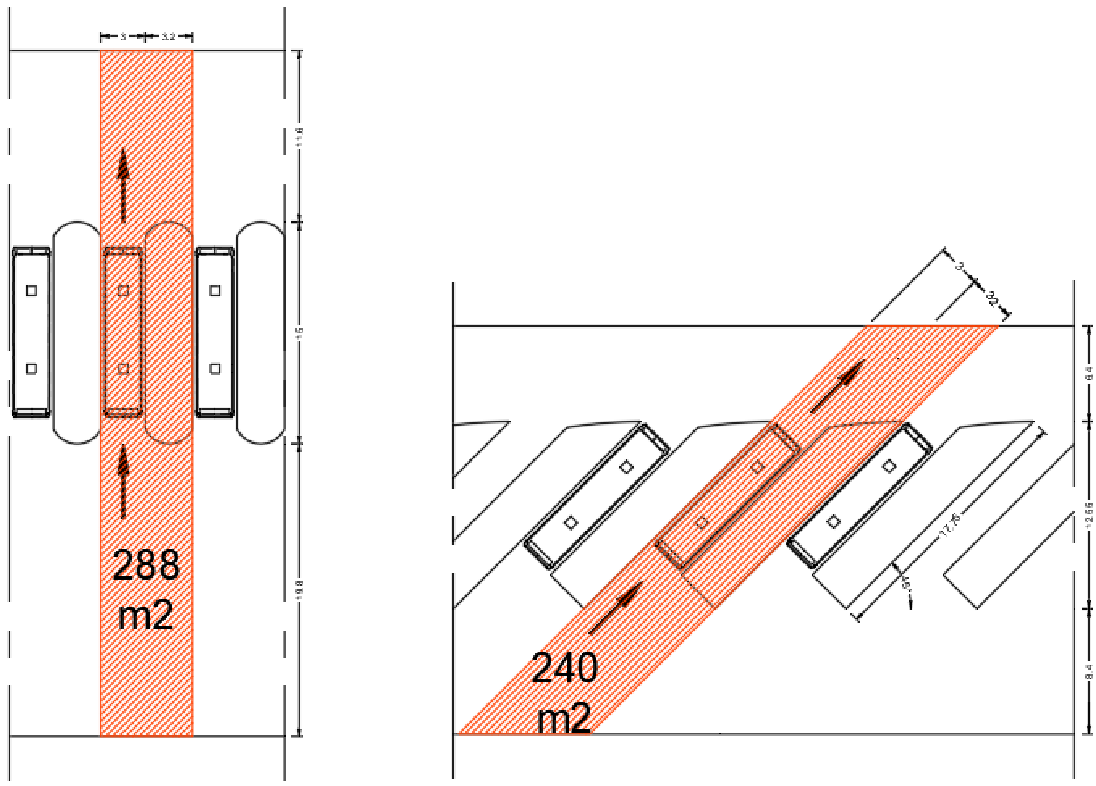


Figure E.10 Bus station platforms - fishbone layout, perpendicular (left) and 45 degrees (right)

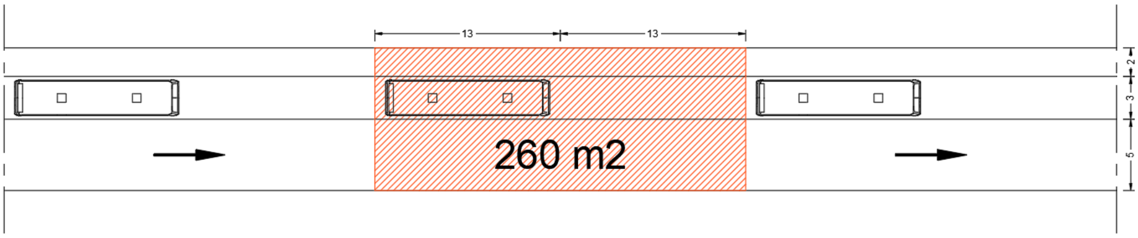


Figure E.11 Bus station platforms - parallel layout

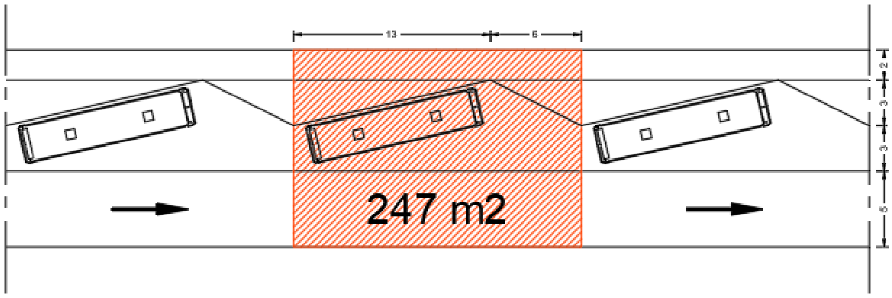


Figure E.12 Bus station platforms - sawtooth layout

F FOOTPRINT INDICATOR

Means of access/egress transport	**Storage area** [m²]	**Design frequency** [vehicles/peak period]	**Occupancy rate** [travellers/vehicle]	**Footprint** [m²/traveller]
Walking	0	NA	NA	**0.00**
Private bicycle	0.6	2	1	**0.30**
Roundtrip bikesharing vehicle	0.6	1	1	**0.60**
Free-floating bikesharing vehicle	0.6	2	1	**0.30**
P2P bikesharing vehicle	0.6	2	1	**0.30**
Private e-scooter	0.2	2	1	**0.10**
Roundtrip e-scooter sharing vehicle	0.2	1	1	**0.20**
Free-floating e-scooter sharing vehicle	0.2	2	1	**0.10**
P2P e-scooter sharing vehicle	0.2	2	1	**0.10**
Private on-board vehicle	0	NA	1	**0.00**
Private car	21	1	1.2	**17.50**
Roundtrip carsharing vehicle	11	1	1.2	**9.17**
Free-floating carsharing vehicle	11	2	1.2	**4.48**
P2P carsharing vehicle	21	2	1.2	**8.75**
Individual traditional ride service	28	6	1.2	**3.89**
Collective traditional ride service	260	24	25	**0.43**
Individual on-demand ride service	28	48	1.2	**0.49**
Collective on-demand ride service	130	48	8	**0.34**

G RAILWAY STATION ALMERE CENTRUM

G.1 Map and available access/egress facilities

The map of railway station Almere Centrum is depicted at the end of this appendix. The four connections to the train platforms are illustrated by the person walking the stairs. The two in the east are located inside the station building, while the other two are located at the bus station.

In the remainder of this Appendix, the available access/egress facilities are analysed. For each access/egress facility at railway station Almere Centrum, the total area and the capacity of the facility is determined. The capacities of each facility are counted during a visit at the railway station. The areas of each facility are measured online in Google Maps and represent the total area of the facility. All values are depicted on the map and in Table G.1. The last column shows the area per parking space (i.e. storage area) and will be used to make comparisons with the storage areas determined in paragraph 4.3.

Table G.1 Information on the facilities at railway station Almere Centrum

Facility	Designated for	Area [m^2]	Capacity [parking spaces]	Storage area [m^2]
Bicycle racks (East) (floor rack, single- and double-sided) and other	Private bicycle Scooter/moped/e-bike/carrier cycle	1,000	1,076 52	0.9
Bicycle racks (Centre) (high-low, single- and double-sided) and other	Private bicycle	420	232	1.8
Bicycle racks (West) (high-low, single-sided)	Private bicycle	135	120	1.1
Bicycle lockers	Private bicycle	225	80	2.8
Bicycle rental	Shared bicycle (OV-bicycle)	45	32	1.4
Parking garage	Private car	7,300	350	21
Car rental	Shared car (Greenwheels)	34.5[1]	1	35
Taxi stands	Individual traditional ride services	960	17	57
Bus station	Collective traditional ride services	7,750	17	456
Kiss and Ride	Individual on-demand ride services	725.5[1]	21	35

[1] The total area of 760m^2 is divided over the two facilities in the same proportion as the capacity.

Bicycle facilities

Four private bicycle facilities with a total capacity of 1,508 parking spaces (1,076 + 232 + 120 + 80) are present at the railway station area. The total area of these facilities equals 1,780m^2 (1,000 + 420 + 135 + 225). Still, the capacity of the facilities seems too low since bicycles are being placed outside the racks due to the unavailability of free spaces.

Figure G.1 Bicycle racks (East) at Almere Centrum
Figure G.2 Bicycle racks (Centre) at Almere Centrum

The bicycle racks (West), bicycle lockers and bicycle rental facilities are all opened as a result of the closure of a secured bicycle facility in the West. A flyer at the door of the meanwhile closed, facility provides the following information: 'Since 31st of July 2018, this facility is closed because the facility is outdated in terms of appearance and user-friendliness'. Cyclists are asked to make use of another facility at the railway station area or, if there are no parking spaces available, to make use of a free secured facility in the city centre. It is expected that the new facilities will be ready in 2021, but detailed information is lacking.

Figure G.3 Bicycle racks (West) at Almere Centrum
Figure G.4 Bicycle lockers at Almere Centrum
Figure G.5 Bicycle rental at Almere Centrum

Parking garage

The parking garage, called *Schoutgarage*, is the nearest car parking facility to the railway station and has a capacity of 350 parking spaces spread over two floors of 3,650m². The surrounding area includes several other car parking facilities, but none of them provides a special service for train travellers. This means that no agreements are made between *NS Stations* and the operational organisation of the parking garage regarding parking fees. This is most likely the result of the location of the railway station. Because it is undesirable to have cars (parked) in the city centre, high fees are asked to discourage its use. This also explains why other railway stations in Almere, which are not located in the city centre, do have designated P+R facilities where train users pay less to park their car. Regarding the storage area, a similar value of 21m² is found as determined in paragraph 4.3 for private car facilities.

Car rental / Kiss and Ride

The Kiss and Ride (K+R) facility has a capacity of 22 parking spaces. 21 of them are available for individual on-demand ride services. Vehicles are allowed to park here for a maximum of fifteen minutes. The storage area of 35m² is in line with 28m², the value determined in paragraph 4.3. One of the parking spaces at the K+R facility is reserved for the shared car of *Greenwheels*. In paragraph 4.3, the storage area for these type of carsharing vehicles (roundtrip) was estimated on

11m². In practice, the vehicle occupies one of the 22 parking spaces which equals 35m². Figure G.7 shows that the parking space for the shared vehicle is overdimensioned. This emphasises the statement that was made to design these facilities different from other car parking facilities.

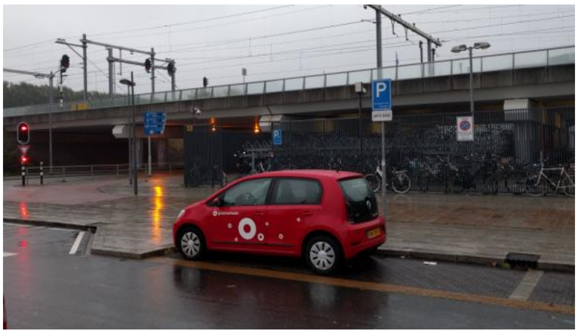


Figure G.6 Kiss and Ride facility at Almere Centrum
Figure G.7 Shared car at the Kiss and Ride facility of Almere Centrum

Taxi stands
Railway station Almere Centrum has a designated area where individual traditional ride service vehicles are allowed to park. In paragraph 4.3, vehicles of these ride services were assigned a storage area of 28m². At railway station Almere Centrum, a storage area of 57m² is found. Figure G.8 shows the area including a platform in the middle.

Figure G.8 Taxi stands at Almere Centrum

Bus station
Railway station Almere Centrum is characterised by a large bus station with seventeen platforms. The bus station connects the eastern part of the railway station area with the western part and also contains two connections to the train platforms (Figure G.9). As a result, the storage area is considerably higher than determined in paragraph 4.3. Moreover, the buses use different platforms for travellers to embark and disembark. Travellers are dropped-off close to the train connection and wait for passengers to embark at the platforms further away.

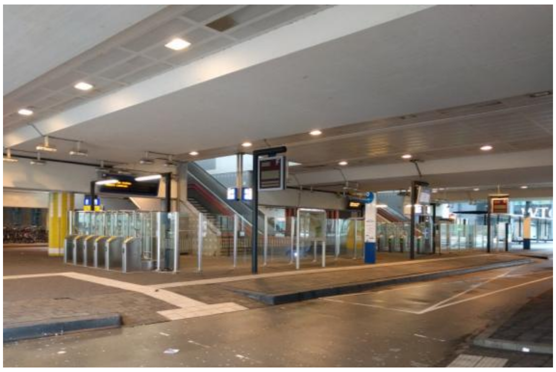
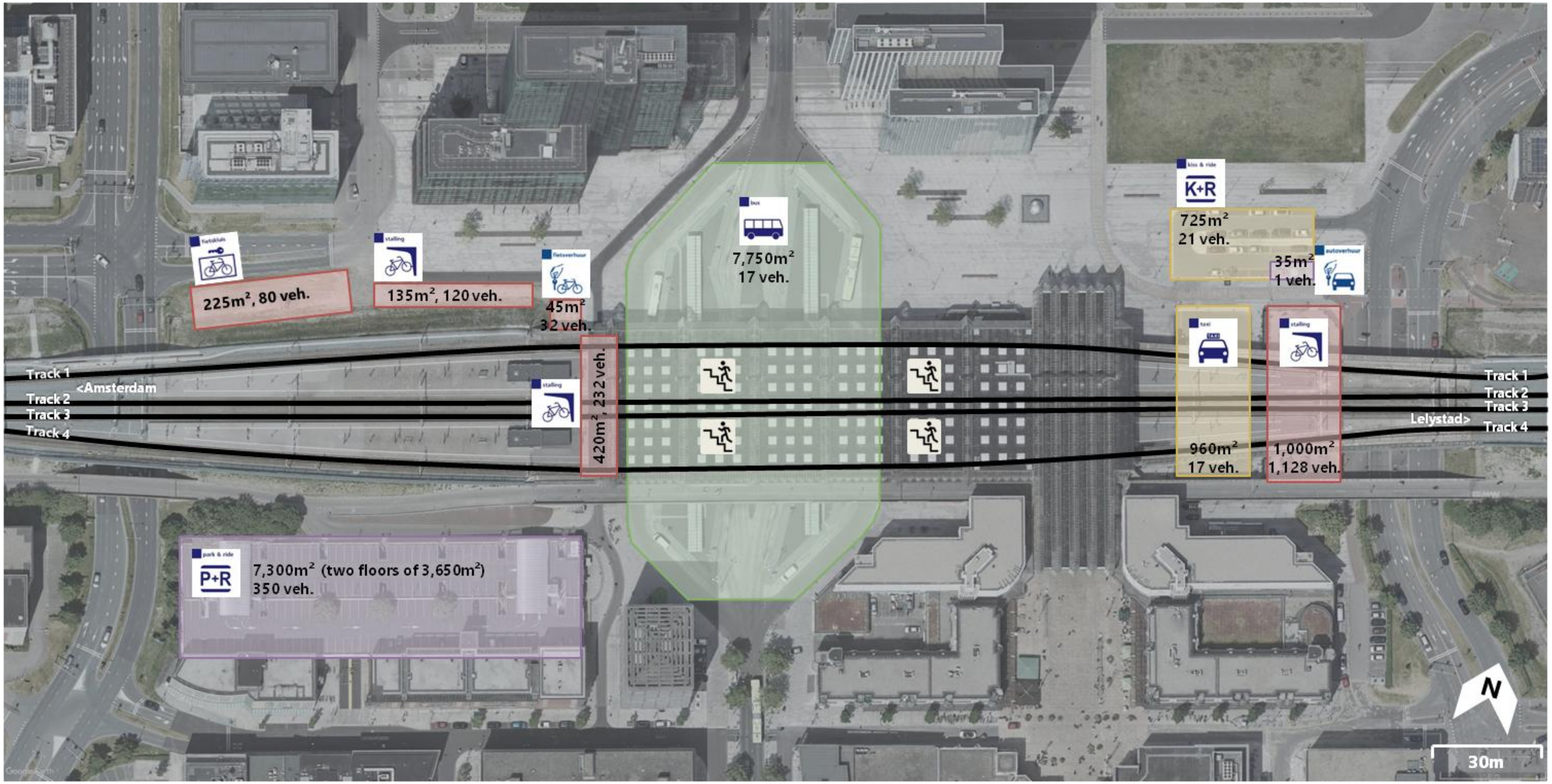


Figure G.9 Connections to the train platforms at the bus station of Almere Centrum



fietsklub
225m², 80 veh.
stalling
135m², 120 veh.
fietsverhuur
45m²
32 veh.
bus
7,750m²
17 veh.
kiss & ride
K+R
725m²
21 veh.
35m²
1 veh.
autoverhuur
taxi
stalling
420m², 232 veh.
stalling
Track 1
<Amsterdam
Track 2
Track 3
Track 4
Track 1
Track 2
Track 3
Lelystad>
Track 4
960m²
17 veh.
1,000m²
1,128 veh.
park & ride
P+R
7,300m² (two floors of 3,650m²)
350 veh.
N
30m

G.2 Data

All data in this appendix was requested for research specific purposes and is provided by *NS Stations* via personal communication (NS Stations, 2018). The data is collected from surveys which are held in 2016 by *NS Reizigers*, another subdivision of *NS*.

Number of travellers
25,888 travellers used station Almere Centrum on an average weekday in 2017 (NS, 2018a). Approximately 12,800 of this total number were unique travellers.

Age	
0-19	16%
20-24	24%
25-44	31%
45-64	26%
65+	4%
	100%

Trip purpose	
Commuting / business	54%
School / study	13%
Social / recreation	33%
	100%

Station function	
Attraction	42%
Production[1]	58%
	100%

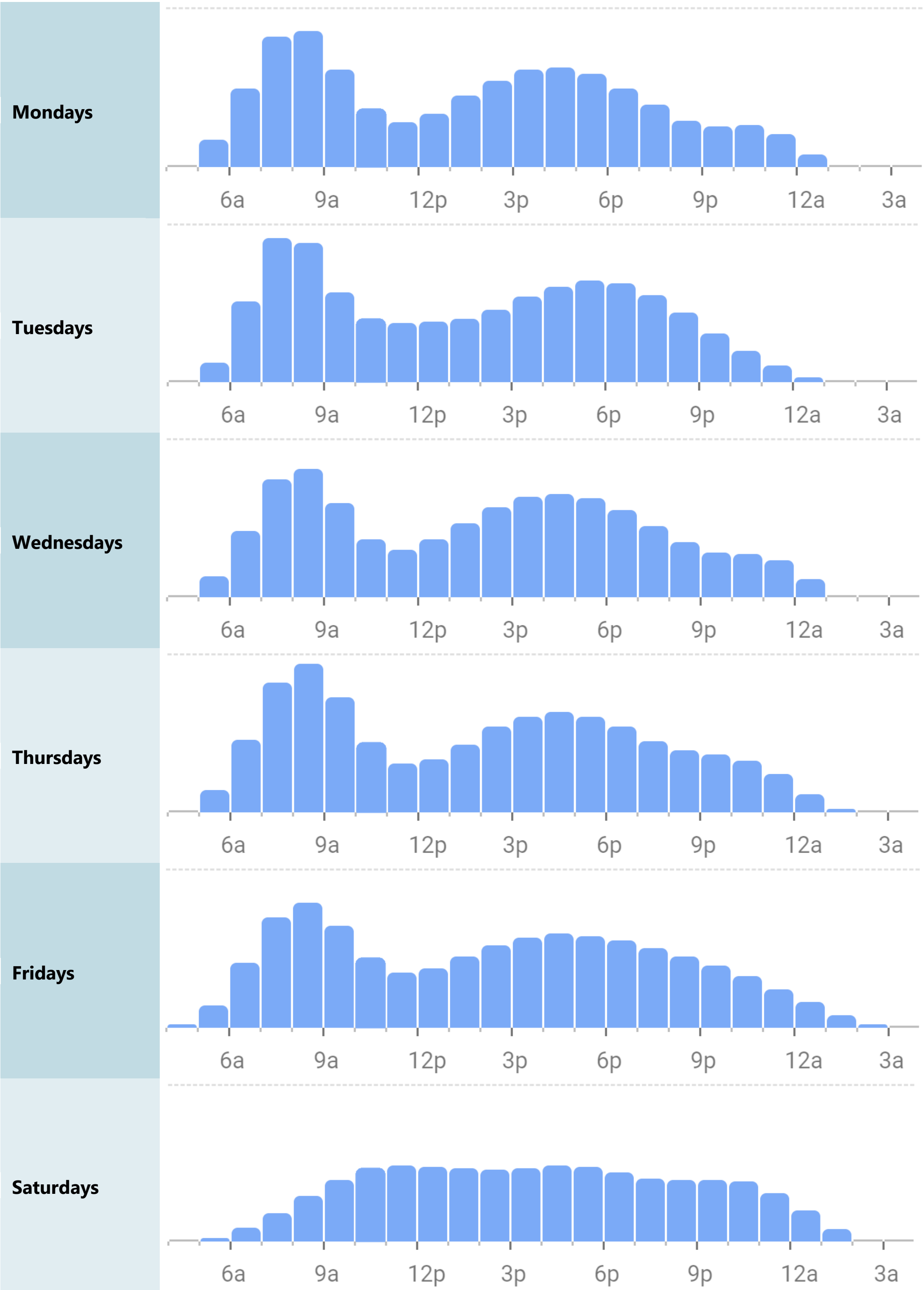
[1] The higher percentage for production illustrates that railway station Almere Centrum is especially used as a departure station, with most important destinations Amsterdam Centraal (18%) and Lelystad Centrum (10%).

Home-end modal split	
Walking	20%
Bicycle	23%
Car (driver)	2%
Car (passenger)	4%
Bus / tram / metro	51%
Taxi	0%
	100%

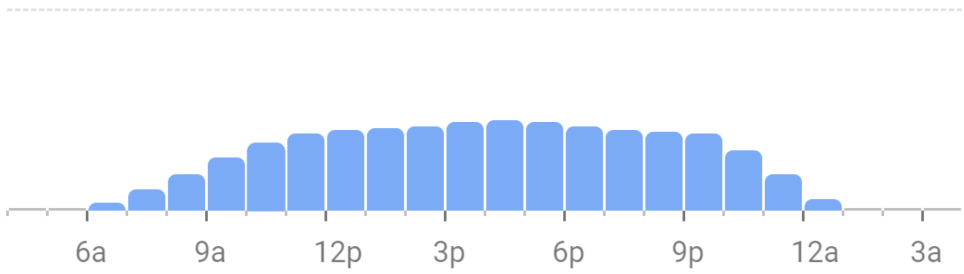
Activity-end modal split	
Walking	65%
Bicycle	8%
Car (driver)	2%
Car (passenger)	8%
Bus / tram / metro	16%
Taxi	1%
	100%

G.3 Distribution of travellers

The distribution of travellers over the day for railway station Almere Centrum was not available at *NS Stations*. This information is available on Google Maps when searching for railway station Almere Centrum (Google Maps, 2018). Graphs for all days of the week are shown below.



Sundays



The distribution graphs are used to determine the share of travellers during the peak hours. The numbers in the table below represent the area of each bar of the distribution graph. The area of the two morning peak bars (07:00 – 08:00 and 08:00 – 09:00) relative to the total area of all bars, represent the morning peak share. For the evening peak share, the area of the bars 16:00 – 17:00 and 17:00 – 18:00 are divided by the total area. The average weekday peak shares are:

Average weekday morning peak share: **18.2%**
Average weekday evening peak share: **13.5%**

	Mondays	Tuesdays	Wednesdays	Thursdays	Fridays
04:00 – 05:00	0	0	0	0	15
05:00 – 06:00	114	82	86	92	95
06:00 – 07:00	327	340	277	303	271
07:00 – 08:00	**544**	**605**	**494**	**541**	**461**
08:00 – 09:00	**566**	**584**	**537**	**621**	**523**
09:00 – 10:00	406	376	393	480	426
10:00 – 11:00	245	270	242	293	293
11:00 – 12:00	187	250	197	201	230
12:00 – 13:00	222	254	240	219	250
13:00 – 14:00	297	266	308	282	299
14:00 – 15:00	359	303	376	358	343
15:00 – 16:00	406	360	418	399	377
16:00 – 17:00	**414**	**401**	**429**	**418**	**392**
17:00 – 18:00	**388**	**426**	**413**	**397**	**380**
18:00 – 19:00	327	416	362	356	365
19:00 – 20:00	260	367	298	296	335
20:00 – 21:00	192	293	229	258	299
21:00 – 22:00	170	205	187	240	259
22:00 – 23:00	174	132	180	214	218
23:00 – 24:00	138	72	154	159	162
24:00 – 01:00	52	22	72	74	108
01:00 – 02:00	0	0	0	13	54
02:00 – 03:00	0	0	0	0	15
03:00 – 04:00	0	0	0	0	0
	5,788	**6,024**	**5,892**	**6,214**	**6,170**

Morning peak (07:00 | 09:00)	1,110	1,189	1,031	1,162	984
Morning peak share	**19.2%**	**19.7%**	**17.5%**	**18.7%**	**15.9%**
Evening peak (16:00 | 18:00)	802	827	842	815	772
Evening peak share	**13.9%**	**13.7%**	**14.3%**	**13.1%**	**12.5%**

H FLYER

Note 1: The flyers that are depicted in this appendix represent the original dimensions of the flyers (A6 format: 14.8 x 10.5cm).
Note 2: The flyers were made in Dutch, the English version in grey was made for this appendix.

Enquête vervoermiddelkeuze

Station Almere Centrum

Voor mijn afstudeeronderzoek aan de TU Delft ben ik geïnteresseerd in uw huidige en toekomstige vervoermiddelkeuze om van en naar de trein te reizen op station Almere Centrum. De resultaten moeten bijdragen om het vervoeraanbod in de toekomst beter op u, als reiziger, af te stemmen.

Het invullen duurt ongeveer 5 minuten en zou mij ontzettend helpen!

Ga naar: https://goo.gl/forms/Z4LcDVjNqBSRobK52

of scan de QR code:

Alvast bedankt!
Bas Stam

TU Delft   Witteveen + Bos

Survey mode choice

Railway station Almere Centrum

For my graduation research at the TU Delft, I am interested in your current and future mode choice to travel to/from railway station Almere Centrum. The results must contribute to better align the supply of access/egress transport in the future with you, as a traveller.

It takes approximately 5 minutes to complete the survey and you would help me a lot!

Go to: https://goo.gl/forms/Z4LcDVjNqBSRobK52

or scan the QR code:

Thanks in advance!
Bas Stam

TU Delft   Witteveen + Bos

SURVEY

Note 1: The survey was made in Dutch, the English translation in grey was added for this appendix.
Note 2: All text written in *italic* was not visible for the respondents but shows the logic that was used in the survey.
Note 3: The pictures and text are reduced in size for this appendix, the original survey was provided online and varied in size dependent of the respondents' device.

Enquête vervoermiddelkeuze station Almere Centrum	**Survey mode choice at railway station Almere Centrum**
Beste reiziger, Fijn dat u bereid bent om deel te nemen aan deze enquête voor mijn afstudeeronderzoek aan de TU Delft. Het onderzoek gaat over welk vervoermiddel u zou kiezen om van en naar station Almere Centrum te reizen in verschillende scenario's. Heeft u onlangs in- of uitgecheckt bij de trein op station Almere Centrum, dan ben ik geïnteresseerd in uw keuze. De resultaten moeten bijdragen om het vervoeraanbod in de toekomst beter op u, als reiziger, af te stemmen. De enquête bestaat uit 4 onderdelen en duurt ongeveer 5 minuten. Alle informatie die u geeft is vertrouwelijk en wordt alleen voor dit afstudeeronderzoek gebruikt. Voor eventuele vragen kunt u contact met mij opnemen via: b.stam@student.tudelft.nl Bas Stam Master student TU Delft	Dear traveller, Thank you for the willingness to participate in this survey for of my graduation research at the TU Delft. The research is about which means of transport you would choose to travel to/from the railway station Almere Centrum in different scenarios. Have you recently checked in or out at the train at Almere Centrum, then I am interested in your response. The results must contribute to better align the supply of access/egress transport in the future with you, as a traveller. The survey consists of 4 parts and takes approximately 5 minutes to complete. All information you provide is confidential and is only used for this graduation research. If you have any questions, please contact me at: b.stam@student.tudelft.nl Bas Stam Master student TU Delft

Deel 1 – Stationsfunctie	**Part 1 – Station function**
1. Tijdens mijn laatste bezoek aan station Almere Centrum ... ○ nam ik de trein nadat ik van huis kwam. *Na deel 1 naar vraag 3+4 (enquête A)* ○ verliet ik de trein om naar huis te gaan. *Na deel 1 naar vraag 5+6 (enquête A)* ○ verliet ik de trein om naar mijn bestemming te gaan (werk, studie, sport, recreatie etc.). *Na deel 1 naar vraag 13+14 (enquête B)* ○ nam ik de trein nadat ik op mijn bestemming was geweest (werk, studie, sport, recreatie etc.). *Na deel 1 naar vraag 15+16 (enquête B)* ○ stapte ik over tussen twee treinen. *Na deel 1 naar deel 'Einde enquête'* ○ maakte ik geen gebruik van de trein. *Na deel 1 naar deel 'Einde enquête'* 2. De datum en het tijdstip waarop ik dit deed was: ○ __ - __ - ____ (dag – maand – jaar) ○ __ : __ (uren : minuten)	1. During my last visit at railway station Almere Centrum ... ○ I took the train after I came from my home. *After part 1 to question 3+4 (survey A)* ○ I left the train to go home. *After part 1 to question 5+6 (survey A)* ○ I left the train to go to my destination (work, study, sports, recreation etc.). *After part 1 to question 13+14 (survey B)* ○ I took the train after I had been at my destination (work, study, sports, recreation etc.). *After part 1 to question 15+16 (survey B)* ○ I transferred between two trains. *After part 1 to part 'End of survey'* ○ I did not use the train. *After part 1 to part 'End of survey'* 2. The date and time at which I did this, was: ○ __ - __ - ____ (day – month – year) ○ __ : __ (hours : minutes)

Deel 2 – Huidige vervoermiddelkeuze (Enquête A, woningzijde station)

3. Het vervoermiddel waar ik mee aankwam op station Almere Centrum was:
5. Het vervoermiddel waar ik station Almere Centrum mee verliet was:

- Lopen
- Fiets
- Auto (als bestuurder)
- Auto (als passagier)
- Bus
- Vraaggestuurd vervoer (Uber, NS Zonetaxi of gereserveerde taxi)
- Anders, namelijk [..........]

4./6. Geef een indicatie van de afstand van deze reis:

- <1 km
- 1-5 km
- 5-10 km
- >10 km
- Weet ik niet

Part 2 – Current mode choice (Survey A, home-end station)

3. The transport mode with which I arrived at railway station Almere Centrum was:
5. The transport mode with which I left railway station Almere Centrum was:

- Walking
- Bicycle
- Car (driver)
- Car (passenger)
- Bus
- Demand responsive transport (Uber, NS Zonetaxi or reserved taxi)
- Other, namely [..........]

4./6. Give an indication of the distance of this trip:

- <1 km
- 1-5 km
- 5-10 km
- >10 km
- I don't know

Deel 3 – Toekomstige vervoermiddelkeuze (Enquête A, woningzijde station)

Hierna volgen vier toekomstscenario's waarin u dezelfde reis maakt, maar dan over 20 jaar. Aan u de vraag om in elk scenario het vervoermiddel te kiezen waar uw voorkeur naar uitgaat. U kunt aannemen dat de benodigde faciliteiten voor elk vervoermiddel bij het station aanwezig zijn. Hieronder worden alle mogelijke vervoermiddelen uitgelegd.

Deelvoertuigen zijn voertuigen waar meerdere mensen tegen betaling gebruik van kunnen maken.

Vraaggestuurd vervoer zijn ritten die op aanvraag besteld kunnen worden en flexibel zijn in de route en de tijd waarop ze rijden.

Overzicht van de keuzemogelijkheden

Lopen

Part 3 – Future mode choice (Survey A, home-end station)

Hereafter four future scenarios are given in which you make the same trip in 20 years time. For you the question to select the transport mode that has your preference in each scenario. You can assume that the required facilities for each transport are present at the railway station area. Below, all possible transport modes are explained.

Shared vehicles are vehicles which can be used by multipe travellers upon payment of a special fee.

Demand responsive rides are rides that can be reserved when needed and are flexible in terms of routes and timetables.

Overview of the options

Walking

Eigen fiets: Fiets die u bezit of moet aanschaffen en parkeert op station Almere Centrum.

Deelfiets: Fiets waarvan meerdere mensen gebruik kunnen maken.

Eigen e-step: Elektrische step die u bezit of moet aanschaffen en parkeert op station Almere Centrum.

Deel e-step: Elektrische step waarvan meerdere mensen gebruik kunnen maken.

Eigen voertuig mee in de trein: Een voertuig die u bezit of moet aanschaffen en klein genoeg is om mee te nemen in de trein.
(vb. vouwfiets, hoverboard, elektrische eenwieler)

Eigen auto: Auto die u bezit of moet aanschaffen en parkeert op station Almere Centrum.

Deelauto: Auto waarvan meerdere mensen gebruik kunnen maken.

Bus: Een gewone bus die rijdt volgens een vaste route en een vaste dienstregeling zoals de huidige bussen op station Almere Centrum.

Individueel vraaggestuurd vervoer: Een service waarbij u een voertuig kunt oproepen. U spreekt af waar u heen wilt en op welk moment.

Collectief vraaggestuurd vervoer: Een service waarbij u een voertuig kunt oproepen die ook gebruikt wordt door andere gebruikers. Hierdoor wordt de service goedkoper in vergelijking met de individuele variant, maar duurt de rit wellicht iets langer.

In alle onderstaande scenario's wordt deze informatie opnieuw gegeven voor de vervoermiddelen waaruit gekozen kan worden.

Private bicycle: Bike that you own or need to purchase and park at station Almere Centrum.

Shared bicycle: Bicycle that can be used by several people.

Private e-scooter: Electric scooter that you own or need to purchase and park at station Almere Centrum.

Shared e-scooter: Electric scooter that can be used by several people.

Private on-board vehicle: A vehicle that you own or need to purchase which is small enough to take on-board in the train.
(e.g. folding bicycle, hoverboard, electric unicycle)

Private car: Car that you own or need to purchase and park at station Almere Centrum.

Shared car: Car that can be used by several people.

Bus: A regular bus that operates according to a fixed route and a fixed timetable such as the current buses at station Almere Centrum.

Individual on-demand rides: A service where you can call for a ride. You agree where you want to go and at what time.

Collective on-demand rides: A service where you can call for a ride in a vehicle that is shared with other users. This makes the service cheaper compared to the individual variant, but the ride may take a little longer.

In all upcoming scenarios this information is provided again for the means of transport that can be chosen.

Scenario 1 Stelt u zich eens voor dat er over 20 jaar geen mogelijkheid is om te kiezen voor deelvoertuigen of vraaggestuurd vervoer. *7.* Dan gaat mijn voorkeur uit naar:	**Scenario 1** Imagine that in 20 years, there is no possibility to use shared vehicles or demand responsive rides. *7.* Then, my preference goes to:

o Lopen o Walking	o Eigen fiets o Private bicycle	o Eigen e-step o Private e-scooter	o Eigen voertuig mee in de trein o Private on-board vehicle	o Eigen auto o Private car	o Bus o Bus

Scenario 2 Stelt u zich eens voor dat er over 20 jaar wel gekozen kan worden voor deelvoertuigen, maar niet voor vraaggestuurd vervoer. *8.* Dan gaat mijn voorkeur uit naar:	**Scenario 2** Imagine that in 20 years, you can opt for shared vehicles, but not for demand responsive rides. *8.* Then, my preference goes to:

o Lopen o Walking	o Deelfiets o Shared bicycle	o Deel e-step o Shared e-scooter	o Deelauto o Shared car	o Bus o Bus

Reizigers die een deelvoertuig kiezen worden gevraagd onderstaande vraag te beantwoorden: *9.* Naar welke vorm van delen gaat uw voorkeur uit: o Enkele rit delen Ik zou gebruik willen maken van een voertuig die ik kan pakken en neerzetten waar ik zelf wil, ook al is er een kans dat er geen voertuig beschikbaar is. o Particulier delen Ik zou een eigen voertuig aanschaffen en verhuren aan andere mensen in de tijd dat ik	*Travellers choosing for a shared vehicle are asked to answer the following question:* *9.* Which form of sharing do you prefer: o Free-floating sharing I would like to use a vehicle that I can pick up and drop off where I want, even if there is a chance that no vehicle is available. o P2P sharing I would purchase my own vehicle and rent it to other people in the time that I do not use

deze niet gebruik. Hierdoor heb ik zelf wel altijd toegang tot een voertuig.	it. As a result, I always have access to a vehicle.

Scenario 3 Stelt u zich eens voor dat er over 20 jaar wel gekozen kan worden voor vraaggestuurd vervoer, maar niet voor deelvoertuigen. *10.* Dan gaat mijn voorkeur uit naar:	**Scenario 3** Imagine that in 20 years, you can opt for demand responsive rides, but not for shared vehicles. *10.* Then, my preference goes to:

○ Lopen ○ Walking	○ Eigen fiets ○ Private bicycle	○ Eigen e-step ○ Private e-scooter	○ Eigen voertuig mee in de trein ○ Private on-board vehicle	○ Eigen auto ○ Private car	○ Individueel vraaggestuurd vervoer ○ Individual on-demand rides	○ Collectief vraaggestuurd vervoer ○ Collective on-demand rides

Scenario 4 Stelt u zich eens voor dat er over 20 jaar gekozen kan worden voor deelvoertuigen en vraaggestuurd vervoer. *11.* Dan gaat mijn voorkeur uit naar:	**Scenario 4** Imagine that in 20 years, you can opt for shared vehicles and demand responsive rides. *11.* Then, my preference goes to:

○ Lopen ○ Walking	○ Deelfiets ○ Shared bicycle	○ Deel e-step ○ Shared e-scooter	○ Deelauto ○ Shared car	○ Individueel vraaggestuurd vervoer ○ Individual on-demand rides	○ Collectief vraaggestuurd vervoer ○ Collective on-demand rides

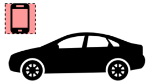
Reizigers die een deelvoertuig kiezen worden gevraagd onderstaande vraag te beantwoorden:	*Travellers choosing for a shared vehicle are asked to answer the following question:*

12. Naar welke vorm van delen gaat uw voorkeur uit: o Enkele rit delen Ik zou gebruik willen maken van een voertuig die ik kan pakken en neerzetten waar ik zelf wil, ook al is er een kans dat er geen voertuig beschikbaar is. o Particulier delen Ik zou een eigen voertuig aanschaffen en verhuren aan andere mensen in de tijd dat ik deze niet gebruik. Hierdoor heb ik zelf wel altijd toegang tot een voertuig.	12. Which form of sharing do you prefer: o Free-floating sharing I would like to use a vehicle that I can pick up and drop off where I want, even if there is a chance that no vehicle is available. o P2P sharing I would purchase my own vehicle and rent it to other people in the time that I do not use it. As a result, I always have access to a vehicle.

Deel 2 – Huidige vervoermiddelkeuze (Enquête B, activiteitenzijde station)	**Part 2 – Current mode choice (Survey B, activity-end station)**
13. Het vervoermiddel waar ik station Almere Centrum mee verliet was: 15. Het vervoermiddel waar ik mee aankwam op station Almere Centrum was: o Lopen o Fiets o Deelfiets (OV-fiets) o Deelauto (Greenwheels) o Taxi van taxistandplaats o Bus o Vraaggestuurd vervoer (Uber, NS Zonetaxi of gereserveerde taxi) o Anders, namelijk [..........]	13. The transport mode with which I left railway station Almere Centrum was: 15. The transport mode with which I arrived at railway station Almere Centrum was: o Walking o Bicycle o Shared bicycle (OV-bicycle) o Shared car (Greenwheels) o Non-reserved taxi o Bus o Demand responsive transport (Uber, NS Zonetaxi or reserved taxi) o Other, namely [..........]
14./16. Geef een indicatie van de afstand van deze reis: o <1 km o 1-5 km o 5-10 km o >10 km o Weet ik niet	14./16. Give an indication of the distance of this trip: o <1 km o 1-5 km o 5-10 km o >10 km o I don't know

Deel 3 – Toekomstige vervoermiddelkeuze (Enquête B, activiteitenzijde station)	**Part 3 – Future mode choice (Survey B, activity-end station)**
Hierna volgen vier toekomstscenario's waarin u dezelfde reis maakt, maar dan over 20 jaar. Aan u de vraag om in elk scenario het vervoermiddel te kiezen waar uw voorkeur naar uitgaat. U kunt aannemen dat de benodigde faciliteiten voor elk vervoermiddel bij het station aanwezig zijn. Hieronder worden alle mogelijke vervoermiddelen uitgelegd.	Hereafter four future scenarios are given in which you make the same trip in 20 years time. For you the question to select the transport mode that has your preference in each scenario. You can assume that the required facilities for each transport are present at the railway station area. Below, all possible transport modes are explained.

Deelvoertuigen zijn voertuigen waar meerdere mensen tegen betaling gebruik van kunnen maken. **Vraaggestuurd vervoer** zijn ritten die op aanvraag besteld kunnen worden en flexibel zijn in de route en de tijd waarop ze rijden. **Overzicht van de keuzemogelijkheden**	**Shared vehicles** are vehicles which can be used by multipe travellers upon payment of a special fee. **Demand responsive rides** are rides that can be reserved when needed and are flexible in terms of routes and timetables. **Overview of the options**
Lopen	**Walking**
Eigen fiets: Fiets die u bezit of moet aanschaffen en parkeert op station Almere Centrum.	**Private bicycle:** Bike that you own or need to purchase and park at station Almere Centrum.
Deelfiets: Fiets waarvan meerdere mensen gebruik kunnen maken.	**Shared bicycle:** Bicycle that can be used by several people.
Eigen e-step: Elektrische step die u bezit of moet aanschaffen en parkeert op station Almere Centrum.	**Private e-scooter:** Electric scooter that you own or need to purchase and park at station Almere Centrum.
Deel e-step: Elektrische step waarvan meerdere mensen gebruik kunnen maken.	**Shared e-scooter:** Electric scooter that can be used by several people.
Eigen voertuig mee in de trein: Een voertuig die u bezit of moet aanschaffen en klein genoeg is om mee te nemen in de trein. (vb. vouwfiets, hoverboard, elektrische eenwieler)	**Private on-board vehicle:** A vehicle that you own or need to purchase which is small enough to take on-board in the train. (e.g. folding bicycle, hoverboard, electric unicycle)
Deelauto: Auto waarvan meerdere mensen gebruik kunnen maken.	**Shared car:** Car that can be used by several people.
Taxi: Een auto op een taxistandplaats waar u ter plekke afspreekt waar u heen wilt en tegen welke prijs.	**Taxi:** A car at a taxi stand where you decide where you want to go and at what price.
Bus: Een gewone bus die rijdt volgens een vaste route en een vaste dienstregeling zoals de huidige bussen op station Almere Centrum.	**Bus:** A regular bus that operates according to a fixed route and a fixed timetable such as the current buses at station Almere Centrum.

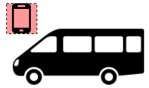


Individueel vraaggestuurd vervoer: Een service waarbij u een voertuig kunt oproepen. U spreekt af waar u heen wilt en op welk moment.

Collectief vraaggestuurd vervoer: Een service waarbij u een voertuig kunt oproepen die ook gebruikt wordt door andere gebruikers. Hierdoor wordt de service goedkoper in vergelijking met de individuele variant, maar duurt de rit wellicht iets langer.

In alle onderstaande scenario's wordt deze informatie opnieuw gegeven voor de vervoermiddelen waaruit gekozen kan worden.

Individual on-demand rides: A service where you can call for a ride. You agree where you want to go and at what time.



Collective on-demand rides: A service where you can call for a ride in a vehicle that is shared with other users. This makes the service cheaper compared to the individual variant, but the ride may take a little longer.

In all upcoming scenarios this information is provided again for the means of transport that can be chosen.

Scenario 1

Stelt u zich eens voor dat er over 20 jaar geen mogelijkheid is om te kiezen voor deelvoertuigen of vraaggestuurd vervoer.

17. Dan gaat mijn voorkeur uit naar:

Scenario 1

Imagine that in 20 years, there is no possibility to use shared vehicles or demand responsive rides.

17. Then, my preference goes to:

- ○ Lopen / ○ Walking
- ○ Eigen fiets / ○ Private bicycle
- ○ Eigen e-step / ○ Private e-scooter
- ○ Eigen voertuig mee in de trein / ○ Private on-board vehicle
- ○ Taxi / ○ Taxi
- ○ Bus / ○ Bus

Scenario 2

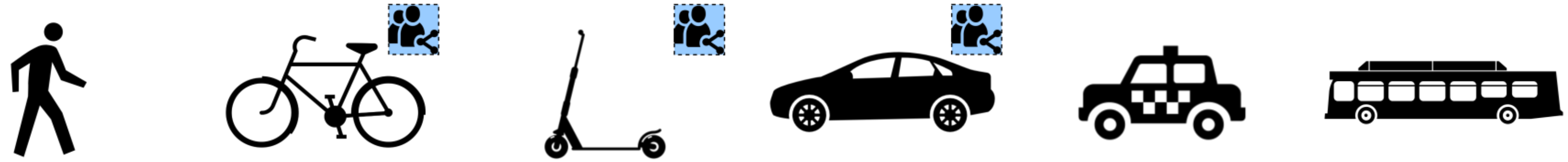
Stelt u zich eens voor dat er over 20 jaar wel gekozen kan worden voor deelvoertuigen, maar niet voor vraaggestuurd vervoer.

18. Dan gaat mijn voorkeur uit naar:

Scenario 2

Imagine that in 20 years, you can opt for shared vehicles, but not for demand responsive rides.

18. Then, my preference goes to:



○ Lopen	○ Deelfiets	○ Deel e-step	○ Deelauto	○ Taxi	○ Bus
○ Walking	○ Shared bicycle	○ Shared e-scooter	○ Shared car	○ Taxi	○ Bus

Reizigers die een deelvoertuig kiezen worden gevraagd onderstaande vraag te beantwoorden:	*Travellers choosing for a shared vehicle are asked to answer the following question:*
19. Naar welke vorm van delen gaat uw voorkeur uit: ○ Rondrit delen Ik zou gebruik willen maken van een voertuig die ik kan gebruiken totdat ik het voertuig weer terugbreng naar de verhuurlocatie. ○ Enkele rit delen Ik zou gebruik willen maken van een voertuig die ik kan pakken en neerzetten waar ik zelf wil, ook al is er een kans dat er geen voertuig beschikbaar is.	*19.* Which form of sharing do you prefer? ○ Roundtrip sharing I would like to use a vehicle that I can use until I return the vehicle to the rental location. ○ Free-floating sharing I would like to use a vehicle that I can pick up and drop off where I want, even if there is a chance that no vehicle is available.

Scenario 3 Stelt u zich eens voor dat er over 20 jaar wel gekozen kan worden voor vraaggestuurd vervoer, maar niet voor deelvoertuigen. *20.* Dan gaat mijn voorkeur uit naar:	**Scenario 3** Imagine that in 20 years, you can opt for demand responsive rides, but not for shared vehicles. *20.* Then, my preference goes to:

○ Lopen ○ Walking	○ Eigen fiets ○ Private bicycle	○ Eigen e-step ○ Private e-scooter	○ Eigen voertuig mee in de trein ○ Private on-board vehicle	○ Individueel vraaggestuurd vervoer ○ Individual on-demand rides	○ Collectief vraaggestuurd vervoer ○ Collective on-demand rides

Scenario 4 Stelt u zich eens voor dat er over 20 jaar gekozen kan worden voor deelvoertuigen en vraaggestuurd vervoer. *21.* Dan gaat mijn voorkeur uit naar:	**Scenario 4** Imagine that in 20 years, you can opt for shared vehicles and demand responsive rides. *21.* Then, my preference goes to:

					
o Lopen o Walking	o Deelfiets o Shared bicycle	o Deel e-step o Shared e-scooter	o Deelauto o Shared car	o Individueel vraaggestuurd vervoer o Individual on-demand rides	o Collectief vraaggestuurd vervoer o Collective on-demand rides

Reizigers die een deelvoertuig kiezen worden gevraagd onderstaande vraag te beantwoorden:

22. Naar welke vorm van delen gaat uw voorkeur uit:
   - Rondrit delen
   Ik zou gebruik willen maken van een voertuig die ik kan gebruiken totdat ik het voertuig weer terugbreng naar de verhuurlocatie.
   - Enkele rit delen
   Ik zou gebruik willen maken van een voertuig die ik kan pakken en neerzetten waar ik zelf wil, ook al is er een kans dat er geen voertuig beschikbaar is.

Travellers choosing for a shared vehicle are asked to answer the following question:

22. Which form of sharing do you prefer?
   - Roundtrip sharing
   I would like to use a vehicle that I can use until I return the vehicle to the rental location.
   - Free-floating sharing
   I would like to use a vehicle that I can pick up and drop off where I want, even if there is a chance that no vehicle is available.

Deel 4 – Afsluitende vragen

23. Wat is uw geslacht?
   - Man
   - Vrouw

24. Wat is uw leeftijd?
   - 0-19
   - 20-24
   - 25-44
   - 45-64
   - 65+

25. Bent u in het bezit van een autorijbewijs?
   - Ja
   - Nee

Part 4 – Final questions

23. What is your gender?
   - Man
   - Woman

24. What is your age?
   - 0-19
   - 20-24
   - 25-44
   - 45-64
   - 65+

25. Do you own a drivers license?
   - Yes
   - No

26. Wat was het doel van uw reis? o Werk / zakelijk o School / studie o Sociaal / recreatief Na vraag 26 naar deel 'Bedankt!'	26. What was your trip purpose? o Commuting / business o School / study o Social / recreation After question 26 to part 'Thank you!'

Einde enquête *Dit deel is voor mensen die vraag 1 beantwoorden met: 'stapte ik over tussen twee treinen' of 'maakte ik geen gebruik van de trein'* U heeft aangegeven niet in- of uit te checken bij de trein op station Almere Centrum. Helaas behoort deze reis niet tot de scope van dit onderzoek. Toch bedankt voor uw medewerking.	**End of survey** *This part is for respondents that answered question 1 with: 'I transferred between two trains' or 'I did not use the train'* You have indicated that you do not check in or out at the train at railway station Almere Centrum. Unfortunately, this trip does not belong to the scope of this research. Thank you for your cooperation.

Bedankt! Bedankt voor het invullen van de enquête! Mocht u nog vragen hebben dan kunt u contact met mij opnemen via: b.stam@student.tudelft.nl	**Thank you!** Thank you for completing the survey! If you have any questions, please contact me at: b.stam@student.tudelft.nl

J RESULTS

J.1 Modal split results

Current situation

Home-end	Means of access/egress transport	Activity-end
10%	Walking	67%
41%	Private bicycle	10%
NA	Shared bicycle (OV-bicycle)	0%
1%	Private car (driver)	NA
4%	Private car (passenger)	3%
NA	Shared car (Greenwheels)	0%
NA	Individual traditional ride service (non-reserved taxi)	0%
43%	Collective traditional ride service (bus)	18%
0%	Individual on-demand ride service (Uber, NS Zonetaxi, reserved taxi)	1%
1%[1]	Other	1%[2]
100%		**100%**

[1] Scooter (2x) and moped (1x).
[2] Scooter (1x).

Scenario 1: what there is, when it is available

Home-end	Means of access/egress transport	Activity-end
7%	Walking	44%
35%	Private bicycle	15%
2%	Private e-scooter	7%
7%	Private on-board vehicle	5%
18%	Private car	NA
NA	Individual traditional ride service (non-reserved taxi)	2%
31%	Collective traditional ride service (bus)	27%
100%		**100%**

Scenario 2: what you want, when it is available

Home-end	Means of access/egress transport	Activity-end
12%	Walking	39%
22%	Shared bicycle	14%
3%	Shared e-scooter	8%
13%	Shared car	12%
NA	Individual traditional ride service (non-reserved taxi)	2%
50%	Collective traditional ride service (bus)	25%
100%		**100%**

Home-end		Means of access/egress transport	Activity-end	
Free-floating	P2P		Roundtrip	Free-floating
52%	48%	Shared bicycle	52%	48%
50%	50%	Shared e-scooter	50%	50%
43%	57%	Shared car	45%	55%
49%	**51%**		**49%**	**51%**

Scenario 3: what there is, when and how you want

Home-end	Means of access/egress transport	Activity-end
7%	Walking	37%
37%	Private bicycle	19%
2%	Private e-scooter	6%
6%	Private on-board vehicle	5%
17%	Private car	NA
14%	Individual on-demand ride service	23%
17%	Collective on-demand ride service	10%
100%		**100%**

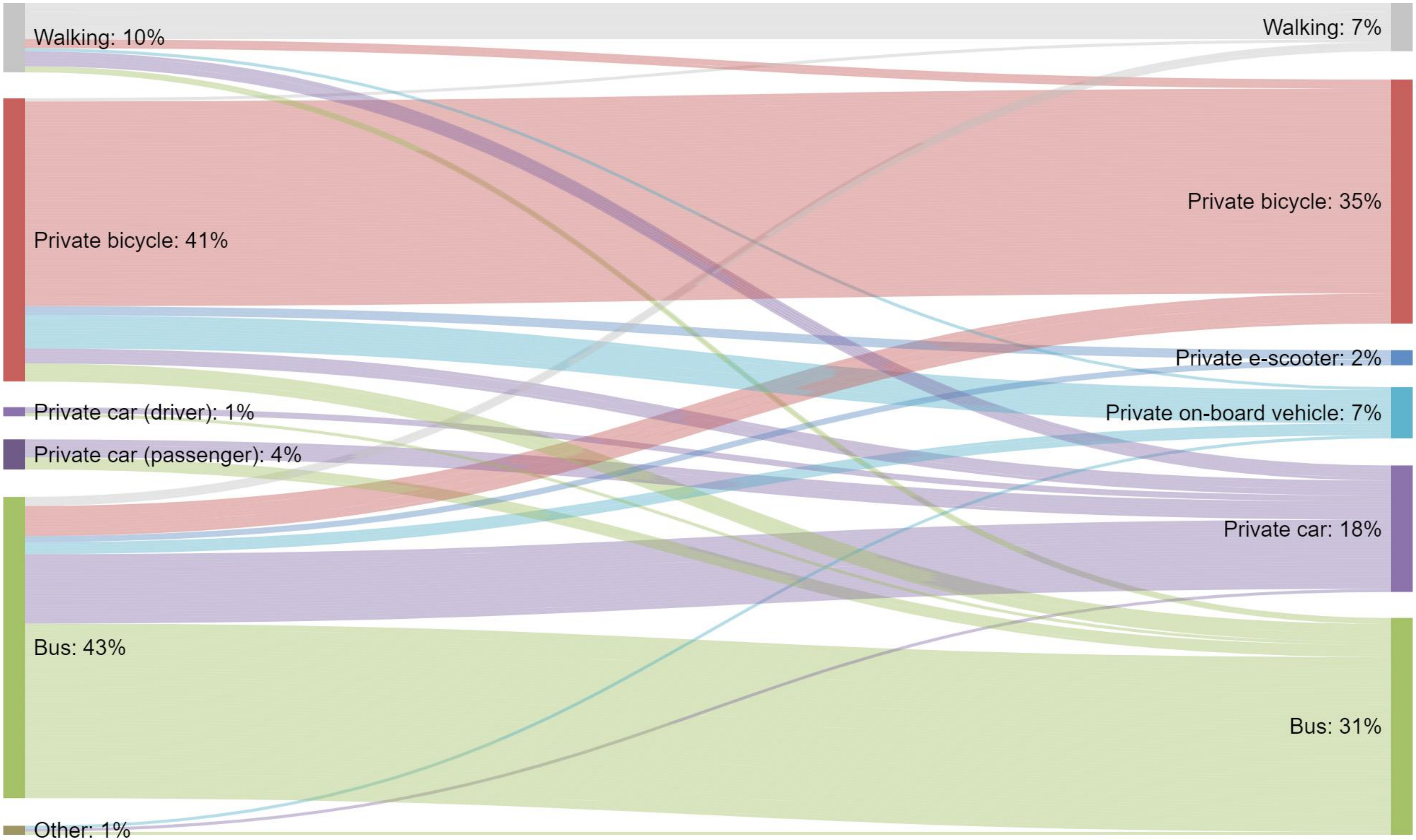
Scenario 4: what, how and when you want

Home-end	Means of access/egress transport	Activity-end
18%	Walking	42%
25%	Shared bicycle	13%
2%	Shared e-scooter	6%
10%	Shared car	8%
21%	Individual on-demand ride service	19%
24%	Collective on-demand ride service	12%
100%		**100%**

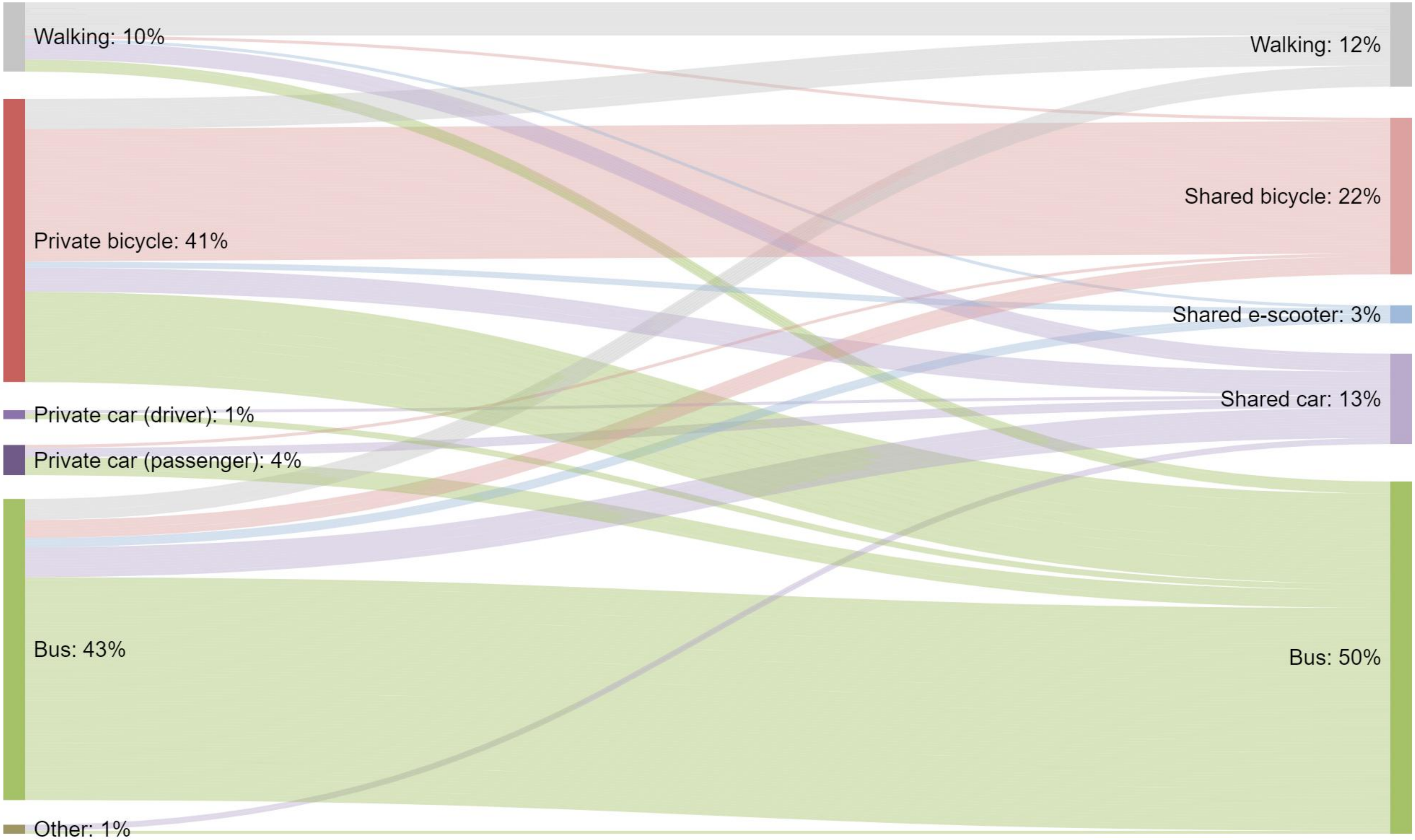
Home-end		Means of access/egress transport	Activity-end	
Free-floating	P2P		Roundtrip	Free-floating
57%	43%	Shared bicycle	55%	45%
40%	60%	Shared e-scooter	50%	50%
52%	48%	Shared car	29%	71%
55%	**45%**		**46%**	**54%**

J.2 Sankey diagrams

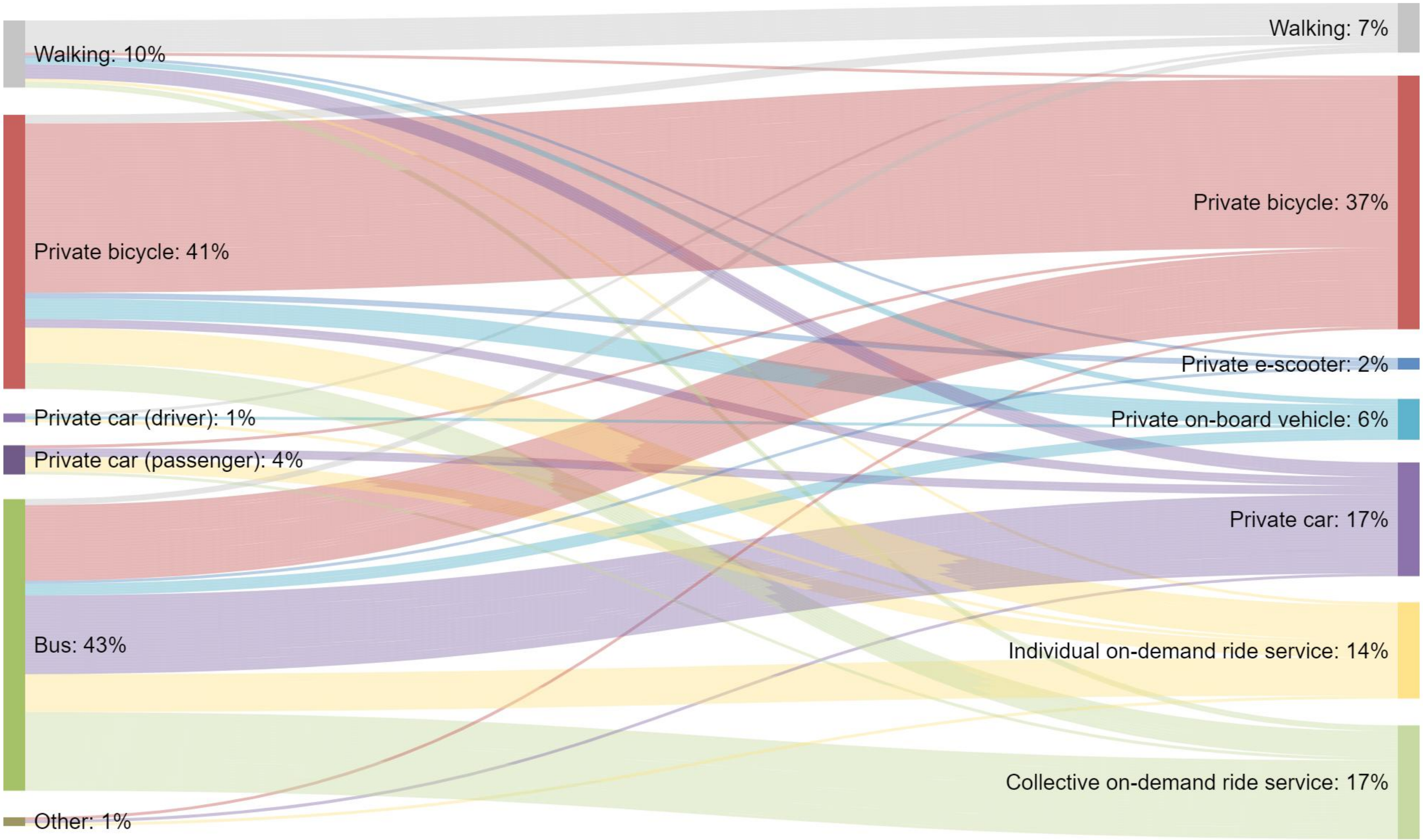
HOME-END SCENARIO 1



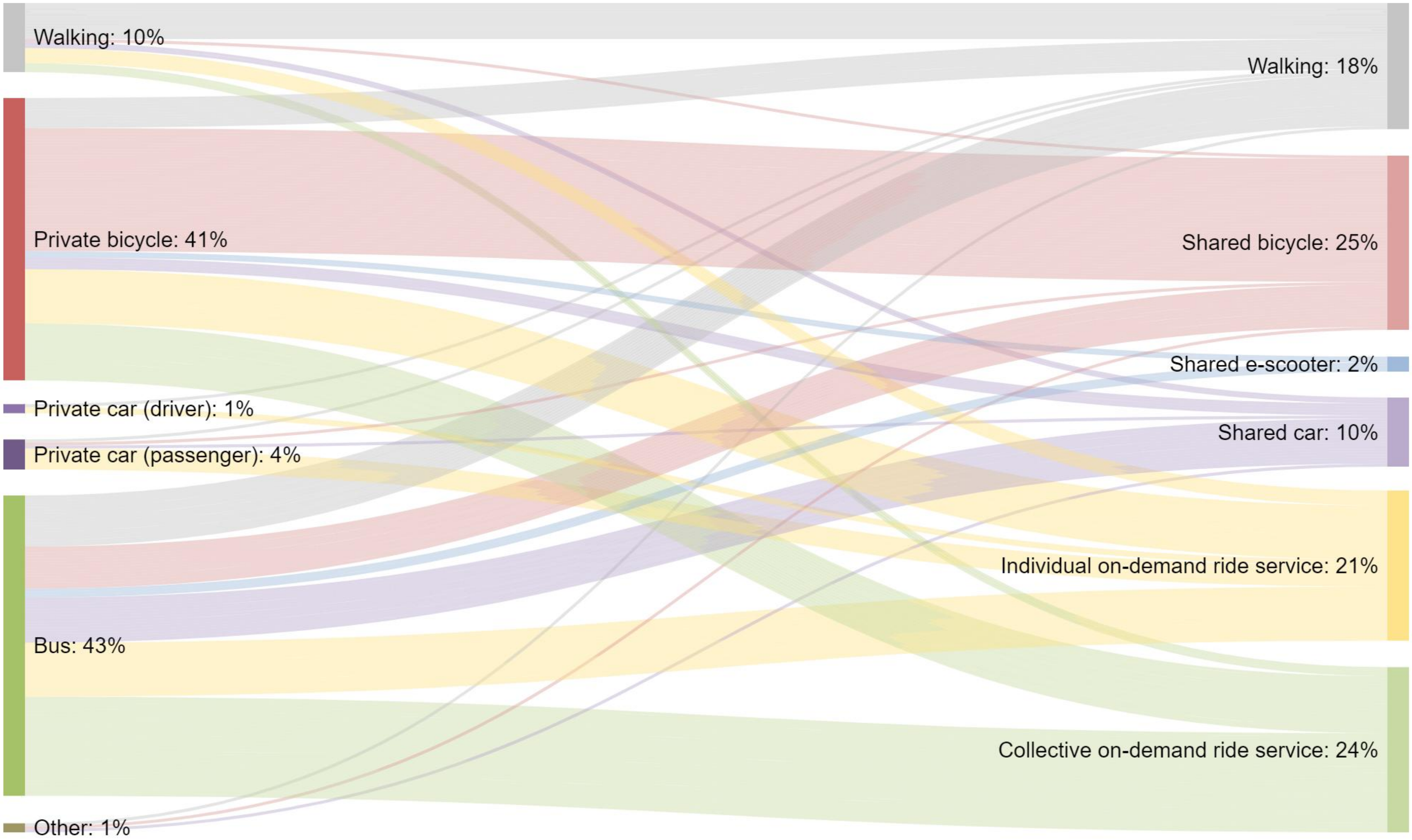
HOME-END SCENARIO 2



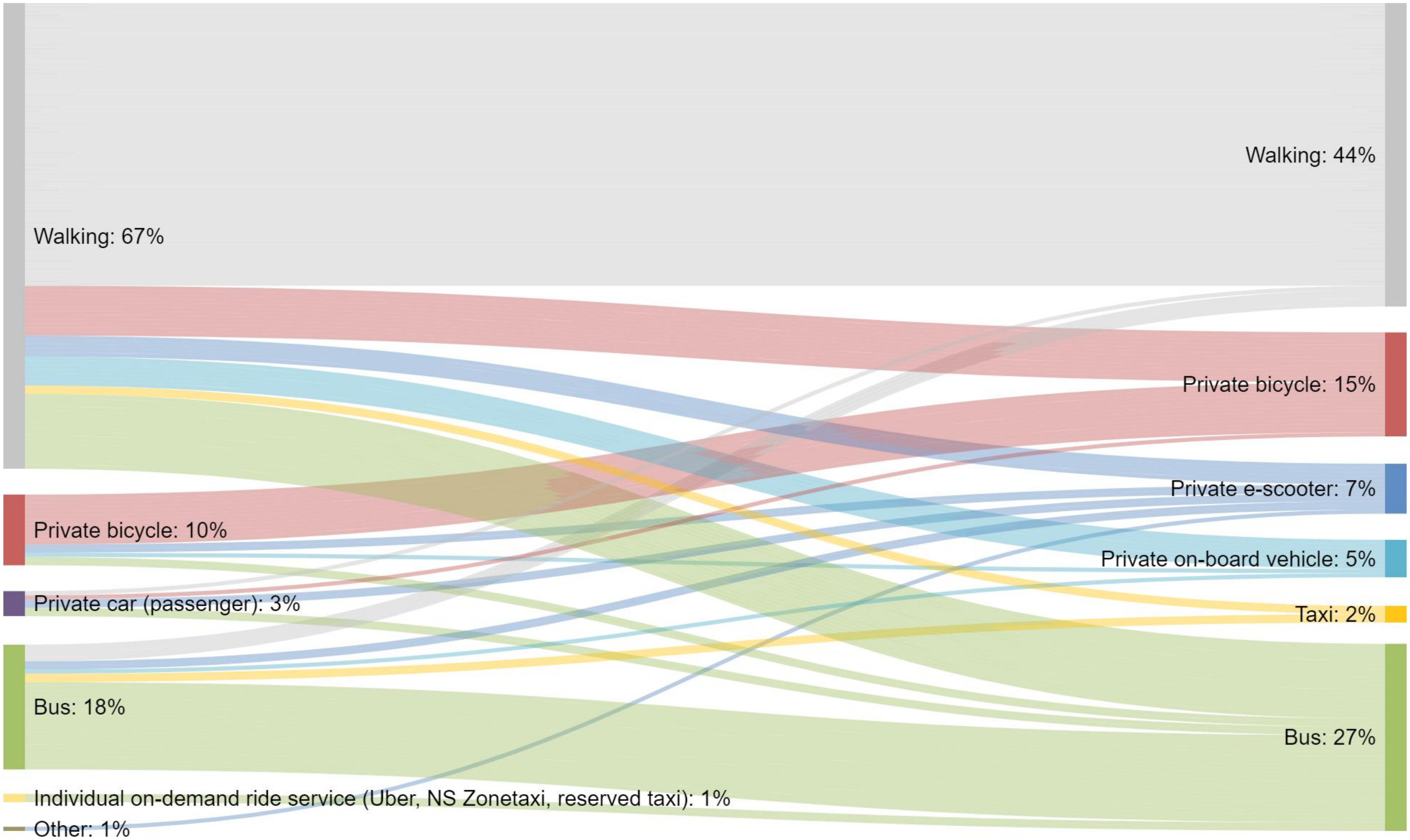
HOME-END SCENARIO 3



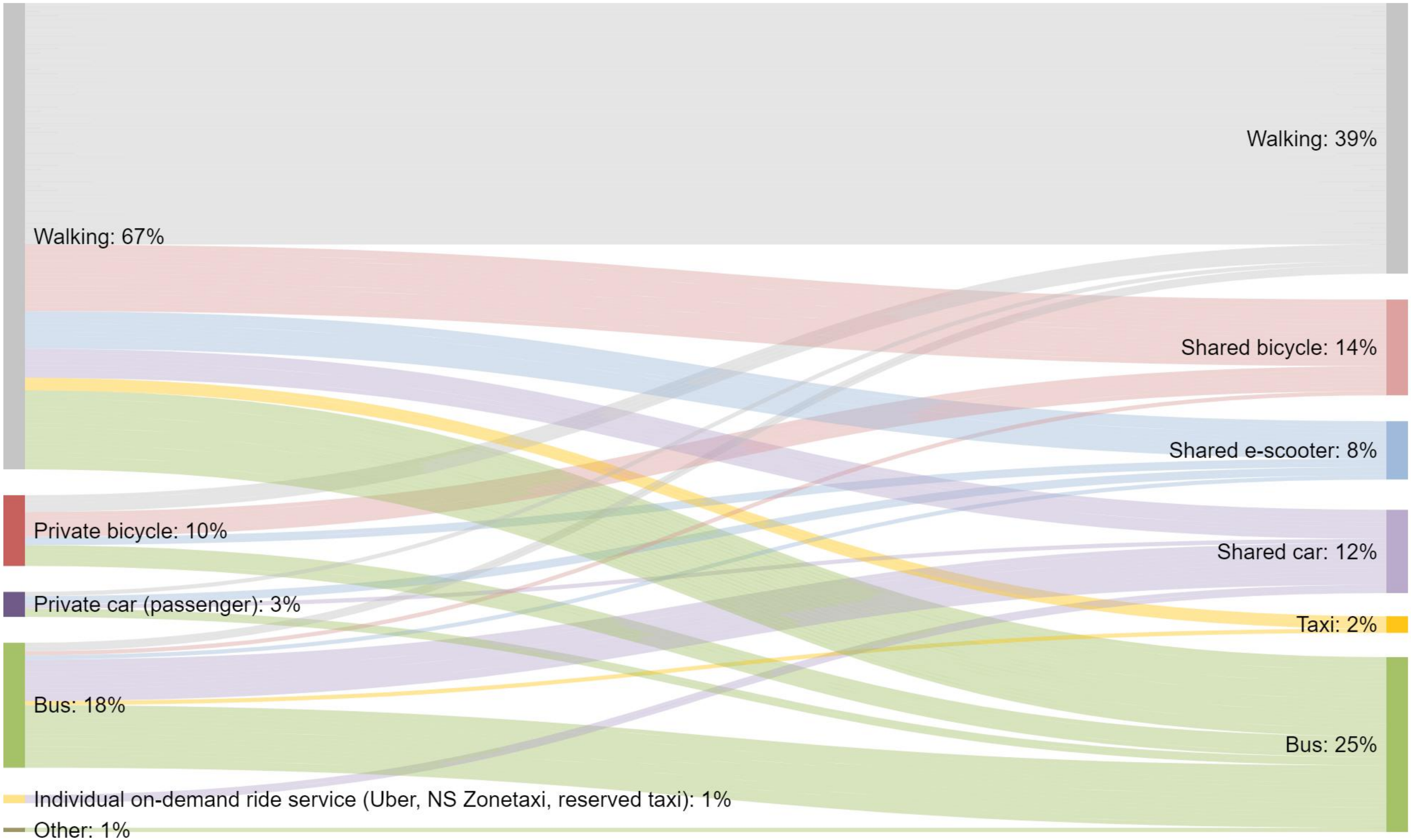
HOME-END SCENARIO 4



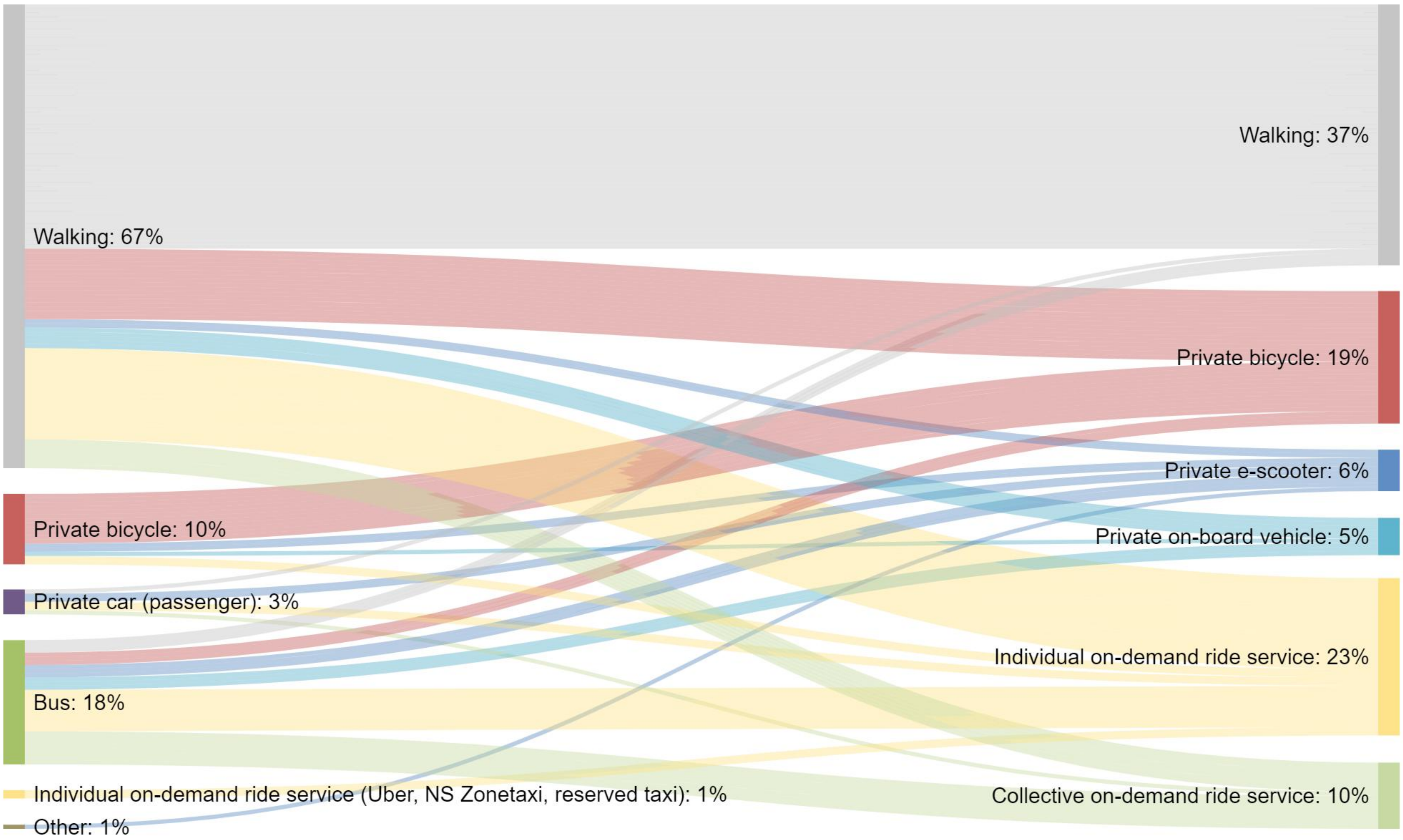
ACTIVITY-END SCENARIO 1



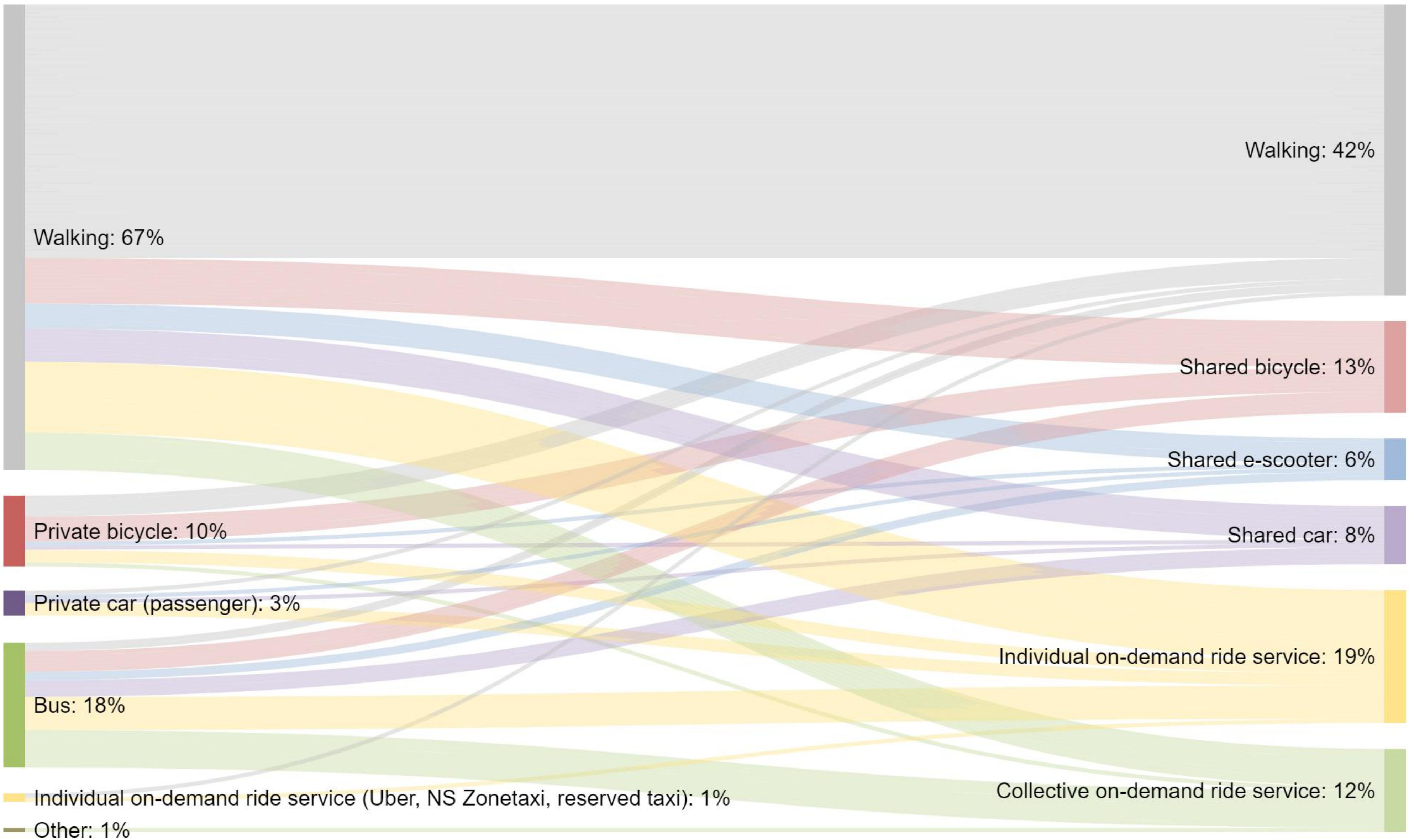
ACTIVITY-END SCENARIO 2



ACTIVITY-END SCENARIO 3



ACTIVITY-END SCENARIO 4



K TRIP-END OBSERVATIONS

K.1 Home-end

Car popularity

Observation 1: Travellers who prefer a car (private or shared) in at least one scenario.
Observation 2: Travellers who prefer a private car when available (both scenario 1 and 3).

		Average (N=233)	Observation 1 (N=74)		Observation 2 (N=25)	
		[%]	[%]	[Δ%]	[%]	[Δ%]
Modal split	Walking	10%	11%	1%	20%	10%
	Bicycle	41%	19%	-21%	4%	-36%
	Car (driver)	1%	3%	1%	0%	-1%
	Car (passenger)	4%	9%	5%	12%	8%
	Bus	43%	55%	12%	60%	17%
	Other	1%	3%	1%	4%	3%
		100%	100%		100%	
Home-end distance	<1 km	12%	9%	-2%	0%	-12%
	1-5 km	64%	50%	-14%	52%	-12%
	5-10 km	16%	24%	8%	28%	12%
	>10 km	6%	12%	6%	12%	6%
	I don't know	2%	4%	2%	8%	6%
		100%	100%		100%	
Gender	Men	54%	38%	-16%	28%	-26%
	Women	46%	62%	16%	72%	26%
		100%	100%		100%	
Age	0-19	12%	27%	15%	40%	28%
	20-24	15%	30%	15%	32%	17%
	25-44	32%	28%	-4%	24%	-8%
	45-64	38%	15%	-23%	4%	-34%
	65+	3%	0%	-3%	0%	-3%
		100%	100%		100%	
Trip purpose	Commuting / business	70%	43%	-27%	40%	-30%
	School / study	24%	51%	27%	56%	32%
	Social / recreation	6%	5%	-1%	4%	-2%
		100%	100%		100%	
Driver's license	Yes	80%	68%	-12%	60%	-20%
	No	20%	32%	12%	40%	20%
		100%	100%		100%	

Percentages may not add up to 100% due to rounding.

Bus users

Observation: Travellers who prefer the traditional bus when available (both scenario 1 and 2).

		Average (N=233)	Observation (N=57)	
		[%]	[%]	[Δ%]
Modal split	Walking	10%	2%	-8%
	Bicycle	41%	9%	-32%
	Car (driver)	1%	2%	0%
	Car (passenger)	4%	5%	1%
	Bus	43%	82%	40%
	Other	1%	0%	-1%
		100%	100%	
Home-end distance	<1 km	12%	5%	-6%
	1-5 km	64%	60%	-5%
	5-10 km	16%	28%	12%
	>10 km	6%	7%	1%
	I don't know	2%	0%	-2%
		100%	100%	
Gender	Men	54%	54%	0%
	Women	46%	46%	0%
		100%	100%	
Age	0-19	12%	4%	-8%
	20-24	15%	14%	-1%
	25-44	32%	39%	6%
	45-64	38%	39%	0%
	65+	3%	5%	2%
		100%	100%	
Trip purpose	Commuting / business	70%	81%	11%
	School / study	24%	16%	-8%
	Social / recreation	6%	4%	-2%
		100%	100%	
Driver's license	Yes	80%	81%	1%
	No	20%	19%	-1%
		100%	100%	

Percentages may not add up to 100% due to rounding.

K.2 Activity-end

Ex pedestrians

Observation: Travellers who currently walk, but who never prefer to walk in all four scenarios.

		Average (N=168)	Observation (N=33)	
		[%]	[%]	[Δ%]
Modal split	Walking	67%	100%	33%
	Bicycle	10%	0%	-10%
	Car (driver)	0%	0%	0%
	Car (passenger)	3%	0%	-4%
	Bus	18%	0%	-18%
	Taxi	1%	0%	-1%
	Other	1%	0%	-1%
		100%	0%	
Activity-end distance	<1 km	54%	82%	28%
	1-5 km	34%	15%	-19%
	5-10 km	9%	0%	-9%
	>10 km	1%	0%	-1%
	I don't know	2%	3%	1%
		100%	100%	
Gender	Men	57%	55%	-2%
	Women	43%	45%	2%
		100%	100%	
Age	0-19	10%	9%	-1%
	20-24	20%	18%	-1%
	25-44	35%	33%	-1%
	45-64	33%	33%	1%
	65+	3%	6%	3%
		100%	100%	
Trip purpose	Commuting / business	76%	76%	0%
	School / study	16%	15%	-1%
	Social / recreation	8%	9%	1%
		100%	100%	
Driver's license	Yes	80%	76%	-5%
	No	20%	24%	5%
		100%	100%	

Percentages may not add up to 100% due to rounding.

Pedestri(F)ans

Observation: Travellers who prefer to walk in all scenarios.

		Average (N=168)	Observation (N=51)	
		[%]	[%]	[Δ%]
Modal split	Walking	67%	94%	27%
	Bicycle	10%	0%	-10%
	Car (driver)	0%	0%	0%
	Car (passenger)	3%	2%	-2%
	Bus	18%	4%	-14%
	Taxi	1%	0%	-1%
	Other	1%	0%	-1%
		100%	100%	
Activity-end distance	<1 km	54%	71%	16%
	1-5 km	34%	27%	-7%
	5-10 km	9%	2%	-7%
	>10 km	1%	0%	-1%
	I don't know	2%	0%	-2%
		100%	100%	
Gender	Men	57%	65%	8%
	Women	43%	35%	-8%
		100%	100%	
Age	0-19	10%	4%	-6%
	20-24	20%	16%	-4%
	25-44	35%	45%	11%
	45-64	33%	35%	3%
	65+	3%	0%	-3%
		100%	100%	
Trip purpose	Commuting / business	76%	86%	10%
	School / study	16%	8%	-8%
	Social / recreation	8%	6%	-2%
		100%	100%	
Driver's license	Yes	80%	86%	6%
	No	20%	14%	-6%
		100%	100%	

Percentages may not add up to 100% due to rounding.

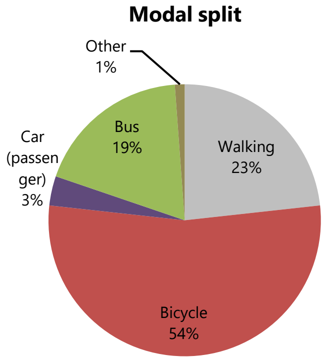
L GENERAL OBSERVATIONS

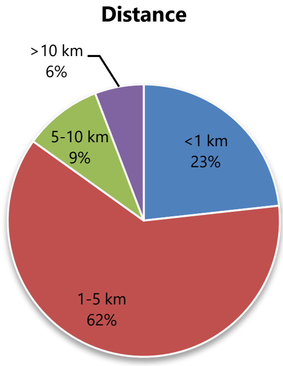
		Average (N=401)	Sharing is hot (N=86)		.. or not (N=85)		Flexible rides are hot (N=94)		.. or not (N=47)		On-board fans (N=40)		E-scooter fans (N=33)	
		[%]	[%]	[Δ%]	[%]	[Δ%]	[%]	[Δ%]	[%]	[Δ%]	[%]	[Δ%]	[%]	[Δ%]
Modal split	Walking	34%	23%	-10%	11%	-23%	23%	-10%	17%	-17%	33%	-1%	36%	3%
	Bicycle	28%	53%	26%	48%	21%	20%	-7%	2%	-26%	38%	10%	27%	0%
	Car (driver)	1%	0%	-1%	1%	0%	1%	0%	2%	1%	3%	2%	0%	-1%
	Car (passenger)	4%	3%	-1%	5%	1%	9%	5%	2%	-2%	0%	-4%	6%	2%
	Bus	32%	19%	-14%	33%	1%	46%	13%	74%	42%	25%	-7%	27%	-5%
	Taxi	0%	0%	0%	0%	0%	1%	1%	0%	0%	0%	0%	0%	0%
	Other	1%	1%	0%	2%	1%	0%	-1%	2%	1%	3%	2%	3%	2%
		100%	100%		100%		100%		100%		100%		100%	
Trip distance	<1 km	29%	23%	-6%	16%	-13%	22%	-7%	17%	-12%	25%	-4%	36%	7%
	1-5 km	52%	62%	10%	64%	12%	53%	1%	47%	-5%	55%	3%	33%	-19%
	5-10 km	13%	9%	-4%	14%	1%	17%	4%	26%	12%	13%	-1%	27%	14%
	>10 km	4%	6%	2%	2%	-1%	5%	2%	6%	3%	3%	-1%	3%	-1%
	I don't know	2%	0%	-2%	4%	2%	2%	0%	4%	3%	5%	3%	0%	-2%
		100%	100%		100%		100%		100%		100%		100%	
Gender	Men	55%	58%	3%	48%	-7%	54%	-1%	51%	-4%	55%	0%	52%	-4%
	Women	45%	42%	-3%	52%	7%	46%	1%	49%	4%	45%	0%	48%	4%
		100%	100%		100%		100%		100%		100%		100%	
Age	0-19	11%	8%	-3%	16%	5%	11%	0%	17%	6%	5%	-6%	9%	-2%
	20-24	17%	16%	-1%	16%	0%	12%	-5%	30%	13%	18%	1%	15%	-2%
	25-44	33%	35%	2%	34%	1%	23%	-10%	34%	1%	43%	9%	45%	12%
	45-64	36%	40%	4%	29%	-6%	49%	13%	13%	-23%	33%	-3%	30%	-6%
	65+	3%	1%	-2%	4%	1%	5%	2%	6%	3%	3%	0%	0%	-3%
		100%	100%		100%		100%		100%		100%		100%	
Trip purpose	Commuting / business	73%	78%	5%	64%	-9%	71%	-1%	60%	-13%	78%	5%	79%	6%
	School / study	21%	21%	0%	25%	4%	18%	-3%	36%	15%	20%	-1%	15%	-6%
	Social / recreation	7%	1%	-6%	12%	5%	11%	4%	4%	-2%	3%	-4%	6%	-1%
		100%	100%		100%		100%		100%		100%		100%	
Driver's license	Yes	80%	84%	4%	81%	1%	81%	1%	66%	-14%	80%	0%	79%	-1%
	No	20%	16%	-4%	19%	-1%	19%	-1%	34%	14%	20%	0%	21%	1%
		100%	100%		100%		100%		100%		100%		100%	

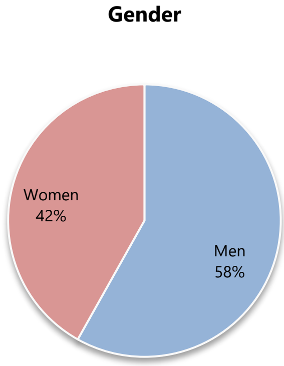
Percentages may not add up to 100% due to rounding.

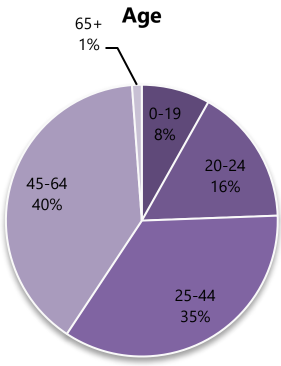
Sharing is hot

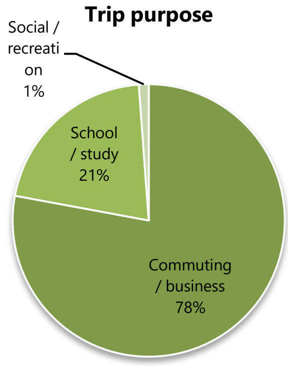
Observation: Travellers who prefer any type of shared vehicle when available (scenario 2 and 4). (N=86)

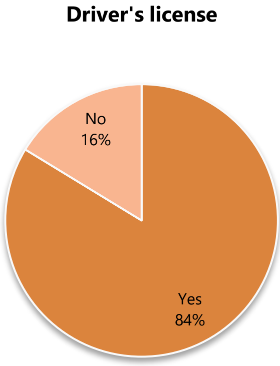






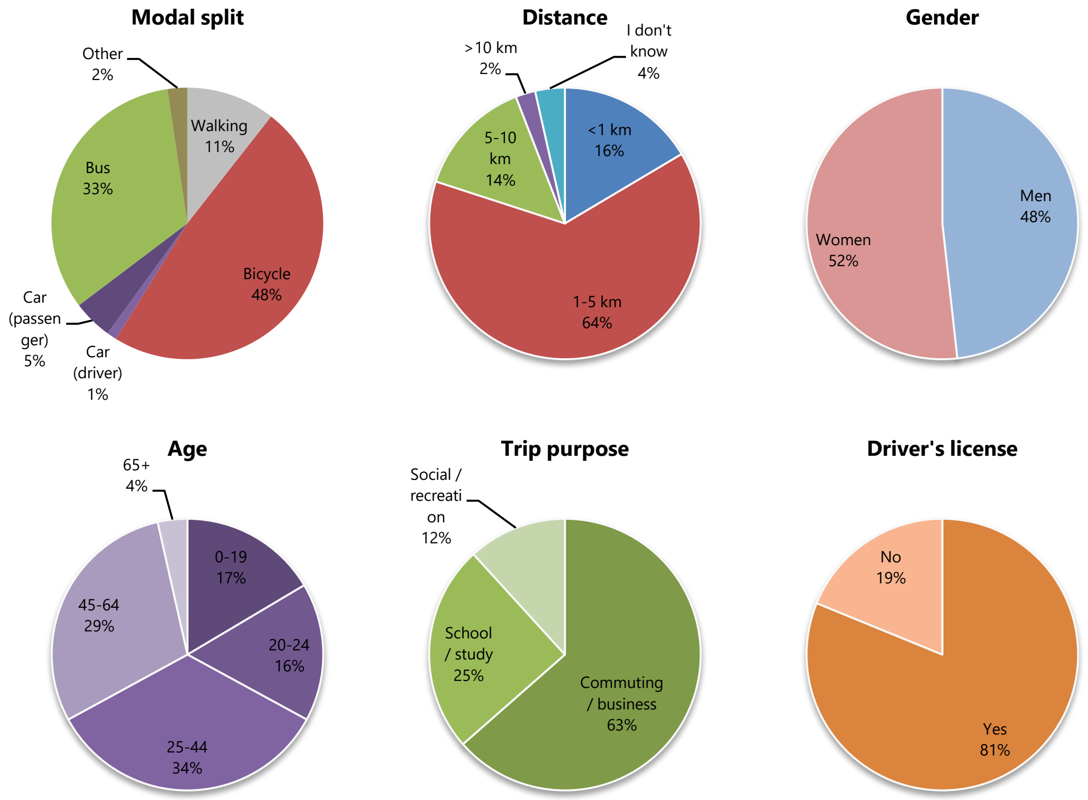






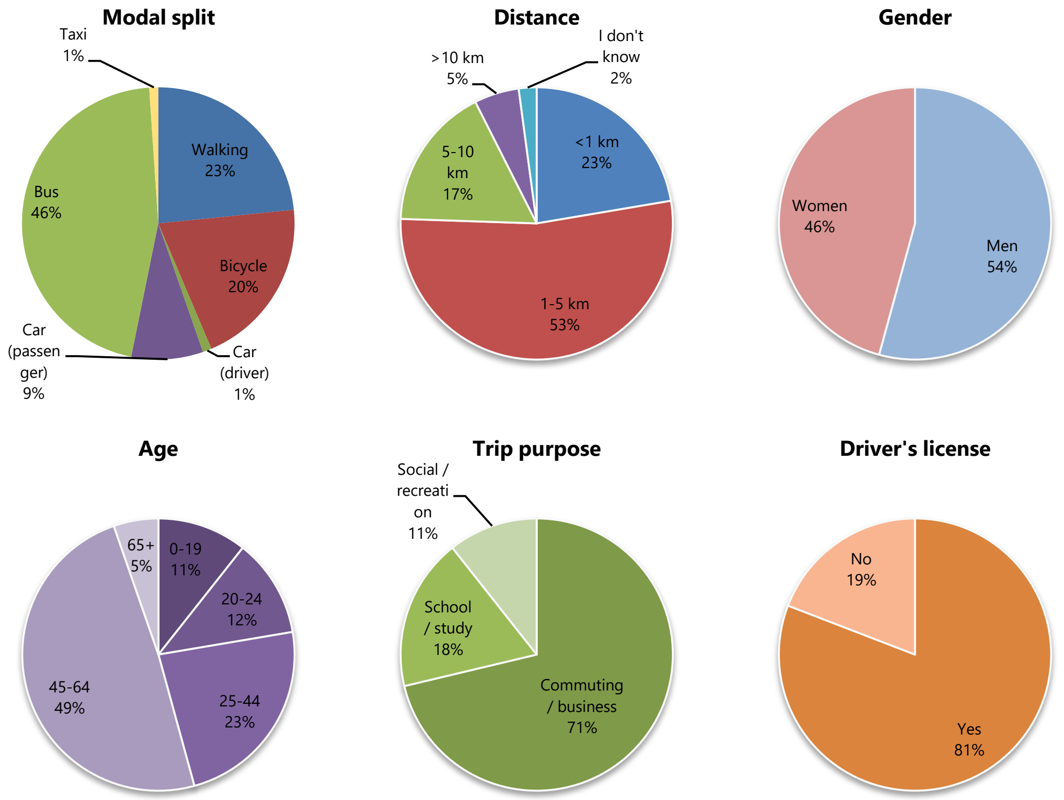
Sharing is hot.. or not

Observation: Travellers who prefer a private vehicle in scenario 1, but no shared vehicle in scenario 2. (N=85)



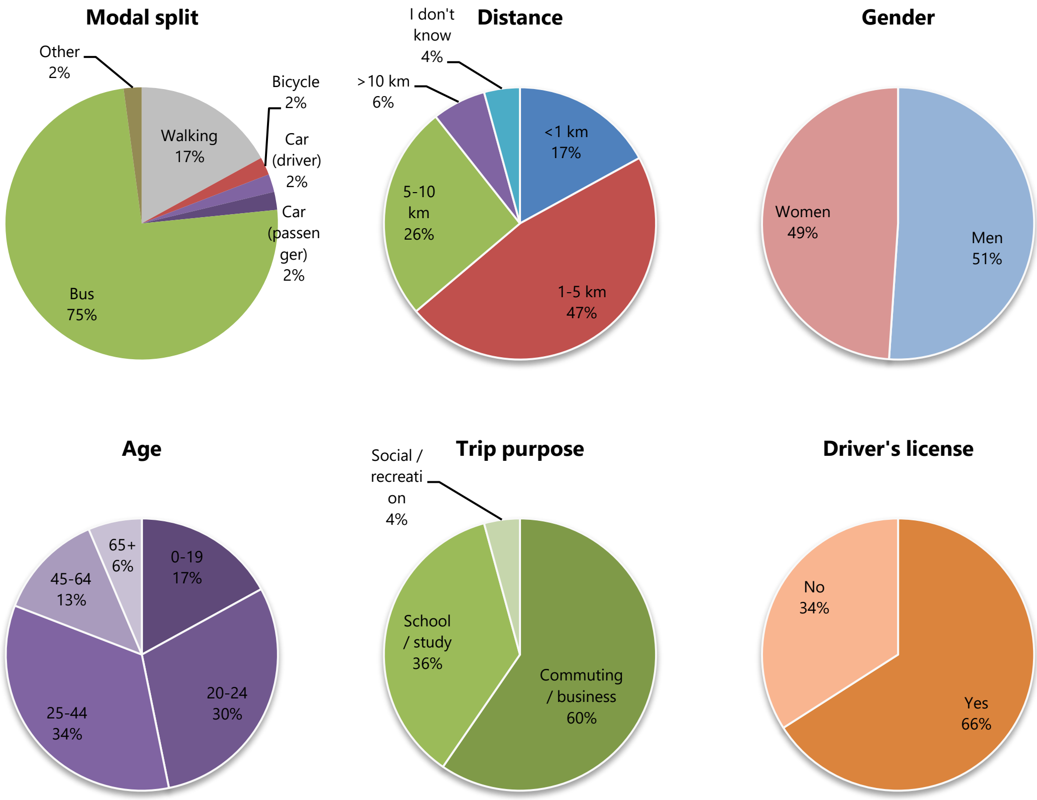
Flexible rides are hot

Observation: Travellers who prefer any type of on-demand ride service when available (scenario 3 and 4). (N=94)



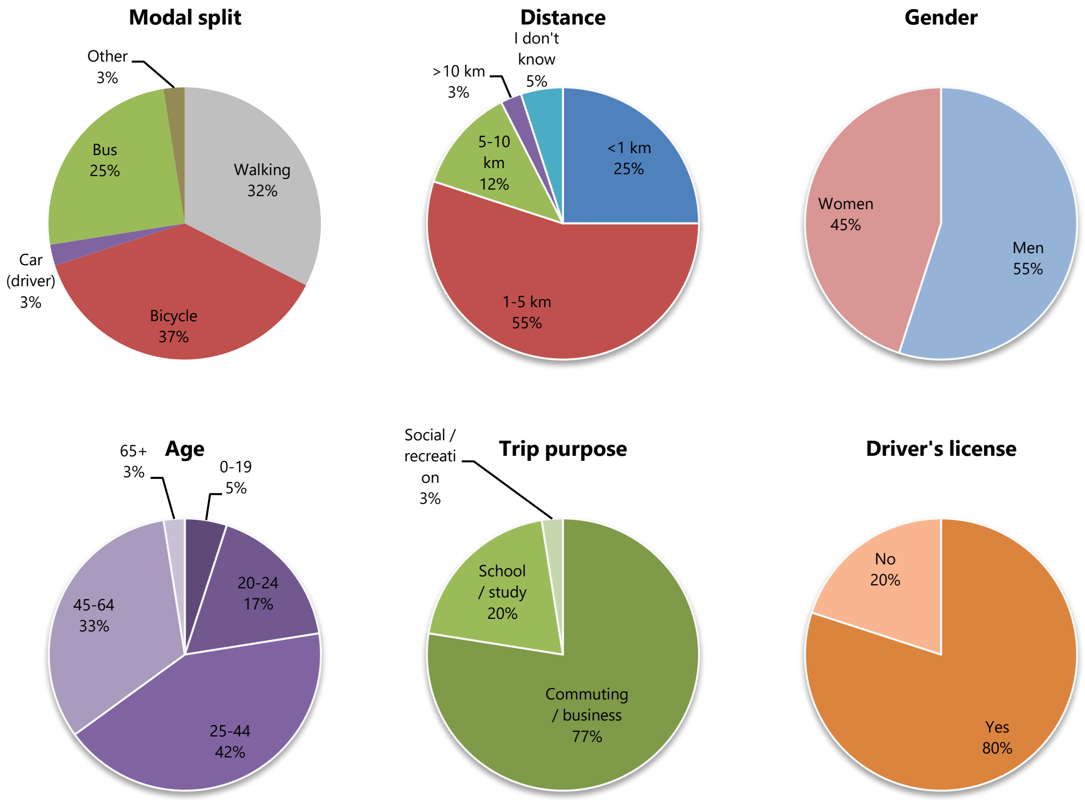
Flexible rides are hot.. or not

Observation: Travellers who prefer a traditional ride service in scenario 1, but no on-demand ride service in scenario 3. (N=47)



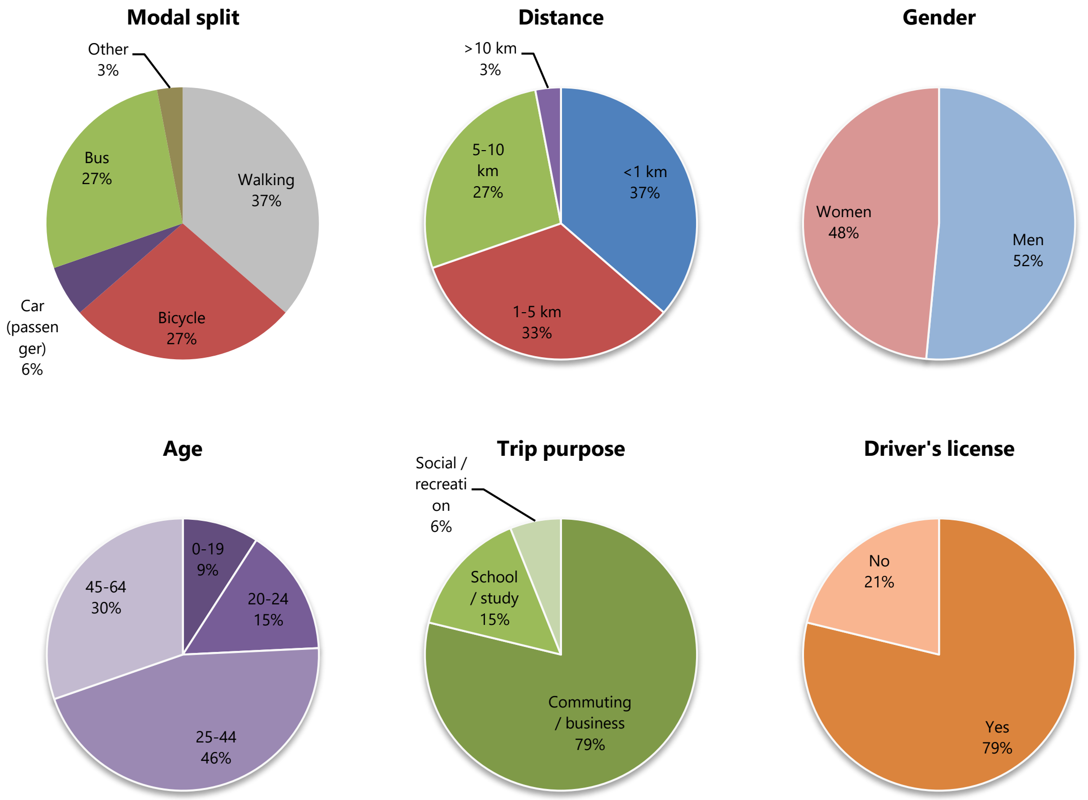
On-board fans

Observation: Travellers who prefer to take a vehicle on-board in at least one scenario (scenario 1 and/or 3). (N=40)



E-scooter fans

Observation: Travellers who prefer an e-scooter (private or shared) in at least one scenario. (N=33)



M LAND USE FOR ACCESS/EGRESS FACILITIES

This Appendix shows the total required land use for access/egress facilities by means of the footprints that were determined in Chapter 4 and the modal splits that were collected via the mode choice experiment in Chapter 5.

For the current situation and the four scenarios, four different tables are created and depicted on the following pages of this Appendix. The columns that can be distinguished are: [1] means of access/egress transport, [2] footprints, [3] home-end modal split percentages, [4] activity-end modal split percentages, [5] number of home-end travellers, [6] number of activity-end travellers, [7] total number of travellers, [8] total number of travellers in percentages, [9] land use and [10] land use percentages.

- [2] are from Appendix F.
- [3] and [4] are from Appendix J.1.
- [5] and [6] are calculated with [3] and [4] and the values in Table M.1.

Table M.1 Number of travellers for periods and trips of interest

	Number of travellers
Average weekday	**25,888**
Weekday morning peak (18.2%)	**4,712**
• Home-end (58%)	**2,738**
• Activity-end (42%)	**1,974**

- [7] is the sum of [5] and [6].
- [8] shows [7] in percentages.
- [9] is the result of the multiplication of [2] with [7].
- [10] shows [9] in percentages.

An overview of the calculated values (sum of [9]) is depicted in Table M.2.

Table M.2 Land use for access/egress facilities

	Land use [m^2]
Current situation	**2,772 m^2**
Scenario 1	**9,808 m^2**
Scenario 2	**5,340 m^2**
Scenario 3	**9,079 m^2**
Scenario 4	**3,861 m^2**

Current situation

Means of access/egress transport	Footprint [m²/traveller]	HE [%]	AE [%]	HE [travellers]	AE [travellers]	Total [travellers]	Total [%]	Land use [m²]	Land use [%]
Walking	0.00 m²	10%	67%	270	1,316	1,586	34%	**0 m²**	0%
Private bicycle	0.30 m²	40%	10%	1,104	200	1,304	28%	**391 m²**	14%
Shared bicycle		NA	0%	-	0	0	0%	**0 m²**	0%
Roundtrip bikesharing vehicle	0.60 m²	-	0%	-	0	0	0%	**0 m²**	0%
Free-floating bikesharing vehicle	0.30 m²	-	0%	-	0	0	0%	**0 m²**	0%
P2P bikesharing vehicle	0.30 m²	-	0%	-	0	0	0%	**0 m²**	0%
Private e-scooter	0.10 m²								
Shared e-scooter									
Roundtrip e-scooter sharing vehicle	0.20 m²								
Free-floating e-scooter sharing vehicle	0.10 m²								
P2P e-scooter sharing vehicle	0.10 m²								
Private on-board vehicle	0.00 m²								
Private car	17.50 m²	3%[1]	NA[2]	94	-	94	2%	**1,645 m²**	59%
Shared car		NA	0%	-	0	0	0%	**0 m²**	0%
Roundtrip carsharing vehicle	9.17 m²	-	0%	-	0	0	0%	**0 m²**	0%
Free-floating carsharing vehicle	4.58 m²	-	0%	-	0	0	0%	**0 m²**	0%
P2P carsharing vehicle	8.75 m²	-	0%	-	0	0	0%	**0 m²**	0%
Individual traditional ride service	3.89 m²	NA	0%	-	0	0	0%	**0 m²**	0%
Collective traditional ride service	0.43 m²	43%	18%	1,175	352	1,527	32%	**662 m²**	24%
Individual on-demand ride service	0.49 m²	2%[1]	5%[2]	59	94	153	3%	**74 m²**	3%
Collective on-demand ride service	0.34 m²								
Other[3]		1%	1%	35	12	47	1%	**0 m²**	0%
		100%	100%	2,738	1,974	4,712	100%	**2,772 m²**	100%

Percentages may not add up to 100% due to rounding.

[1] For home-end trips, the share of private car (passenger) is divided over private car (50%) and on-demand ride service (50%) to determine the land use.

[2] For activity-end trips, the share of private car (passenger) is assigned to individual on-demand ride service to determine the land use.

[3] The option 'other' is not taken into account for the total land use because no values are determined for vehicles among this category in this research.

Scenario 1

Means of access/egress transport	Footprint [m²/traveller]	HE [%]	AE [%]	HE [travellers]	AE [travellers]	Total [travellers]	Total [%]	Land use [m²]	Land use [%]
Walking	0.00 m²	7%	43%	188	858	1,046	22%	**0 m²**	0%
Private bicycle	0.30 m²	35%	15%	952	294	1,245	26%	**374 m²**	4%
Shared bicycle									
Roundtrip bikesharing vehicle	0.60 m²								
Free-floating bikesharing vehicle	0.30 m²								
P2P bikesharing vehicle	0.30 m²								
Private e-scooter	0.10 m²	2%	7%	59	141	200	4%	**20 m²**	0%
Shared e-scooter									
Roundtrip e-scooter sharing vehicle	0.20 m²								
Free-floating e-scooter sharing vehicle	0.10 m²								
P2P e-scooter sharing vehicle	0.10 m²								
Private on-board vehicle	0.00 m²	7%	5%	200	106	305	6%	**0 m²**	0%
Private car	17.50 m²	18%	NA	493	-	493	10%	**8,636 m²**	88%
Shared car									
Roundtrip carsharing vehicle	9.17 m²								
Free-floating carsharing vehicle	4.58 m²								
P2P carsharing vehicle	8.75 m²								
Individual traditional ride service	3.89 m²	NA	2%	-	47	47	1%	**183 m²**	2%
Collective traditional ride service	0.43 m²	31%	27%	846	529	1,375	29%	**596 m²**	6%
Individual on-demand ride service	0.49 m²								
Collective on-demand ride service	0.34 m²								
Other									
		100%	100%	2,738	1,974	4,712	100%	**9,808 m²**	100%

Percentages may not add up to 100% due to rounding.

Scenario 2

Means of access/egress transport	Footprint [m²/traveller]	HE [%]	AE [%]	HE [travellers]	AE [travellers]	Total [travellers]	Total [%]	Land use [m²]	Land use [%]
Walking	0.00 m²	12%	39%	329	764	1,093	23%	**0 m²**	0%
Private bicycle	0.30 m²								
Shared bicycle		22%	14%	611	270	881	19%	**307 m²**	6%
Roundtrip bikesharing vehicle	0.60 m²	-	52%	-	141	141	3%	**85 m²**	2%
Free-floating bikesharing vehicle	0.30 m²	52%	48%	317	129	446	9%	**134 m²**	3%
P2P bikesharing vehicle	0.30 m²	48%	-	294	-	294	6%	**88 m²**	2%
Private e-scooter	0.10 m²								
Shared e-scooter		3%	8%	70	164	235	5%	**32 m²**	1%
Roundtrip e-scooter sharing vehicle	0.20 m²	-	50%	-	82	82	2%	**16 m²**	0%
Free-floating e-scooter sharing vehicle	0.10 m²	50%	50%	35	82	117	2%	**12 m²**	0%
P2P e-scooter sharing vehicle	0.10 m²	50%	-	35	-	35	1%	**4 m²**	0%
Private on-board vehicle	0.00 m²								
Private car	17.50 m²								
Shared car		13%	12%	352	235	587	12%	**4,010 m²**	75%
Roundtrip carsharing vehicle	9.17 m²	-	45%	-	106	106	2%	**969 m²**	18%
Free-floating carsharing vehicle	4.58 m²	43%	55%	153	129	282	6%	**1,292 m²**	24%
P2P carsharing vehicle	8.75 m²	57%	-	200	-	200	4%	**1,748 m²**	33%
Individual traditional ride service	3.89 m²	NA	2%	-	47	47	1%	**183 m²**	3%
Collective traditional ride service	0.43 m²	50%	25%	1,375	493	1,868	40%	**810 m²**	15%
Individual on-demand ride service	0.49 m²								
Collective on-demand ride service	0.34 m²								
Other									
		100%	100%	2,738	1,974	4,712	100%	**5,340 m²**	100%

Percentages may not add up to 100% due to rounding.

Scenario 3

Means of access/egress transport	Footprint [m²/traveller]	HE [%]	AE [%]	HE [travellers]	AE [travellers]	Total [travellers]	Total [%]	Land use [m²]	Land use [%]
Walking	0.00 m²	7%	38%	200	740	940	20%	**0 m²**	0%
Private bicycle	0.30 m²	37%	19%	1,022	376	1,398	30%	**419 m²**	5%
Shared bicycle									
Roundtrip bikesharing vehicle	0.60 m²								
Free-floating bikesharing vehicle	0.30 m²								
P2P bikesharing vehicle	0.30 m²								
Private e-scooter	0.10 m²	2%	6%	47	117	164	3%	**16 m²**	0%
Shared e-scooter									
Roundtrip e-scooter sharing vehicle	0.20 m²								
Free-floating e-scooter sharing vehicle	0.10 m²								
P2P e-scooter sharing vehicle	0.10 m²								
Private on-board vehicle	0.00 m²	6%	5%	164	106	270	6%	**0 m²**	0%
Private car	17.50 m²	17%	NA	458	-	458	10%	**8,019 m²**	88%
Shared car									
Roundtrip carsharing vehicle	9.17 m²								
Free-floating carsharing vehicle	4.58 m²								
P2P carsharing vehicle	8.75 m²								
Individual traditional ride service	3.89 m²								
Collective traditional ride service	0.43 m²								
Individual on-demand ride service	0.49 m²	14%	23%	388	446	834	18%	**406 m²**	4%
Collective on-demand ride service	0.34 m²	17%	10%	458	188	646	14%	**219 m²**	2%
Other									
		100%	100%	2,738	1,974	4,712	100%	**9,079 m²**	100%

Percentages may not add up to 100% due to rounding.

Scenario 4

Means of access/egress transport	Footprint [m²/traveller]	HE [%]	AE [%]	HE [travellers]	AE [travellers]	Total [travellers]	Total [%]	Land use [m²]	Land use [%]
Walking	0.00 m²	18%	42%	493	822	1,316	28%	**0 m²**	0%
Private bicycle	0.30 m²								
Shared bicycle		25%	13%	681	258	940	20%	**324 m²**	8%
Roundtrip bikesharing vehicle	0.60 m²	-	55%	-	141	141	3%	**85 m²**	2%
Free-floating bikesharing vehicle	0.30 m²	57%	45%	388	117	505	11%	**152 m²**	4%
P2P bikesharing vehicle	0.30 m²	43%	-	294	-	294	6%	**88 m²**	2%
Private e-scooter	0.10 m²								
Shared e-scooter		2%	6%	59	117	176	4%	**23 m²**	1%
Roundtrip e-scooter sharing vehicle	0.20 m²	-	50%	-	59	59	1%	**12 m²**	0%
Free-floating e-scooter sharing vehicle	0.10 m²	40%	50%	23	59	82	2%	**8 m²**	0%
P2P e-scooter sharing vehicle	0.10 m²	60%	-	35	-	35	1%	**4 m²**	0%
Private on-board vehicle	0.00 m²								
Private car	17.50 m²								
Shared car		10%	8%	270	164	435	9%	**2,746 m²**	71%
Roundtrip carsharing vehicle	9.17 m²	-	29%	-	47	47	1%	**431 m²**	11%
Free-floating carsharing vehicle	4.58 m²	52%	71%	141	117	258	5%	**1,185 m²**	31%
P2P carsharing vehicle	8.75 m²	48%	-	129	-	129	3%	**1,131 m²**	29%
Individual traditional ride service	3.89 m²								
Collective traditional ride service	0.43 m²								
Individual on-demand ride service	0.49 m²	21%	19%	587	376	963	20%	**468 m²**	12%
Collective on-demand ride service	0.34 m²	24%	12%	646	235	881	19%	**298 m²**	8%
Other									
		100%	100%	2,738	1,974	4,712	100%	**3,861 m²**	100%

Percentages may not add up to 100% due to rounding.