Choice modelling for planned special events

A study on improving accessibility of the AFAS AZ Stadium

Master Thesis

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by

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TU Delft

Preface

Having immersed myself in the academic atmosphere of Delft, I am delighted to present this master thesis, marking the culmination of my educational voyage. Before starting the Master Transport & Planning, I obtained a University of Applied Science (HBO) degree. This means I had to endure a bridging program during the height of the COVID-19 pandemic. Looking back at this period, I realise settling for a new experience in Delft was quite difficult. Nonetheless, I have found the opportunity to merge my studies with one of my passions. During weekends, I am usually present at the home- or away section to watch the team I support. During this project, I got the opportunity to learn from the people involved in organising the events I attend once every seven days.

The thesis focuses on improving accessibility of the AFAS AZ Stadium by looking at the choices made by supporters. During this process, I encountered various people involved with matchday experiences. Firstly, I want to extend my sincere gratitude to my committee members for their invaluable guidance and constructive feedback throughout this research. A special acknowledgement goes to my daily supervisor, Winnie, for her dedicated mentorship. Her availability for numerous discussions about the progress and challenges of my work, especially in navigating the complexities inherent in the subject matter, has been instrumental. Also, the people of the Municipality of Alkmaar and AZ Alkmaar have played a vital role in this research. Via their networks and with their access to various data sources, useful insights have been obtained.

Also, I would like to express my gratitude to my colleagues at IV-Infra, with a special acknowledgement to Bertjan de Boer, my company supervisor. In addition to providing overall guidance, he imparted a wealth of knowledge during our office sessions and various activities. Particularly in the initial months, I had the chance to explore diverse areas. Beyond being intellectually stimulating, these experiences offered valuable insights that significantly contributed to my research. I also appreciate the support of my fellow students, who fostered a stimulating work environment in our thesis experiences. Their insights and inspiration were pivotal in enhancing my understanding of the subject, providing motivation during the entire process. The coffee breaks and lunchtime distractions, while seemingly trivial, played a significant role in helping me maintain focus and energy.

Also, I want to take a moment to thank my dear friends who have encouraged and helped me during this process. Some of these friends are also supporters of AZ, which was very helpful in meaningful discussions. Also, their expertise regarding the topic contributed to the result of this thesis. Lastly, I wish to express heartfelt appreciation to my family, whose love, guidance, and encouragement have been the bedrock of my academic and personal development. Their unwavering belief in my abilities and constant support have been sustaining forces throughout the challenges and successes of this journey.

In conclusion, I am thankful for the opportunity to undertake this research and contribute to advancing knowledge in this field. I sincerely hope this thesis proves to be a valuable addition to the existing body of research in this domain.

V.I. (Vincent) Nijholt
Delft, February 2024

Abstract

This study focuses on the AFAS AZ Stadium, located in Alkmaar. The modern multi-purpose stadium serves as the home ground of the Dutch Eredivisie football club AZ Alkmaar. The stadium events are called Planned Special Events (PSEs). PSEs are defined as recurring events of limited duration developed to increase a city's appeal in the short and long term. At the venue and in the stadium environment, disturbance is experienced by supporters, inhabitants, and road users. Frequently mentioned bottlenecks are the active mode tunnel and lack of parking for both bicycles and cars. This occurs mostly on departure after matches. Some other mentioned topics are traffic congestion, connectivity to a train station and the conflict points between cyclists and pedestrians. Besides the social relevance, this study has a scientific relevance. This study tends to fill the knowledge gap regarding mode choice behaviour of visitors to PSEs. This is done by proposing a mode choice model for PSEs in The Netherlands. This report investigates effective accessibility improvements which can be applied at the AFAS AZ Stadium. To systematically reach the goal of the report, a main research question is formulated:

What effective accessibility improvements can be applied to enhance accessibility for visitors attending planned special events, with a specific focus on their modal choice behaviour for the AFAS AZ Stadium?

The first part of this study focuses at how the AFAS AZ Stadium and its surroundings are utilised over space and time by its 19,500 spectators. The venue is located between a national (A9), provincial (N242) and municipal road (Smaragdweg) as shown in Figure 1. In total, 2,857 parking lots are facilitated by the football club from P1 to P9. Pedestrians and cyclists use a tunnel which crosses the Smaragdweg. The bicycle racks (2,250) are located between the tunnel and the stadium. Services which are offered to reach the stadium safely and efficiently are shuttle services and traffic controllers. There are three busses shuttle between Alkmaar station and the AFAS AZ Stadium. For vehicle guidance, a total of 25 traffic controllers are applied.

Within this research, visitor origin information was collected from ticket sales for five Eredivisie and UEFA Conference League events in the 2022-2023 season. On average, 18,200 supporters attended these matches. The analysis found no statistical difference in the origin of supporters for these different events, with an average travel distance of 12.3 kilometres and a standard deviation of 15.0 kilometres. Turnstile data revealed no significant difference in arrival times for these events, although the time before kick-off varied between them. According to the stated preference sample from the KNVB Expertise (2023), half of the supporters prefer to travel by car. Followed by one-third travelling by bicycle to the AFAS AZ Stadium as shown in Table 1. For car traffic, a study near the AFAS AZ Stadium on event days showed that 53.3% of supporters parked within the stadium's vicinity, with approximately 1,550 vehicles coming from freeway A9. This suggests a modal share of cars between 55% and 70%. For cyclists, measurements taken during three events in the 2023-2024 season revealed a modal share of 12% to 15% of supporters using bicycles to reach the stadium. Pedestrians were measured using radio wave sensors for two events in the 2023-2024 season, with an average count of 5,000 pedestrians. After accounting for parked vehicles and cyclists, approximately 1.0% of supporters were found to walk to the venue. The summarised modal preferences are presented in Table 1.

Table 1: Result of observed modal share compared to KNVB Expertise (2023)

	KNVB Survey	Revealed preference	
		Lower bound	Upper bound
Car	51,6%	55%	70%
Bicycle	37,8%	12%	15%
Public transport	5,6%	-	-
Walking	2,6%	0.8%	1.2%
Other	2.4%	-	-

After obtaining stakeholders' experience and utilising the infrastructure, accessibility improvements are found. These interventions are derived via interviews with fourteen organisers of similar PSEs. The most frequently mentioned measures by these organisers are fan zones (10 times). The usage of traffic controllers, having agreements

Figure 1: Location of AFAS AZ Stadium (Google Earth, 2023)

with transit operators and usage of supporter buses are each mentioned five times. Measures to improve accessibility at the AFAS AZ Stadium focus on two main characteristics (service- and infrastructural-related). Within the service-related interventions, three enhance public transport. This is done by having combi tickets for public transport when one has a valid entry ticket. Also, an event-related time schedule can be introduced. Additionally, the use of supporter buses can be an effective intervention. Other measures involve the enhancement of carpooling or the introduction of park plus bike facilities. Minimising conflicts for car traffic via the distribution of parking tickets based on direction can be another intervention. Personalised messages can be sent to visitors to the AFAS AZ Stadium via online applications. Lastly, having other entertainment options to lure supporters to the venue earlier via fan zones, discounts on beverages or on-field entertainment. Besides these service-related interventions, the infrastructural measures focus on physical changes. In this sense, public transportation can be enhanced by investing in bus stops. Other interventions per mode imply investing in additional road-, bicycle and pedestrian infrastructure, with (secured) parking for cars and bicycles as separate measures. Other interventions are shared space in the active mode tunnel, additional turnstiles and traffic signs. The last intervention is rearranging routing at the stadium site before and after an event.

To measure the effect that the accessibility interventions have on the mode choice of visitors to the AFAS AZ Stadium, a survey is held. Within this stated preference method, the accessibility- and decision factors are derived. Following a literature review, the factors that influence mode choice are elaborated. Four mode choice attribute groups are derived from the literature study: Spatial-, Journey-, Socio-demographic- and Socio-psychological characteristics. Afterwards, a survey is composed to obtain visitors' preferences and experiences. The determinants that are found to have a direct influence on mode choice are party size, habit, socio-demographics, and satisfaction. For the stated preference experiment, a kick-off time of Sunday 14:30 is chosen against Ajax Amsterdam at the AFAS AZ Stadium. Decision variables (costs, comfort, time and reliability) indicate the changing environments with the measures to increase accessibility. These variables are considered for six distances (2, 3, 8, 13, 17 and 26 km). An efficient design is derived based on the pilot survey results. A minimum of eight questions per respondent is recommended. Three main parts exist within the final survey design (Match-day experience): choice modelling and descriptive statistics, as shown below.

Match-day experience	Choice modelling	Descriptive statistics
· Season ticket	· Scenario's	· Licence
· Length of season ticket		· Vehicle availability
· Number of attended games		· Habit
· Habit		· Age
· Satisfaction		· Gender
· Ticket group		· Distance
· Purpose		
· Party size		
· Ease		
· Arrival time		
· Parking		

In total, the stated preference survey is filled in by 2,218 respondents. This group is reduced to a final sample of 1,808 useful responses by validating the results and using exclusion criteria. With this sample, a discrete choice model is derived, which assesses the effect of the accessibility improvements on the mode choice probability. In this survey, supporters aged 46 to 65 make up to half the sample size, with a gender distribution similar to previous studies (77% male, 22.6% female). Travel distances to the venue vary, with fewer respondents travelling less than 2 kilometres and more travelling over 21 kilometres, suggesting less use of active transportation like walking and cycling. Most respondents are season ticket holders, mainly in the Molenaar stand and Ben-Side. Half have held their tickets for over ten years. Different multi-nominal logit (MNL) choice models have been derived to quantify the survey findings. At first, a generic approach is taken with an estimation of generic variables which are not dependent on the modality. Afterwards, the number of variables is increased by making these variables mode-specific. By doing so, the goodness of fit increased from 0.166 to 0.374 significantly. A total of 66 parameters are estimated within the final choice model. Negative ASC values imply a preference for car usage, consistent with the car being the dominant mode of transportation to the AFAS AZ Stadium. The attendance rate reveals higher utility for public transport when supporters are not always present, suggesting a greater willingness to use transit. Conversely, walking and cycling have lower utility for those attending matches more than seven times per season, aligning with cycling being less dominant in this scenario. Habit positively impacts mode utility, indicating a significant relationship between commuters' usual means of transport and their travel patterns to the stadium. This aligns with existing transport choice modelling discussions, emphasising the role of habit as both a preference and a barrier to behavioural changes. Travel time negatively influences supporter utility, indicating decreased utility with increased travel time.

The last two sub-questions aim to gain insight into accessibility and decision factors for accessibility of the AFAS AZ Stadium. Additionally, the accessibility interventions are rated based on the Best-Worst Method (BWM). In this method, the accessibility alternatives are differentiated via six attributes (implementation costs, financial revenue, effectiveness on flow, period of effect, livability and environmental impact and public order). The relative importance of these attributes is determined per stakeholder, with the municipality of Alkmaar prioritising safety and public order. At the same time, AZ's marketing department emphasises measures impacting fan behaviour and accessibility. The safety department naturally values safety and public order. Rijkswaterstaat, interpreting effectiveness on flow as most crucial, and the police prioritise safety and public order at the AFAS AZ Stadium.

To find the answer to the main research question, the overall scores for measures are calculated by multiplying the relative importance of stakeholders with the relative importance of attributes. This way, the effective accessibility improvements to enhance accessibility at the AFAS AZ Stadium are derived. The scores highlight investments in road infrastructure and flipped routing as the most feasible measures. These measures score higher in increasing accessibility to the AFAS AZ Stadium than shared space, sidewalks, bicycle paths and turnstiles.

The research exhibits several limitations concerning its applicability to diverse scenarios. Notably, the estimated choice model may not be transferable to venues other than the AFAS AZ Stadium due to the bias inherent in the sample of respondents, primarily comprising AZ supporters with season tickets, potentially skewing mode choice. The Multinomial Logit (MNL) model assumes independence among alternatives, which might not hold in real-world settings, necessitating consideration of alternative models such as Nested- or Mixed Logit for better estimation results. The survey methodology, conducted using NGene and Biogeme software, introduces challenges related to the pilot survey's large choice sets, influencing respondent answers and potentially compromising reliability. Additionally, the research lacks consideration for certain factors affecting mode choices, such as weather conditions and transportation's first- and last-mile aspects. At the same time, measurement of intervention effectiveness relies on modal split analysis, which may not fully capture public transport effects. Moreover, the study's assessment of perceived accessibility and stakeholder consultation methodology raises concerns regarding the consistency and robustness of conclusions, suggesting the need for sensitivity testing and validation of obtained rankings.

The study suggests two avenues for future research: one focusing on academic exploration and the other on further investigation of the AFAS AZ Stadium case study. Regarding academic research, alternative mode choice estimation models, such as Nested- and Mixed Logit functions, could be employed to enhance the robustness of the study's findings. Validation of obtained stated preferences with revealed preference studies, calibration of choice parameters, and testing the entire sample size rather than specific groups are recommended for improved reliability. The study's focus on mode choice preferences at the AFAS AZ Stadium could be extended for a broader view of event visitors in the Netherlands, allowing for the determination of differences in willingness to adapt mode choices among various supporter groups. For the AFAS AZ Stadium case study, the top six solutions could benefit from a more in-depth examination using design guidelines, expressing the performance matrix in monetary values, and employing macro- or microscopic simulation models for assessing flow effectiveness. A sensitivity analysis would enhance result reliability and filter out potential biases. The study also proposes considering new modes of transportation, such as shared bicycle systems or e-scooters. It suggests exploring stakeholder collaboration through a plenary session to align everyone with potential changes to the stadium environment.

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Abbreviation	Definition
AIC	Akaike Information Criterion
ASC	Alternative Specific Constants
BIC	Bayesion Information Criterion
BWM	Best-Worst Method
CR	Consistency Ratio
KNVB	Royal Dutch Football Association
KS	Kolmogorov-Smirnov
MCDM	Multi Criteria Decision Making
MNL	Multinomial Logit
NDW	Dutch traffic portal
P+B	Park and Bike
PSE	Planned Special Event
RP	Revealed Preference
SP	Stated Preference
UEFA	European Football Association

1 Introduction

Fernando (2018) shows that congestion effects are observed at almost every Planned Special Event (PSE). PSEs are defined by Burns et al. (1986) as recurring events of limited duration which have been developed to increase the appeal of a city in the short and long term. The demand is considered over a short period, typically leading to peak problems in main service industries (Burns et al., 1986; Hall, 1989). Robinson et al. (2011) has classified events based on the planning involved. A distinction is made between special events involving planning and ordinary events. Towards the events, traffic flows are concentrated into very short periods of time, which causes frequent issues (Moutinho, 2000; Talaat & Rashwan, 2018). Next to this, event visitors have a different travel pattern than commuters. Since they demand a wide range of travel experiences (Jang et al., 2004). Following the definition of Federal Highway Administration (2007), a PSE can be defined as: ”A public activity with a predetermined date, venue, and duration”. Due to these events, traffic demand is increased, which influences the functioning of the transport network (Burns et al., 1986; Ergin & Tezcan, 2021). The events can be classified based on Attendance size, Event frequency, Venue type, Start- and End time, Duration, Time of the week, Location and Impact area (Ergin & Tezcan, 2021; Kuppam et al., 2013). The effect is also known as non-recurring congestion (Ambühl et al., 2023; Kwoczek et al., 2014). Non-recurring congestion is described as atypical traffic congestion, the specifics of which, such as time, location, and duration, are largely unpredictable. Accidents, construction areas, PSE, etc often cause this. While the impact on traffic depends on the conditions locally, non-recurring congestion is mostly caused by external factors (Di Martino et al., 2019; Yang et al., 2015; Zhao et al., 2016). As for non-recurring traffic, examples are accidents or changes in the weather. While planned events are road construction or special events (Fernando, 2018).

The study focuses on the AFAS AZ Stadium in Alkmaar. The modern multi-purpose stadium serves as the home ground of the Dutch Eredivisie football club AZ Alkmaar. The stadium was officially opened as the DSB Stadium on August 4, 2006, with a seating capacity of 17,023 (AZ Alkmaar, 2021; AZ Fanpage, 2006). In 2019, a part of the roof structure of the stadium collapsed. Therefore, a new roof, together with additional investments, has been made. The stadium's capacity has increased to 19,500 seats (The Stadium Consultancy, 2021; ZJA, 2021). With this expansion comes challenges relating to the accessibility of the AFAS AZ Stadium for visitors. In the KNVB Expertise (2023), the AFAS AZ Stadium visitors are asked how they rate logistic accessibility. Common answers indicate that the tunnel is often mentioned as a bottleneck. Moreover, parking for both bicycles and cars is mentioned. This is focused mostly on departure after matches. Some other mentioned topics are traffic congestion, connectivity to a train station and the conflict points between cyclists and pedestrians. These disturbances are various in terms of transportation. However, they can be divided into arrival at the stadium and departure after games. The most commonly mentioned bottlenecks are shown in Table 1.1. This study focuses on reducing the disturbances experienced by visitors of the AFAS AZ Stadium. Reducing the experienced disturbances can be done by designing effective demand management measures. Kuppam et al. (2013) proposed that it is crucial to investigate the travel behaviour before these events. As stated by de Dios Ortúzar and Willumsen (2011), modal choice behaviour is critical in travel behaviour studies following the conventional four-step model. Other travel behavioural aspects concern choices regarding travel choices, origin choice, arrival time and route choice. Since this study focuses on visitors of PSEs at the AFAS AZ Stadium, the travel choices are not considered. Also, it is assumed that the origin choices are fixed and, therefore, are not necessarily choices.

Table 1.1: Experienced disturbances at AFAS AZ Stadium (KNVB Expertise, 2023)

Arrival	Departure
○ Traffic congestion at the main arterials	○ Overcrowding at active mode tunnel
○ Parking of cars within residential area	○ Egress time of parking facilities
○ Bicycle stalling before tunnel	○ Early departure of supporters
○ Connectivity to Alkmaar train station	○ Improper use of Smaragdweg roundabout
○ Improper use of exit ramp at A9	

1.1. Scientific relevance

Various topics are covered in research that combines PSEs with transportation research. From a PSE perspective, studies have been focusing on event management (Fai, 2019; Newman & Falcous, 2012; Talaat & Rashwan, 2018), demand models (Di Martino et al., 2019; Ergin & Tezcan, 2021; Kumar & Khani, 2020; Kuppam et al., 2013), choice models (Ergin & Tezcan, 2022; Lin & Chen, 2017; Musgrave et al., 2019; Shahin et al., 2014), activity patterns (Abkarian et al., 2022), multimodal simulation (Cummings et al., 2022; Fernando, 2018; Kwoczek et al., 2014; Ruan et al., 2016; Zheng et al., 2023) and equity (Darcy & Harris, 2003; Kitchin et al., 2022; Pulugurtha et al., 2020). While it is generally known that PSEs significantly impact road traffic and urban space, research regarding these events is limited (Di Martino et al., 2019; Han et al., 2018; Kuppam et al., 2013). Due to PSEs, travel demands within a short period are overall more severe (Talaat & Rashwan, 2018). Since the travel behaviour of PSE attendees differs from that of commuters, it is crucial to investigate such behaviour to design effective demand management measures and evaluate their effectiveness (Kuppam et al., 2013; Szeto et al., 2016). To my knowledge, there is no research on travel behaviour for PSEs in the Netherlands.

Choice models which have been investigated for similar special events focus on pre-game activity patterns for visitors of PSEs in Istanbul (Abkarian et al., 2022; Ergin & Tezcan, 2022; Shahin et al., 2014). A mode choice model proposed by Lin and Chen (2017) focuses only on a large PSE in Taiwan. This study intends to fill this gap by proposing a mode choice model for PSEs in the Netherlands. Following research of Fai (2019), further research towards travel demand and participation of PSEs is necessary. This finding is also underlined by Lin and Chen (2017), who states that additional research in exploring the travel demands of other PSEs and their participation is advisable. Moreover, a knowledge gap exists in connecting these choice models with accessibility. Via this choice model, a connection will be made with accessibility for visitors of PSEs. Many studies have been performed on accessibility for transport planning. However, only a little research is done on accessibility for visitors of PSEs. Jamei et al. (2022) has discussed a difference between conventional and perceived accessibility. While Pot et al. (2021) derived performance indicators for perceived accessibility based on traditional accessibility measures. This research proposes a knowledge gap between the concept of perceived accessibility for community (end-user) perspectives and policymakers. Therefore, methods to quantify perceived accessibility should be developed in future research (Glock & Gerlach, 2023; Pot et al., 2021).

1.2. Research questions

Research questions are composed to systematically reach the report's goal. Acknowledging the identified research gaps, this study proposed measures to reduce the disturbances experienced by visitors of the AFAS AZ Stadium. To ensure that these measures are effective, it is essential to understand the problems experienced around the AFAS AZ Stadium. The main research question, supported by various sub-questions, is formulated to mitigate these problems. The main research question is expressed as follows:

What effective accessibility improvements can be applied to enhance accessibility for visitors attending planned special events, with a specific focus on their modal choice behaviour for the AFAS AZ Stadium?

To answer this main question, the following set of sub-research questions are derived:

1. How do local stakeholders around the AFAS AZ Stadium utilise the infrastructure during PSEs and what criteria for accessibility do they follow?
2. Through which accessibility improvements can the experienced disturbances be mitigated focusing on similar PSE organisers who enhance accessibility for PSEs at their venue?
3. What choice attributes are mentioned in literature regarding modal choice behaviour?

4. To what extent do the choice attributes affect the modal choice behaviour per accessibility improvement by which the probability of modal choice is predicted for visitors of the AFAS AZ Stadium?
5. Which accessibility- and decision factors are applicable for visitors of the AFAS AZ Stadium?
6. How do the accessibility improvements score on the decision factors of the AFAS AZ Stadium?

These research questions are derived based on specific objectives. An overview of these objectives and their relationship is shown in more detail in Figure 2.2. The objective of the main research question is to enhance accessibility for visitors attending planned special events, focusing on their modal choice behaviour for the AFAS AZ Stadium. The first step in reaching this objective is to provide insight into the infrastructural use of space. This is the objective of the first research question, which aims to understand the logistical requirements of the stakeholders involved with the AFAS AZ Stadium. With this information, different ways to improve accessibility can be formulated. These interventions are derived based on the experiences of organisers of similar PSEs. The impact on the modal choice behaviour is tested to measure the effectiveness of the accessibility improvements. Therefore, the choice attributes influencing mode choice behaviour need to be determined, which is done by the third research question. This question aims to derive a theoretical framework for mode choice behaviour. Afterwards, the objective of the fourth question is to find to which extent the choice attributes affect the modal choice behaviour per accessibility improvement. Since accessibility improvement is not the only factor considered within event organisation, other decision factors are derived. The related research question aims to find these decision factors for the case of the AFAS AZ Stadium. The objective of the last question is to rank the accessibility improvements based on the decision factors. This results in effective improvements, focusing on their effect on mode choice behaviour, to enhance accessibility at the AFAS AZ Stadium.

1.3. Project scope

In this project, the focus lies on the accessibility of the AFAS Stadium in Alkmaar. The area assessed in this study is the stadium ground for active modes (bicycles and pedestrians), parking facilities and direct adjacent (key) roads with on- and off-ramps. These roads are the ones which are regulated using traffic controllers and where the event causes traffic congestion. Destination for the AFAS AZ Stadium visitors in this study focuses on the inside of the stadium (i.e. behind the entry gates). The travel modes assessed are car-, bicycle-, pedestrian and public transport oriented. Public transport is only assessed based on the shuttle bus services from and to NS Station: Alkmaar. Other modes, such as mopeds, shared mobility, etc., are not considered.

As mentioned before, the time of day is another crucial factor in travel behaviour. This study uses the standard playing times of the Koninklijke Nederlandse Voetbal Bond (KNVB) and the Union of European Football Associations (UEFA). This means that Saturday evening (20:00) and Sunday afternoon (14:30) are used for Eredivisie matches (KNVB, 2022). Also, European matches on Thursday evening (18:45 and 21:00) are used (UEFA, 2022). The recurring congestion related to morning or afternoon peaks is neglected by focusing on these time windows. In addition, only the supporters of AZ are considered. Away supporters who attend the game from the away section are not considered. Since these supporters often travel under police escort to a designated parking facility.

Solutions which will be proposed to improve accessibility focus on two parts mainly. At first, solutions concerning a modal shift are considered. Secondly, infrastructural changes such as new off-ramps are discussed. A reference study will be done on similar stadiums in the Netherlands to find potential solutions. By focusing on these two parts, it is believed that any direct effect of using infrastructure is appointed. This study does not consider any other themed solution (e.g., improving weather conditions).

1.4. Report structure

In this research, the methodology is first elaborated. In chapter 2, the different research methodologies are discussed with a justification for the research questions. Focus is shifted then to the AFAS AZ Stadium (chapter 3). The transportation- and visitor characteristics are discussed. Additionally, interventions to improve accessibility at the AFAS AZ Stadium have been introduced. Afterwards, a literature study is done in chapter 4. This way, the different mode choice factors mentioned in the literature are obtained. In chapter 5, the stated preference choice experiment is introduced. From this chapter, the considered choice attributes are determined together with the setup of the choice experiment. After obtaining responses, the results of the choice model are elaborated in chapter 6. These measures are assessed via multi-criteria decision-making in chapter 7.

2 Methodology

Within this chapter, the methodology to obtain the research objective is elaborated. In Figure 2.1, the overall approach within this study is shown. Different phases and types of research are indicated within this figure. The numbers within the boxes show the paragraph in which this part is discussed. Connectors between the boxes show which following action is the result of a specific step. Within the framework, some main research topics can be derived, which is the backbone of this study. At first, the literature study is done to obtain factors that influence individuals' mode choice. Afterwards, a descriptive analysis is done to obtain the transportation and visitor characteristics. Followed by discrete choice modelling performed based on a stated preference (SP) experiment. At last, a multi-criteria decision analysis is conducted to assess the solutions obtained to improve accessibility at the AFAS AZ Stadium.

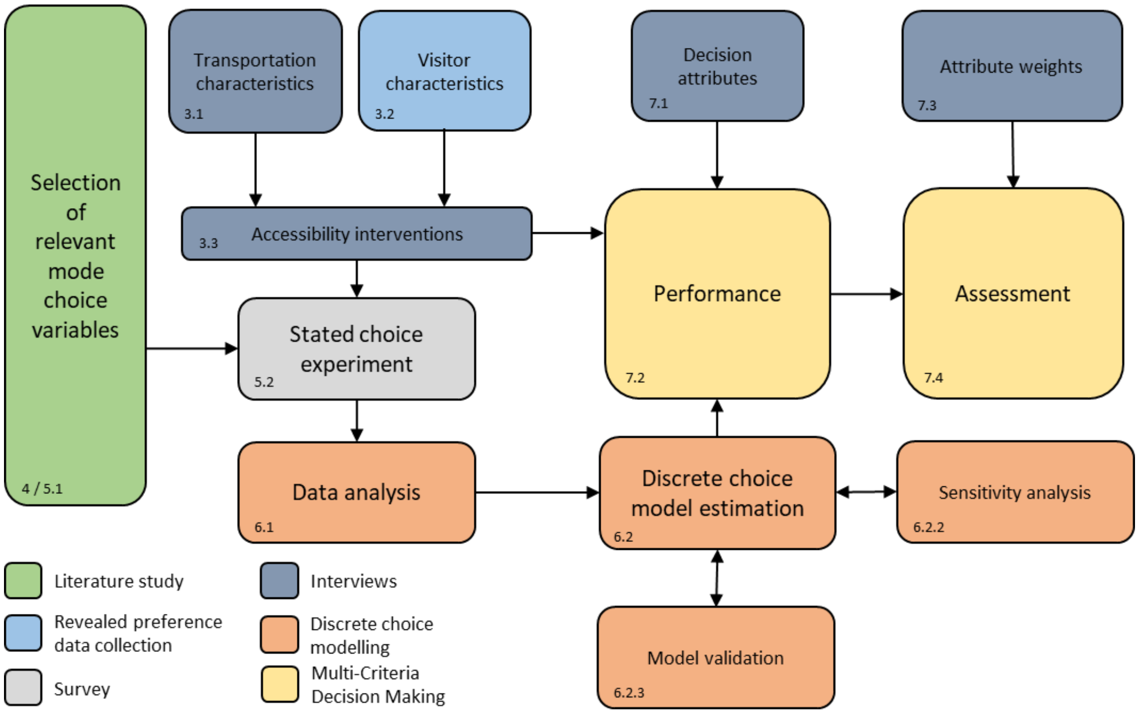

Figure 2.1: Framework of research methodology

Within this research, six different research types are used to answer the main- and sub-research questions. Each method has its objective and activities and answers specific research questions. Various research methodologies have been selected to enable the integration of quantitative and qualitative data collection techniques. Quantitative research entails collecting and analysing numerical data and employing statistical methods to identify patterns and correlations. Conversely, qualitative research concentrates on non-numerical data such as observations, judgements, or images to explore and comprehend individuals' experiences, perspectives, and behaviours. Consequently, qualitative research typically adopts a more flexible and open data collection and analysis approach. In contrast, quantitative research adheres to a more structured and systematic process centred on numerical data and hypothesis testing.

Both qualitative and quantitative research approaches possess distinct strengths and weaknesses. Their combination enhances possibilities and yields more comprehensive findings. Furthermore, the limitations of one approach can be offset by the strengths of the other. The selection of research methods is contingent upon the research questions and objectives. The research initially takes a broad approach and progressively delves into more detail as the project unfolds. The used research methods are shown in Figure 2.2. Two quantitative methods (i.e., literature study and interviews) are used to understand the factors influencing mode choice and to obtain stakeholder perceptions. The different research methods are elaborated in more detail in the following sections.

Research questions	Objective	Activities
How do local stakeholders around the AFAS AZ Stadium utilise the infrastructure during PSEs and what criteria for accessibility do they follow?	Gain understanding of how event-days are experienced by stakeholders of the AFAS AZ Stadium. Also derive how the infrastructure is utilized space and time. Goal is to determine the flow of supporters and their arrival time patterns.	Interviews Revealed preference data collection
Through which accessibility improvements can the experienced disturbances be mitigated focusing on similar PSE organisers who enhance perceived accessibility for PSEs at their venue?	Find which accessibilities are implemented by organisers of similar PSEs to mitigate their accessibility disturbances.	Interviews
What choice attributes are mentioned in literature regarding modal choice behaviour?	Get insights into the factors that are known to influence mode choice.	Literature review
To what extent do the choice attributes affect the modal choice behaviour per accessibility improvement by which the probability of modal choice is predicted for visitors of the AFAS AZ Stadium?	Obtain individuals' preferences and experiences to measure the effect that the accessibility improvements have on the modal choice behavior of visitors to the AFAS AZ Stadium.	Survey Discrete choice modelling
Which accessibility- and decision factors are applicable for visitors of the AFAS AZ Stadium?	Get insight into the accessibility- and decision factors which are applicable for the accessibility improvements for the AFAS AZ Stadium.	Interviews
How do the accessibility improvements score on the decision factors of the AFAS AZ Stadium?	Rate the solutions to improve accessibility of the AFAS AZ Stadium based on the decision attributes.	Multi-Criteria Decision Making

Answer to main research question: *What effective accessibility improvements can be applied to enhance perceived accessibility for visitors attending planned special events, with a specific focus on their modal choice behaviour for the AFAS AZ Stadium*

Figure 2.2: Research methods, objectives and activities

The mentioned research methods are elaborated in more detail in the sections below. In these sections, the boxes from Figure 2.2 are mentioned and discussed as to why the chosen research method is applied. Moreover, the way that these methodologies are used within this research is elaborated in the sections.

2.1. Interviews

To gain an understanding of stakeholders' perspectives on events at the AFAS AZ Stadium, a stakeholder analysis is presented. From this analysis, the influence of different relevant actors is made insightful (Hoory & Bottorff, 2022). This section of the study provides a broad understanding of the physical environment and uses at the AFAS AZ Stadium (*sub research question 1*). Additionally, the improvement solutions' boundaries are set (*sub research question 2*). At last, the stakeholders are consulted regarding their decision attributes for determining effective accessibility interventions. This information sets the boundaries of the improvement solutions (*sub research question 5*). Stakeholders in this context are defined as parties which can affect or are affected by the outcomes of a specific policy/project (Demir et al., 2015). Since stakeholders' needs and expectations can differ from one another and the aim of the project, a good balance is tried to be found (Hoory & Bottorff, 2022). With a good balance, a more successful project can be executed. Demir et al. (2015) has proposed a stakeholder analysis method based on power, interest and attitude. The power factor in this method focuses on the stakeholder's impact on a project's outcome. While the interest focuses on the amount of attention the stakeholder focuses on the project. Attitude relates if the stakeholder acts passive (negative) or active (positive) towards a project (Demir et al., 2015). In Figure 2.3, the classification groups of stakeholders are indicated. Based on this figure, eight groups can be classified: Saviour (1), Friend (2), Saboteur (3), Irritant (4), Sleeping Giant (5), Acquaintance (6), Time Bomb (7) and Trip Wire (8) (Murray-Webster & Simon, 2007).

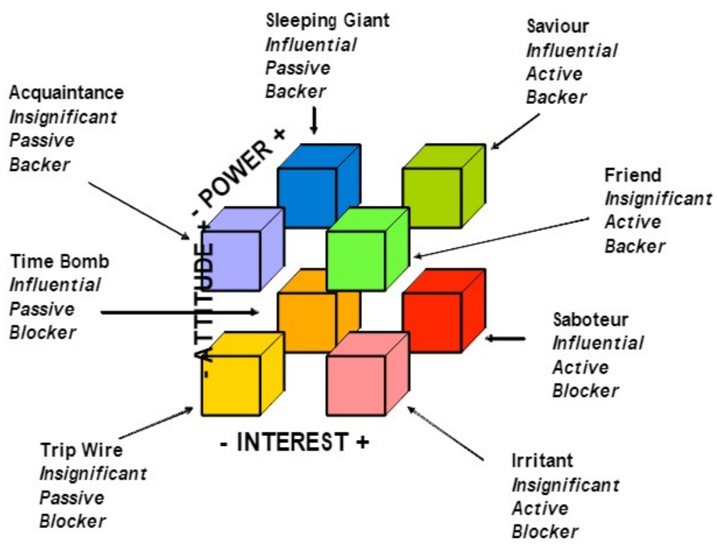

Figure 2.3: Power-interest-attitude matrix (Murray-Webster & Simon, 2007)

Based on this stakeholder-mapping method, the relevant stakeholders for this project are indicated. At first, all relevant stakeholders are introduced. After this introduction, these actors are classified into each of the eight groups. Stakeholders who will be consulted during the project are determined in this way. Only the stakeholders who fall into the Saviour and Saboteur classifications are consulted directly via interviews. This is reasoned because both these parties have high power and interest. If these stakeholders are not involved, it is seen as impossible to get a project off the ground (Murray-Webster & Simon, 2007). On the other hand, friends are used to give voice to a proposed measure. The stakeholder analysis results are shown in Table 2.1. In correlation to Demir et al. (2015), scores are given on a scale from 1 (low) to 5 (high) for power and interest. Regarding attitude, a similar scale from 1 to 5 is used. However, the numbers indicate: Very negative, Somewhat negative, Neutral, Somewhat positive and Very positive (Maeda, 2015). Groups are indicated by numbers from 1 to 8, corresponding with Murray-Webster and Simon (2007).

In this table, it can be obtained that **AZ Alkmaar** and the **Municipality of Alkmaar** are the key stakeholders. In correspondence with Murray-Webster and Simon (2007), both these stakeholders can be classified as saviours. Since they have high power in the study's outcome and high attention to the topic. Also, these stakeholders are very positive towards any improvement proposed for the accessibility of the AFAS AZ Stadium. Other stakeholders which are on the verge of 'saviours' are the **Province of North-Holland**, **Rijkswaterstaat**, **Security services** and

Stakeholders	Power	Interest	Attitude	Group
AZ Alkmaar	5	5	5	1
Municipality Alkmaar	5	5	5	1
Province North-Holland	4	2	2	8
Rijkswaterstaat	4	2	4	5
Supporters Association AZ	2	5	4	2
Security services (e.g. Police, Riot police, Security, etc.)	4	4	3	1 & 3
Business park 'Boeklermeer'	2	4	4	2
Emergency services (e.g. Firebrigade, Ambulances)	4	3	4	1 & 5
Public transport operators (e.g. NS, Conexxion, etc.)	2	2	3	7 & 8
Second-hand municipalities (e.g. Heiloo, etc.)	2	4	2	6
Supporters AZ	1	5	5	2
External road traffic	1	2	4	6
Residents residential area (e.g. Overdie, Zuid, etc.)	2	4	5	2

Table 2.1: Stakeholder map

emergency services. The governmental bodies and emergency services have a large stake in the outcome since they own the roads adjacent to the stadium. However, in terms of interest, this study is not high on their calendar. Although they observe issues in their infrastructure in relation to accessibility, they are somewhat positive in terms of attitude. Because their interest in the project is neutral, they can also be seen as sleeping giants. By engaging them in the project, they can be seen as saviour. For security services, their attitude is more neutral. Since there are no direct safety issues concerning accessibility, they are neither negative nor positive about any improvement. Due to the recent developments with troubles and football supporters, with NOS (2023c) as an example, the interests of security services have changed. From the interviews, perspectives on the transportation characteristics (section 3.1) as well as different decision factors (section 7.1) are obtained.

Via interviews, experts in the event management and organisation field are consulted. For this study, a distinction is made between organisers who are part of the KNVB and consultants active in the event management field. Via AZ Alkmaar and KNVB, contact with professional football clubs is sought. Interviews with similar football event organisers are held to find effective mobility strategies. This information sets the boundaries of the improvement solutions (*sub research question 2*). This means that representatives of football clubs within The Netherlands are interviewed. Only football clubs that have a capacity exceeding 10,000 spectators are invited for these interviews. The reason for this is their influence on the public space. Since football clubs with stadiums less than 10.000 have a lesser. Afterwards, recorded semi-structured interviews are held. A transcript of the complete interview is made from these recordings. After the interviewee's agreement, this transcript is used within this study. Different themes are encoded from these interviews, which can be used to compare the different methods and opinions. The relevant information is extracted from the themes, and the other methods employed for accessibility are elaborated. The different solutions are presented via graphing techniques.

2.2. Revealed preference data collection

Three key visitor characteristics are derived from researching how the AFAS AZ Stadium is utilised during PSEs (*sub research question 1*). At first, AZ Alkmaar's (season) ticket sales are made insightful based on the number of people eligible to enter the stadium. Afterwards, the arrival times of these supporters are indicated from the tourniquet data. At last, the modal preferences of visitors are assessed. This assessment is done by a revealed preference study based on sensors and revealed preference based on KNVB Expertise (2023). An overview of the data used with the uses is shown in Figure 2.4. The traditional four-step method is shown in this figure. This method is used to determine the exact data streams deemed necessary to describe the usage of the venue's infrastructure.

Ticket data is the first kind of revealed data obtained via AZ ticket sales. From this information, certain characteristics of ticket purchases are derived. Examples of this data are the spatial distribution of visitors to the AFAS AZ Stadium. To transform this data into information, the distance one travels to an event at the AFAS AZ Stadium. Between the four stands, a distinction in the data is defined.

The Arrival time data, on the other hand, gives information regarding the number of entrances from the turnstiles.

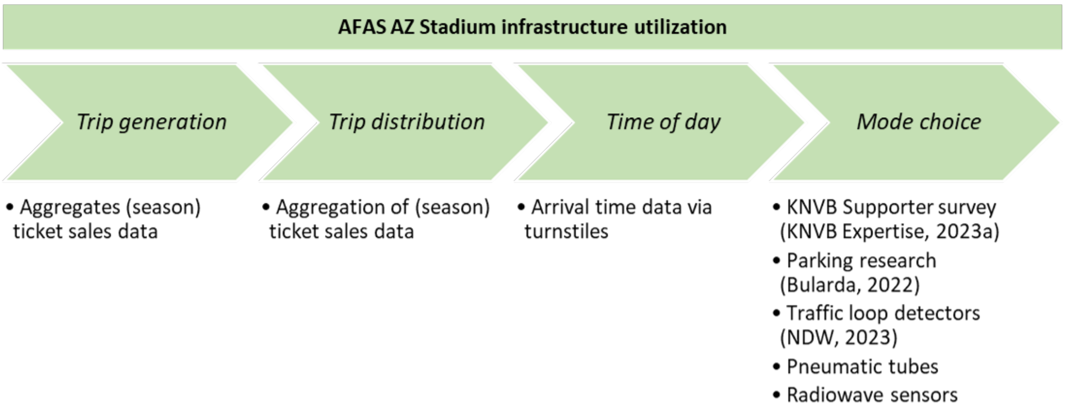

Figure 2.4: Revealed preference data collection framework

Regarding the time before an event starts, the ratio of people inside the AFAS AZ Stadium versus those eligible to enter the stadium can be derived. Similar to the ticket data, an average scenario is derived together with an extreme scenario. The output of this data is the expected arrival time of people during events. When this is known, the demand for infrastructure can be expressed in time.

Mode preference data at last is obtained. By taking field measurements, the demand of modes over time will be measured. This study is executed for three different modes of transport (car, bicycle, and pedestrian). Different kinds of data are used to estimate the number of supporters who travel to the AFAS AZ Stadium by car. At first, the increase in parking pressure in the residential area Overdie is calculated. The first amount of vehicles is calculated in combination with the number of parking facilities at the venue and the average occupancy per vehicle. Afterwards, flow data from the national Dutch traffic portal (NDW) is compared to origin and destination data from TomTomMove. This leads to several movements to and from the stadium per wind direction. After car traffic, cyclists are measured around the AFAS AZ Stadium. Field tests are conducted to measure the exact number of cyclists. Via pneumatic tubes, the quantity and spread in time are derived. One limitation of this measurement method is the possibility that two vehicles are counted as one. Additionally, the tubes can be vulnerable to vandalism since they are in direct reach for anyone. At last, this method only counts for cyclists, which estimates other modes as impossible. So-called pedestrian sensors are installed to measure the number of pedestrians. These boxes send a radio frequency transmission through bodies. If more people are present, the sensor receives a signal in a weakened form. By calibrating this to the current scenario, a null scenario is derived. Afterwards, this data is trained by so-called training data, which helps estimate the flow.

2.3. Literature study

The literature review continues the initial literature survey conducted during the research proposal's orientation phase. Whereas the preliminary phase focused on pinpointing gaps in existing knowledge and ensuring the research's originality by building upon previous work rather than replicating it, this subsequent review aims to enhance comprehension of the present scientific literature. It aims to identify the essential concepts, theories, and methodologies pertinent to the research. Via the literature study, various modal choice behaviour factors are obtained. Utilising specified keywords, along with their synonyms, a collection of papers is chosen primarily through title analysis. To gauge the relevance of these documents, their abstracts are thoroughly examined. Subsequently, the snowballing strategy is employed, involving the analysis of references and citations in the identified papers. All pertinent documents are gathered, and a decision is made to extract information from the most pertinent studies, employing filters such as abstract content, publication year, source, and publisher for advanced evaluation using PROMPT. An electronic database search has been executed in Scopus on the 6th of April, 2023. The papers which have been reviewed are based on the search term as stated below:

("Planned Special Events" ***OR*** "Special Events" ***OR*** "Sport Events" ***OR*** "Hallmark Events" ***OR*** "Sport Event" ***OR*** "Hallmark Event" ***OR*** "Stadium") ***OR*** ("Choice Behaviour" ***OR*** "Choice Behavior" ***OR*** "Choice Modelling" ***OR*** "Choice Modeling" ***OR*** "Behaviour Analysis" ***OR*** "Behavior Analysis" ***OR*** "Explanatory Factor Analysis") ***AND***

(”Perceived Accessibility” ***OR*** ”Accessibility” ***OR*** ”Accessibility Measure”) ***AND*** (”Transport Planning” ***OR*** ”Transportation”)

Based on the search query, 150 scientific papers have been found. Afterwards, a review of these search results is carried out. Articles are scoped based on certain inclusion and exclusion criteria:

Inclusion criteria:

- Articles written only in the English language
- Articles investigating user behaviour during PSEs, or assessing perceived accessibility in combination with choice modelling

Exclusion criteria:

- Papers which cover modes of transportation which do not play a role within the case study of the AFAS AZ Stadium;
- Articles that cover non-transportation related topics (e.g. Healthcare, Computer science, etc.);
- Articles which cover destination choices are neglected, since the destination is fixed for this research;
- Innovative transportation systems which cannot be utilised to reach the AFAS AZ Stadium;
- Cover accessibility in terms of equality for less mobile people;
- Writing in a non-professional manner;
- Data collection techniques which cannot be used for the study.

By assessment of the abstracts and the obtained articles, the complete search term is narrowed to 32 papers. Including and exclusion criteria are used to guide the scoping of the articles. From the analysis, it has been found that only a total of 38 articles are complying with the criteria. The main reason papers are excluded is because of the modes of transportation covered. A total of 23 articles reviewed modes such as metro, train, or electric motorbikes. Another main reason articles are neglected is that they cover different fields of study, such as healthcare ($n = 20$). Also, papers cover location choice modelling from a supply side ($n = 19$). Since the location within this study is fixed, these articles are neglected.

In addition to the Scopus database analysis, literature is retrieved by ’snowballing’. Additional literature is obtained by reading related papers and associated references. A total of 24 extra scientific pieces of literature are therefore reviewed. This brings the total of academic literature used for this review to 56. The complete flowchart of obtaining the articles is shown in Figure 2.5.

Moreover, the environment around the stadium is discussed based on the literature review. Location characteristics are discussed first to give a clear indication of the stadium environment. Under this term is a qualitative explanation of the road network, the stadium plan and other services. For the road network, the different kinds of classification of roads with maximum speeds and pressure are indicated. Together with the regular use of visitors in terms of routes. Zooming in on the AFAS AZ Stadium provides knowledge of the different characteristics of the four stands. Also, the facilities inside the stadium support the understanding of visitor flows. Another quantitative description is made for the other services (e.g., shuttle buses, traffic controllers, etc.). A more quantitative overview of the stadium’s parking facilities is presented afterwards, showing the number of parking facilities. Based on studies from the past, the parking pressure for different matches at various locations is indicated.

2.4. Survey

To measure the extent to which the accessibility improvements affect the modal choice behaviour, an SP study is held (*sub research question 4*). Regarding research on choice behaviour, two key methods exist: revealed preference (RP) and SP. For RP studies, the possibility of making forecasts is based on real-world decisions. Whereas the SP can include new attributes not measured within RP studies (Hinz et al., 2015). An SP research will be executed since new attributes are introduced for the mode choice decisions of visitors to the AFAS AZ Stadium. Via discrete choice modelling, the underlying reasoning behind human choices can be obtained (Train, 2009). Following research of Rao et al. (2014), four kinds of SP methods exist (Rating- or Ranking-based analysis, Discrete Choice Experiments, Self-Explained Methods and Hybrid method). Discrete choice experiments permit survey participants to make repeated choices among different product alternatives (Swait & Andrews, 2003). Hinz

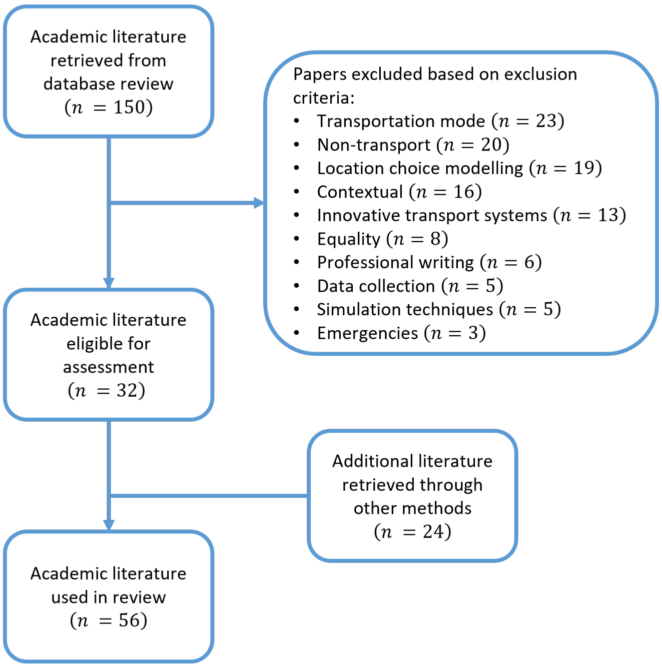

Figure 2.5: Flowchart of methodology for literature review

et al. (2015) and Schlereth et al. (2014) have stated that self-explicated techniques involve direct evaluations of attributes and their significance based on a subset of the attributes. Harris and Brown (2010) have shown that surveys and physical experiments are common methods for discrete choice modelling. Surveys tend to yield more objective and broadly applicable results than interviews, enhancing the likelihood of obtaining a favourable initial understanding of the effects.

Within this study, a discrete choice experiment is used to quantify mode choice behaviour. This method is chosen following recommendations of (Louviere et al., 2010; McFadden, 2000). A pilot survey is first held to find the effects of the mode choice attributes. Within this survey, 20 choices are tested per participant. By doing this, a sample size is determined, which is necessary for representative purposes. Afterwards, a final survey is composed with a limited number of attributes (3- 8). Distribution of this survey is done via the AZ Supporters Association, in combination with private networks and collaboration with AZ.

Concerning the information-gathering process, it is crucial to conduct it systematically. Only essential information for the research is collected to avoid potential privacy-related issues. Additionally, there will be transparency throughout the process, ensuring clarity on what information is being gathered and how it will be utilised. A data monitoring strategy will be implemented through a Data Management Plan, which will be reviewed and approved by the Human Research Ethics Committee of TU Delft. The survey is distributed via four different channels. At first, the supporters association of AZ was used. Within this magazine, a section is used exclusively for the survey through a QR code and an accompanying text. It is expected that a core group of visitors and an older part of the AZ population will be reached via this channel. Secondly, a call has been placed in the Facebook group 'Je bent AZ'er als....'. Within this group, various core groups and not-so-often supporters are reached. Thirdly, an email is distributed via AZ. It is expected that supporters who do not go to the AZ match very often respond to this email. At last, supporters are reached via Instagram. It is expected that these supporters are of the group below 35. A match jersey will be distributed amongst supporters to incentivise supporters to fill in the survey. Within this survey, three main workflows are present. At first, the match-day experience is asked, followed by the mode choice scenarios and finished with descriptive statistics.

2.5. Discrete choice modelling

Within transportation, many studies regarding choice modelling have been performed. While there is little attention for PSEs, some choice models have been proposed on origin choice (Kuppam et al., 2013), mode choice (Shahin et al., 2014), arrival time choice (Ergin & Tezcan, 2022) and activity choice (Abkarian et al., 2022). Within Ergin and Tezcan (2022), a binary logit model is used to estimate the modal choice for individuals regarding private vehicles and public transport. Other studies which include choice modelling in a transportation setting focus on mode choice (Li et al., 2020; Li et al., 2016; Turan et al., 2022), route choice (Basu & Sevtsuk, 2022; Zimmermann et al., 2017), destination choice (Shobeirinejad et al., 2013), travel choice (MacLeod et al., 2020) and commute length (Xianyu & Juan, 2012). Discrete choice models are employed to model the extent to which the choice attributes affect modal choice behaviour per accessibility improvement (*sub research question 4*). The factors identified and selected in the literature review are being incorporated into a Multinomial Logit (MNL) model (Holmgren & Ivehammar, 2020). For this study, the MNL is used. This method is chosen since it is the most commonly used modelling technique and is easy to use and comprehend (Ergin & Tezcan, 2022). The modelling process is conducted using the Biogeme package with the Python programming language, which supports estimating all the mentioned discrete choice models. Subsequently, the parameters resulting from the modelling are subjected to tests for significance and utility to determine their inclusion in the final model.

Before starting the modelling process, the basic statistics are described. From this data analysis, an understanding of the sample is obtained. Additionally, the representativeness of the sample is derived. Two checks are done with two different data sources to check whether the dataset is representative. At first, the gender and age results are compared to the results of the KNVB Survey. Since this is a well-known data source with accepted results, any differences in the sample might tell something about the final results. The gathered population data also includes the arrival time and origin information. Any differences can explain the skew of the results since this population data is based on revealed preference. Besides the comparison, an analysis of the obtained choice factors is done.

The initial phase involves estimating MNL models with individual factors and alternative-specific constants (ASC). Changes in log-likelihood and rho-square-bar are examined to assess the contribution of each variable to the model fit. Following this, the variables are modelled based on categories of factors to observe potential changes in significance and identify correlations between variables. After these two modelling steps, the utility of the variables is evaluated. Some variables may substantially impact mode choice but may not be deemed useful for inclusion in a model designed to estimate mode choice probabilities. The utility of choosing a mode can be defined as the potential costs and benefits of an alternative for an individual. The Akaike information criterion (AIC) estimates a constant plus the relative distance between the data's unknown true likelihood function and the model's fitted likelihood function. The Bayesian Information Criterion (BIC) estimates a function of the posterior probability of a model being true under a certain Bayesian setup. For these parameters, there is no goodness of fit indicator. However, as a rule of thumb, the lower these values, the better the model fit. Estimating the utility of each attribute is achievable through a model. With these estimations, it becomes possible to predict the probability for an individual to choose a specific mode of transport. The utility, denoted as U, comprises a systematic part V and a random part ε for each alternative i, as per Equation 2.1. In this equation, V_i is expressed in terms of attributes $x_{i,k}$ combined with their respective weights β_k, which require estimation. The equations for calculating the utilities are presented in both Equation 2.1 and Equation 2.2.

$$U_i = V_i + \varepsilon_i \tag{2.1}$$

$$V_i = \sum_{i=1}^{n} \beta_k \times x_{i,k} \tag{2.2}$$

Given that only the systematic part of a utility function is ascertainable, it is feasible to estimate the probability of selecting a particular alternative, as illustrated in Equation 2.3. Python-Biogeme will be employed for parameter estimation (β) of the models detailed in the subsequent section (Bierlaire, 2018).

$$P_i = \text{Prob}(U_i > U_j, \forall i \neq j) \tag{2.3}$$

2.6. Multi-Criteria Decision Making

Lastly, after the data is collected and analysed, an assessment of the accessibility improvements is done via Multi-Criteria Decision Making (MCDM) (*sub research question 6*). The solutions are compared based on an appropriate appraisal method. By providing insight into the vectors determined by the expert (Best to others and Others to worst) insight into the process is provided. This gives the public an easy understanding of which choices are made. With regards to the calculations, these are convenient for stakeholders. On the other hand, ethical considerations show that there is a validation of the results to check whether the decision maker is consistent. Therefore, it is hard for people in power to manipulate the decision-maker. From an ethical point of view, ensuring transparency, honesty, and timely, complete, and unbiased information in decision-making can raise issues (Van de Kaa et al., 2020). Regarding usefulness, the BWM method can be applied in group decision-making. Moreover, it shows the most feasible alternative within consistency (Balezentis et al., 2021). The criteria set for the assessment are drawn in agreement with the most relevant stakeholders (i.e. AZ and the Municipality of Alkmaar). These two stakeholders will determine the weight of these criteria in the form of a Best-Worst Method (BWM). In the BWM method, the relative importance of multiple criteria is weighed with a pairwise comparison. The decision-maker will determine the most- and least important criteria from the set of all criteria. Based on this, the importance of every other criterion is used to determine the weight of every criterion. When this weight is known, the value from the performance matrix is multiplied by the criterion's weight. However, before this can happen, the decision-maker's consistency must be checked via a so-called Consistency Ratio (CR). If this value is below a certain threshold, the decision maker has been consistent with their choices (Rezaei, 2015).

The performance matrix will be completed on a 5-scale Likert basis. Besides the fact that this can cause arbitrary outcomes, it gives an idea of the magnitude of ranking solutions. Simplifications in this sense have been opted with regard to time spent on the study. The relative weights are calculated based on the attributes, as introduced in section 7.1. From the stakeholder analysis in section 2.1, interviews are conducted with representatives. In these interviews, a form is introduced in which the stakeholder must identify the most important attribute followed by the least important one. Afterwards, the relative importance of the most important attribute is expressed against the other attributes $(A_B = (a_{B1}, a_{B2}, ..., a_{Bn}))$. This is done on a scale from one to nine. One indicates the attributes are equally important. Nine means the attribute is absolutely more important than the other. This comparison is then also done others to worst $(A_W = (a_{1W}, a_{2W}, ..., a_{nW})^T)$. The optimal weights then are found by taking the maximum absolute difference for all minimised criteria (j). This function is shown in Equation 2.4, in which the weight: $w_j \geq 0, \forall j$ and $\sum_j w_j = 1$. Consistency of these answers is checked via the consistency criterion ($a_{Bj} \times a_{jW} = a_{BW}$). The formula to compute the CR is shown in Equation 2.5. Based on previous studies, the values within the table are derived based on Table 2.2. The ξ^* value equals the maximum of the absolute difference, as shown in Equation 2.4. The outcome is a value between zero and one; the lower the CR, the more consistent the result.

$$\text{min max}_j \left(\left| \frac{w_B}{w_j} - a_{Bj} \right|, \left| \frac{w_j}{w_W} - a_{jW} \right| \right) \tag{2.4}$$

$$CR = \frac{\xi^*}{CI} \tag{2.5}$$

Table 2.2: Consistency table for BWM method

a_{BW}	2	3	4	5	6	7	8	9
CI	0.44	1.00	1.63	2.30	3.00	3.73	4.47	5.23
Threshold (Criteria = 6)	-	0.2087	0.2928	0.3309	0.3924	0.3931	0.4230	0.4225

With the performance matrix and the attribute weights, an assessment can be made. The evaluation is done similarly to the principles of the utility theory. In Equation 2.6, the equation for determination of the score (S) of the measures i is indicated. Per attribute j, the importance of each measure can be calculated.

$$S_i = \sum_{j=1}^{n} (W_j \times E_{i,j}) \tag{2.6}$$

3

Accessibility of the AFAS AZ Stadium

This research focuses on the AFAS AZ Stadium in Alkmaar, The Netherlands. The primary use of this arena is football matches played by the professional football team AZ Alkmaar. As seen in Figure 3.1, the stadium is on the south side of Alkmaar. Within this section, an overview of the location is given. This overview relates to the current accessibility regarding the transport characteristics around the stadium. Also, supporters' characteristics towards matches of AZ from the 2022-2023 season are indicated. This is followed by an overview of relevant stakeholders involved in the stadium. From this chapter, an understanding is obtained of how event days are experienced and the way visitors of the AFAS AZ Stadium utilise the infrastructure. Measures that can be implemented to increase the accessibility of the AFAS AZ Stadium were introduced afterwards. At first some generalised accessibility interventions implemented by similar organisers of PSEs are shown. From this set of measures, the interventions that can be implemented at the AFAS AZ Stadium are set off against the mentioned bottlenecks.

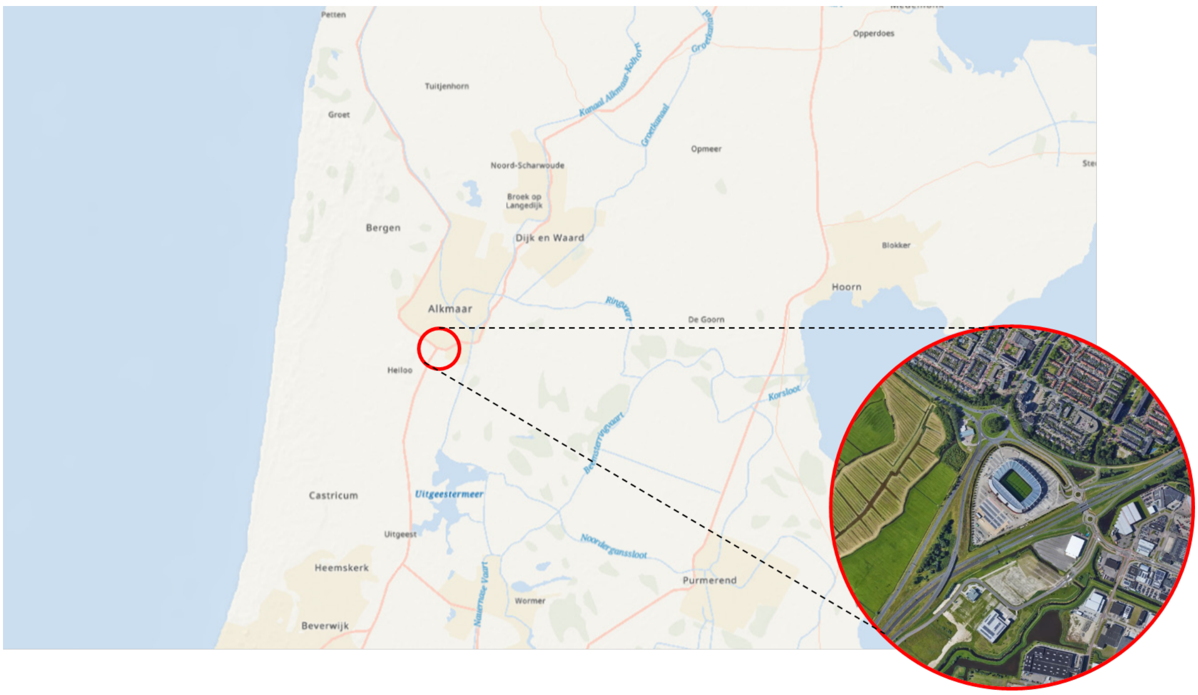

Figure 3.1: Study area AFAS AZ Stadium (Google Earth, 2023)

3.1. Transportation characteristics

In Figure 3.2, the infrastructure around the AFAS AZ Stadium is shown. From a spatial planning perspective, the stadium is surrounded by agricultural land on the west, residential areas in the north and industry in the south and west (Kadaster, 2023). Due to these land-use mixes, characteristics such as the road network and bicycle facilities play a role in accessibility around the stadium during events. In addition, the stadium plan and parking possibilities with other provided services are shown. This section reviews the road network around the AFAS AZ Stadium. The review focuses on roads, cycle paths and footpaths. Afterwards, the facilities at the stadium site are discussed in the second section. The third section elaborates on match-day parking at and around the AFAS AZ Stadium. Followed by an overview of other services offered to visitors of the stadium. At last, an overview of bottlenecks is indicated.

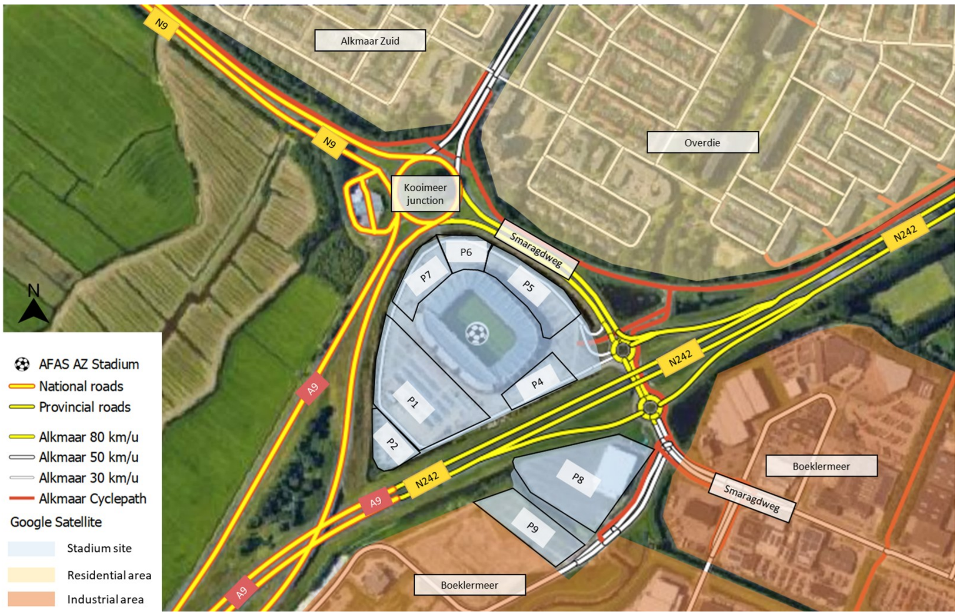

Figure 3.2: AFAS AZ Stadium parking facilities and areas of interest

3.1.1. Road network

As seen in Figure 3.2, many different road categories are present around the stadium. Differentiating in categories also involves different governmental administrators. To start with the main corridor, the A9 connects Alkmaar with Amsterdam/Haarlem (Rijkswaterstaat, 2023). For inbound traffic, the highway contains two lanes with a maximum speed of 100 km/h during the daytime. During rush hours, however, a peak hour lane is activated (Rijkswaterstaat, 2021). After mileage 68,7, the highway splits into two 2-lane highways to Heerhugowaard (East) and Alkmaar Centre (North). Visitors to the stadium have to take the Alkmar Centre exit to get to Kooimeer junction (covered later in this section). However, people who travel to parking facilities P8 and P9 have to take the Heerhugowaard exit (AZ Alkmaar, 2021). Both links contain two lanes with a maximum speed of 80 km/h. Looking at the incident rate, ViaStat information is extracted (ViaStat, 2023). In total, 280 incidents have been reported, four of which were fatal. Three injuries that took place on an event day are reported. The first of these three was before AZ - Tuzla City on 21-07-2021 at 20:30. The timing of the incident corresponds to the start of the inflow of supporters 93 minutes before kick-off. The incident happened between a female cyclist, 81 years injured, and a fixed object. No other incidents have been reported regarding events at the AFAS AZ Stadium in the last ten years.

Other arterials are the N9 and N242, considered provincial roads. The first (N9) comes from Den Helder to the Kooimeer junction with two lanes and a maximum speed of 70 km/h. On the N242, on the other hand, the speed limit is 80 km/h for the two lanes. The municipality of Alkmaar maintains other roads around the stadium. The Smaragdweg, the main entrance towards the stadium for car traffic, is of special significance. On this road are two roundabouts, one of which is the main entrance towards the stadium ground. The Kooimeer junction is a multi-lane roundabout which is regulated by traffic lights. Moreover, the parking facility has a direct entrance and exit for visiting (away) fans. These supporters are diverted from regular traffic to this entrance on game days. Police escort visitors to the stadium with supporter's busses in clusters of five buses at a time. Moreover, when departing, the flow of traffic on this junction is halted to ensure a quick departure of away fans "Interview on August. 23, 2023, with Police Unit Noord-Holland". From this interview, it came forward that these visitors need to exit the stadium area within a maximum time of 10 minutes. Other measures that have been taken are that there are no bridge openings for the Leeghwaterbrug (N242) 2 hours before and after matches of AZ "Interview on June. 12, 2023, with the Province of Noord-Holland". Moreover, there are no road constructions planned which conflict with matches.

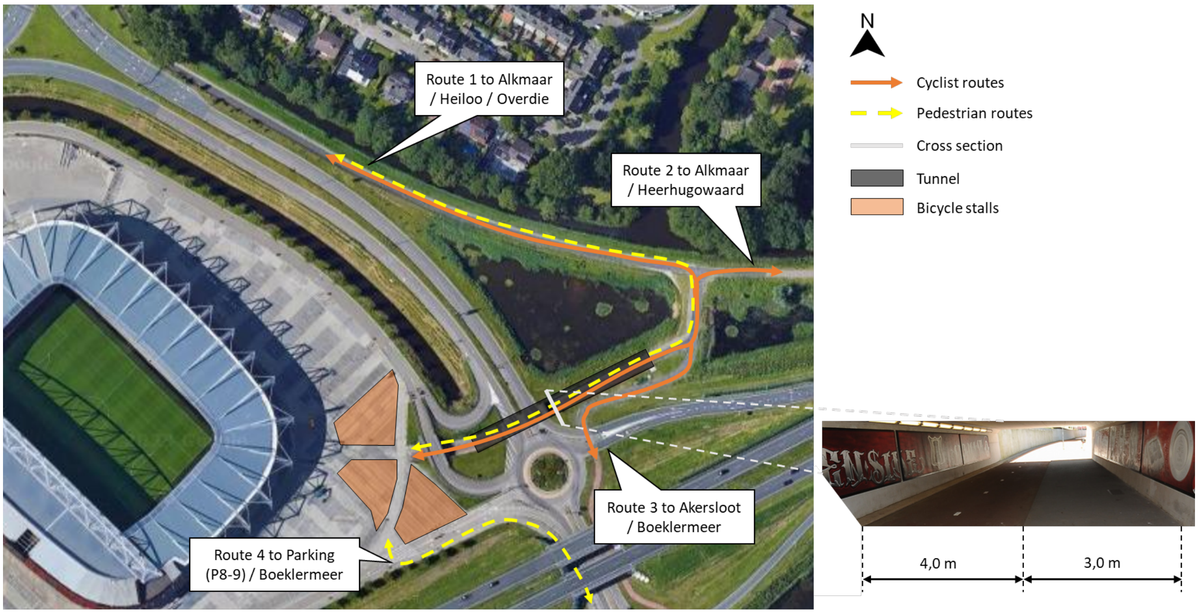

Figure 3.3: Access and egress routes for active modes towards AFAS AZ Stadium

For active modes such as cycling and walking, the routes are shown in Figure 3.3. From this figure, four main routes can be distinguished. The first route is for pedestrians and cyclists towards Alkmaar (Overdie), Heiloo, and other destinations. Most of these active mode users will encounter each other via the tunnel at the marked crossings. In the tunnel, a separate walking and cycling path is created. This route is mainly used for pedestrians to reach parked vehicles in the Overdie neighbourhood (highlighted in subsection 3.1.2). Route two is only made accessible for cyclists, so pedestrians have to walk on the cycle path. Most people who will take this route find their origin in the direction of Alkmaar or Heerhugowaard. The third route is also only accessible by cyclists and connects the stadium to the industrial area 'Boeklermeer' and the direction of Akersloot. At last, route four is used by pedestrians who have parked their car at either 'Boeklermeer' or parking facilities P8 or P9. Pedestrians also use this route to reach the shuttle services as discussed in subsection 3.1.3.

3.1.2. Stadium site

There are six parking facilities at the stadium site, as seen in Figure 3.2. Two other parking facilities are on the opposite side of the provincial road (N242). This comes down to 3,346 parking locations facilitated by AZ (Bularda, 2022). By the Municipality of Alkmaar (2007), the parking standards are set at 0.2 per seat. Considering the stadium's total capacity (including the away section), this comes down to 3,900 parking facilities (19,500 * 0.2). The average pressure during matches is shown in Figure 3.4. This image illustrates that, on average, there is a high demand for parking in the northwestern areas compared to the base scenario in Figure 3.4. This area is popular since it is closest to access to the stadium by foot. Parking within Boeklermeer, on the other hand, is not allowed following (Municipality of Alkmaar, 2005). For bicycles, there are multiple bicycle stalls after exiting the tunnel Figure 3.2. There are approximately 2,250 places to park bicycles at this location. Other facilities for bicycle parking are located parallel to the N242 (500) and in front of the main entrance (250). For mopeds, a few stalls are located at the bicycle racks after the tunnel.

Figure 3.4: Average parking pressure surroundings AFAS AZ Stadium (Google Earth, 2023)

At the stadium site, a variety of facilities are present. The fan shop, restaurant and museum are open at the main entrance on regular days. This main entrance is located at the 'Victorie' stand. This main building also houses the staff offices. On match days, four main sections within the stadium can be determined. As seen in Figure 3.5, the stadium consists of four main stands (Alkmaarderhout, Molenaar, Van Der Ben and Victorie). The Alkmaarderhout stand is the family section where families with children take place. The section for away supporters is located in the corner of the stand (sections K and L). The Molenaar stand houses the majority of supporters and has 70 spots reserved for people with disabilities. The supporterscafé 'Barry van Galen' is used by supporters before and after matches. The third 'Van Der Ben' stand houses the AZ Fanclub and safe-standing sections (X1 and W). The last 'Victorie' stand houses mostly business seats and skyboxes.

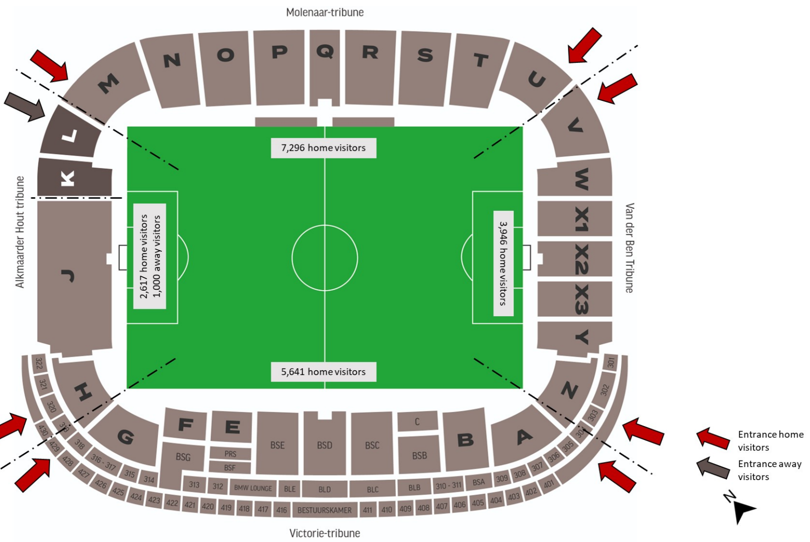

Figure 3.5: AFAS AZ Stadium-plan with entrances for home- and away visitors

3.1.3. Other services

Other convenient services for visitors to the AFAS AZ Stadium are shuttle buses and traffic controllers. During matches, three shuttle buses are provided by AZ to shuttle between Alkmaar station and the stadium. Each of these buses has room for 80 visitors and takes about 10-15 minutes. The buses stop at the site of the viaduct under the N242. From there, the supporters have to walk towards the entrance via route 4 (Figure 3.3).

Regarding traffic controllers, on average, around 25 traffic controllers regulate in- and outbound car traffic. In Figure 3.6 the location of these controllers is shown. In this figure, a distinction is made between traffic- and ticket controllers. Ticket controllers are present around the stadium at the parking facility entrances and the driveways to the stadium site. Also, two ticket controllers are present at the entrances to P8 and P9. At P9, there is also the opportunity to buy parking tickets before a match. Complementary to these ticket controllers are the traffic controllers who manage and regulate traffic flows. On the roundabout at Smaragdweg, there are three regulators present. These controllers aim to keep traffic flowing on the roundabout without gridlock. Also, it is tried to distribute the load from the Smaragdweg and N242 equally before a match. At the intersection between the Smaragdweg and Parelweg, a handful of regulators are also present. These regulators aim to distribute traffic from the west- and east sides of the Smaragdweg equally. Whenever queues are forming, driving against traffic is allowed. This will be managed by the traffic controllers by traffic cone lanes. Also, a traffic controller focuses on the conflict with cars and pedestrians coming from the industrial area. Since it is not allowed to park on the industrial estate (following Municipality of Alkmaar (2005)), traffic controllers are present at the intersections to enforce this covenant between AZ and the industrial area. During the egress of games, a line of traffic regulators is present at the yellow circle. They distribute pedestrians and cars away from the stadium site equally. At the P8 and P9 parking facilities, lanes are prepared with cones to guide visitors to the west or east side of the Smaragdweg. This causes a distribution in traffic and fewer queues at the Kooimeer intersection. Regarding this intersection, a special scheme is implemented after a match at the AFAS AZ Stadium. By having more green-light periods for the Smaragdweg, traffic is resolved earlier. A similar scheme is in place at traffic lights at the intersection of Diamantweg-N242.

Figure 3.6: Deployment of traffic controllers on event days at the AFAS AZ Stadium

3.2. Visitor characteristics

Next to the transportation characteristics, the behaviour of visitors in terms of origins, arrival time and mode choice to the AFAS AZ Stadium is regarded. With this analysis, the way the infrastructure is utilised during events at the venue is derived. How the data is collected corresponds to the four-step model, as presented in Figure 2.4.

3.2.1. (Season) Tickets

Ticket data is obtained via AZ Alkmaar. With this information, the origins of visitors to the AFAS AZ Stadium are made insightful. Data provided by AZ focuses on the four digits of the zip codes. In this way, the ticket sales data is anonymous. Moreover, the number of people from an area is expressed as a percentage of the total number of tickets sold. This has a downside since there is a bandwidth in the data. However, with these percentages, additional effort was taken to anonymise the data. Data obtained is based on the 2022-2023 season. This table shows the total variability of visitors to the AFAS AZ Stadium. It also indicates the magnitude of the visitors.

Data regarding ticket sales is obtained for five events within the season 2022-2023. The first event is (AZ - Ajax), played in the 7th round of the Eredivisie. Kick-off time was Sunday, 16:45, the 18th of September 2022. Before this match, AZ's position on the league table was fourth. Ajax was top of the league table (Transfermarkt, 2023). That day's temperature had a maximum of 13.8 °C with 10.9 mm of rain (KNMI, 2023). Secondly, the match against Feyenoord was played on Sunday, the 16th of October 2022, at 16:45. This was the 10th round of the

Eredivisie, with AZ being first in the league. The opposition's position was fourth in the league (Transfermarkt, 2023). Based on data from KNMI (2023), it was a dry day with a maximum temperature of 17.1 °C. The match against SC Heerenveen was the 27th round of the Eredivisie. Played on Saturday 16:30 on April 1 2023, the match was fourth (AZ) versus ninth (SC Heerenveen) (Transfermarkt, 2023). It rained 3.1 mm on this day, and the maximum temperature was 11.1 °C (KNMI, 2023). The matches against Lazio and Anderlecht were part of AZ's European campaign in the UEFA Conference league. The first match against Lazio was the return leg in the last 16. The first leg was played in Rome and was won 1-2 in favour of AZ (Transfermarkt, 2023). The match was played on Thursday at 21:00 on March 16th 2023. This day was dry, with 13.1°C as the maximum temperature (KNMI, 2023). The quarter-final was against RSC Anderlecht in this competition. Again, this game was the return fixture. However, this time, the first leg in Brussels was lost 2-0. In Alkmaar, the event kicked off at 18:45 on Thursday, 20th of April 2023 (Transfermarkt, 2023) On this day, there was a maximum temperature of 17.1°C without rain (KNMI, 2023). This information, accompanied by the total amount of tickets sold for these games, is shown in Table 3.1.

Table 3.1: Ticket sale information five events AFAS AZ Stadium

	Ajax	**Feyenoord**	**Heerenveen**	**Lazio**	**Anderlecht**
League	Eredivisie	Eredivisie	Eredivisie	Conference League	Conference League
Date	18-09-2022	16-10-2022	01-04-2023	16-03-2023	27-04-2023
Day	Sunday	Sunday	Saturday	Thursday	Thursday
Time	16:45	16:45	16:30	21:00	18:45
Attendance	18,772	17,039	17,200	18,500	19,500
Away fans	753	730	465	417	980
Home fans	18,019	16,309	16,735	18,083	18,520

In Figure 3.7, the ticket sales per match are set off against the distance. Based on this figure, it can be seen that there is little difference between the games. The median distance of the games is 7.0, 7.0, 7.0, 8.0 and 7.0 kilometres respectively. At the same time, the mean is 12.3, 12.1, 11.5, 13.1 and 11.8 kilometres. The standard deviance is 15.6, 15.1, 13.9, 16.8 and 13.7 kilometres per game. The notable difference between the mean and median for Ajax suggests that the distribution of distances is likely skewed to the right. Therefore, the centroid of the distribution in the distance is higher than the median. This, thus, implies that distance distribution does not comply with a normal distribution. To check whether it can be concluded that there is no statistical difference between the boxplots, a ONE-WAY ANOVA test is done (Appendix A). The null hypothesis is accepted based on the F-statistic (0.974), which is lower than the critical value (2.221).

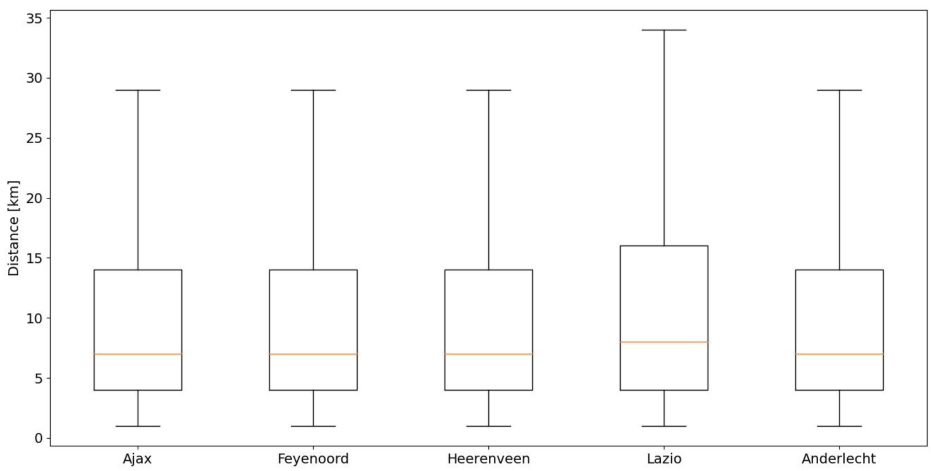

Figure 3.7: Boxplots of travelled distance by visitors of the AFAS AZ Stadium per match

The distribution derived from the average travel distance is discussed afterwards. It can be seen that the average of supporters lies somewhat below 5 kilometres. The smaller steps within the figure indicate the number of supporters travelling towards the stadium decreases per distance value. In this figure, a large jump can be seen at a five-kilometre distance. Connecting the zip code data to the spatial distribution indicates this is mainly because of three neighbourhoods in Alkmaar (De Mare, De Horn and Vronemeer). Another interesting increase in percentage is traced back to Heerhugowaard and Langedijk. Looking further, two smaller jumps stand out at 12 and 19 kilometres. The first is because of Warmenhuizen/Tuitjenhorn in the north and Krommenie in the south. Whereas the 19-kilometre increase is because of Schagen and Winkel.

3.2.2. Arrival times

Also, arrival time data is obtained from AZ. From the tourniquets, the number of entrances over time is obtained. With this information, a distinction can be made between the four stands at the stadium. A downside of this data is that the queues in front of the entrances are not considered. Therefore, this cannot be seen as representative of the actual arrival time. However, with this data, some information regarding the arrival time on a certain interval can be obtained and estimated. The data is extracted based on the five games mentioned before. Within Table 3.2, the average arrival time is shown. The average arrival time and the average per stand in minutes are displayed together. Comparing tables Table 3.1 and Table 3.2 shows differences in sample sizes. Of the 18,019 visitors at the match against Ajax, only 6,178 entrances were measured regarding arrival time. This difference is explained since only season ticket holders are considered. Moreover, does this concern the business to client tickets. Therefore, the sample set at the main (Victorie) stand is the smallest since this stand has more business-to-business tickets. Based on this data, it can be seen there is a large difference between the average arrival times and the matches. Against Lazio, half of the supporters entered the stadium 51 minutes before kick-off, while this was only 23,5 minutes against Heerenveen. Supporters on the Ben-Side were the first ones to be at the stadium, especially against Lazio, when they were present 57 minutes before kick-off. On the other stand, the arrival time, on average, lies closer. Based on this data, a ONEWAY ANOVA test is done as presented in Appendix A. Based on this test, there is no significant difference in arrival times for these five matches.

Table 3.2: Average arrival time before kick-off at the AFAS AZ Stadium [minutes:seconds]

	Ajax	**Feyenoord**	**Heerenveen**	**Lazio**	**Anderlecht**
Average	40:00	35:09	23:32	51:02	37:47
Sample size	6,178	6,894	5,323	6,841	6,271
Molenaar stand	37:33	33:58	22:42	48:01	37:00
Sample size	2,980	3,348	2,513	3,141	2,930
Ben-Side	44:40	37:37	25:10	56:50	40:40
Sample size	2,077	2,346	1,830	2,514	2,283
Victorie stand	39:01	35:19	21:59	49:39	34:47
Sample size	484	525	441	565	484
Alkmaarderhout stand	37:00	32:19	23:11	46:00	32:46
Sample size	637	675	539	621	574

With the distribution of arrival times, the percentage of visitors eligible to enter the stadium is elaborated. Corresponding to Table 3.2, the arrival time before kick-off against Lazio was earliest compared to the other matches. The arrival time distribution between Ajax, Feyenoord and Anderlecht is somewhat comparable. The pattern of arrival times is similar for all competitions. First, there is a slow increase in visitors over time. Once the capacity of the turnstiles and searches has been reached, a linear line follows in terms of arrival time. The steepness of this line shows the number of supporters who have entered and, thus, the capacity of the entrances. The figure shows a higher capacity at the turnstiles at the match versus Heerenveen than against Lazio. The safety profile of the match can explain this. Since the game against Lazio is a European match, stricter controls will be at the entrances. More rigorous control takes place by searching for more supporters at the turnstiles. As a result, it is not the gates that determine the traffic flow but rather the search for supporters.

3.2.3. Modal preferences

Different data sources form the basis for indicating visitors' modal preferences at the AFAS AZ Stadium. A first indication is obtained from the supporter's survey of the KNVB (KNVB Expertise, 2023). Five key modes are derived: car, bicycle, public transport, walking and moped. Distributing these modes over the sample size ($n = 470$), a modal split of 51.6%, 37.8%, 5.6%, 2.6% and 1.1% is found, respectively. Besides regular football-related events, the venue is also home to the Oranjekoningsdag festival on Kinsday, which houses 5.000 visitors. This multiday festival is held on the 26th and 27th of April at the P8 and P9 parking facilities. Within the mobility plan, the modal split of the festival is estimated. Compared to football-related events, small portions of the visitors come by car (13%) and bicycle (18%), which is significantly lower than for football matches. However, the share of public transport users is significantly higher (62%), including touring cars, taxis and regular public transport. Between Alkmaar station and the venue site, five to ten shuttle shuttle services are in operation (Brink Verkeer, 2022).

Car traffic

As presented in Figure 3.4, the pressure on the surrounding area during events increases. From the data, it can be seen that there is a total of 3,055 parking spots available in the area. On average weekdays, these parking lots are occupied by 1,727 vehicles, while this total is 2,608 on event days. Which shows an increase of 880 vehicles within this urbanised area. On the stadium site of AZ, a total of 2,857 vehicles can be stalled. However, the occupancy is not full since there are only 2,223 vehicles parked on average. Adding the surplus of the two sites, 3,103 vehicles come to the AFAS AZ Stadium on average during an event. By taking the average occupancy in a car as 2,9 (KNVB Expertise, 2023), the total number of supporters who come by car is approximately 8,850. The average attendance during the study period was 16,578 spectators, which shows that approximately 53,3% come to the AFAS AZ Stadium by car.

To validate the obtained modal share, NDW flow data is derived together with TomTomMove data. NDW data provides speed and flow data subdivided by vehicle category and lane (NDW, 2023). In Figure 3.9, the flow per five minutes on the A9 (milage 68.7 right) of the matches against Ajax and Feyenoord are shown. These events started at 16:45 (indicated by a red vertical line) on a Sunday afternoon. Ranging between 2:30 and 2:00 before kick-off, the inflow of traffic starts, and a surplus of flow becomes visible. This results in a peak between 60 and 45 minutes before kick-off. Besides the inflow, the average base flow from every Sunday during the 2022-2023 season is displayed. Excluded are the Sundays when an event is held at the AFAS AZ Stadium. The base flow is subtracted from the flow during an event to see the surplus in traffic and, thus, the amount of event traffic. The deduction of the base flow is done from 2.5 hours before the start of the event. This leads to 1,506 and 1.589 vehicles coming to Ajax and Feyenoord, respectively.

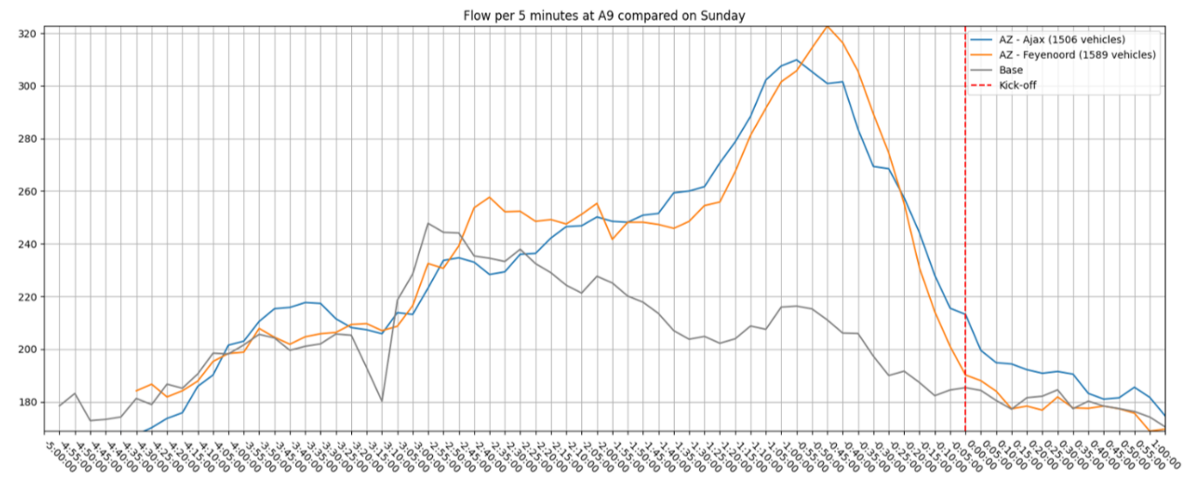

Figure 3.8: Traffic flow data at A9 prior to AZ versus Ajax and Feyenoord (NDW, 2023)

After obtaining the amount of vehicles at the A9, the total origin and destination table can be derived. Anonymous consumer-driven GPS-based measurements collect this data. These signals are derived from anonymous TomTom-connected car in-dash navigation systems, portable navigation devices and anonymous GPS-equipped mobile phones (TomTom Move, 2023). To derive the O-D data, three separate locations are estimated: Stadionweg (Ring road around the stadium), Vondelstraat (to park in the residential area Overdie) and Parelweg (access to P8/P9). The Stadionweg first shows 300 trips for the Ajax match and 270 against Feyenoord. From these trips, 40% comes from the A9 to the stadium site. Completed by 20% of the N9 and 30% of the N242. The last ten per cent have their origin elsewhere. On the Parelweg to get to P8 and P9, a total of 220 and 160 trips are analysed against Ajax and Feyenoord, respectively. This leads to a similar percentage of 40% coming from the A9. Additionally, a total of 25% comes from the N242 and 10% from the N9. Complemented by 5% from Heiloo via the Olivijnstraat. The last link at the Vondelstraat shows 590 and 530 trips respectively. It has to be noted this also concerns regular traffic, which is not part of the trips to the AFAS AZ Stadium. Of this link, 65% comes from the A9. With 15% coming from the N9 and 10% from the N242.

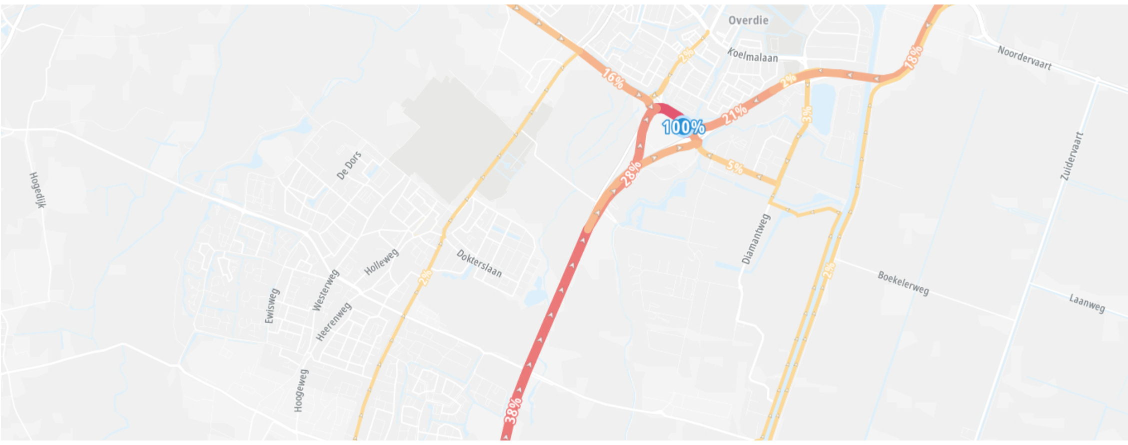

Figure 3.9: Origin data for events versus Ajax and Feyenoord (TomTom Move, 2023)

Combining the flow data with the origin data provides insight into how many vehicles travel to the AFAS AZ Stadium. Approximately 1,550 vehicles travel to the venue via the A9. The origin data shows that this is 40% of the traffic which travels to the stadium. With an uncertainty of 10%, this shows that between 3,480 and 3,880 vehicles travel to the event. Comparing this with the parking data, a difference exists of 80 - to 90%. One reason for this difference can be related to the away visitors who are part of the origin data but not the parking data. Therefore, the conclusion can be drawn that the modal preference for cars lies between 55%

Cyclists

Five locations have been appointed to understand the spread of cyclists in the area. These locations are shown in Figure 3.10. The total of cyclists approaching the stadium is expected to pass location 1. The sum of the three main routes 2, 3 and 4. The last location shows how many cyclists drive against traffic and come from the centre of Alkmaar. Installation of these tubes is done at a 30-degree angle, ensuring the cyclists who cycle next to each other are counted.

Measurements are done for three home matches in October against Heerenveen (Saturday 21st at 21:00), Aston Villa (Thursday 26th at 21:00) and NEC (Sunday 29th at 16:45). These matches are played for the Eredivisie (twice) and the UEFA Conference League. The data for cyclists is collected per minute. The ingress is measured from 1.5 hours from kick-off until the event begins. Egress is measured from 90 minutes past kick-off time until two hours later. The overall cyclists count for the ingress and egress are shown in Table 3.3. This data indicates that approximately 2,200 cyclists who attended the stadium during Eredivisie matches and 2,625 at the European game against Aston Villa have been measured. At location one, the ingress is significantly higher than the egress. This can be related to the way cyclists exit the stadium. Due to the crowdedness within the active mode tunnel, many cyclists walk with their bicycles in hand or on the sidewalk. This can cause missed counts and measurements. The second location is the largest in terms of flow beside the tunnel. At this point, the cyclists from Alkmaar Centre and Heiloo come together. Comparing the inflow differences between locations 2 and 5, an average of 200 cyclists travelling to the AFAS AZ Stadium from Heiloo or Alkmaar West can be distinguished. Taking the fifth location, it can be seen that between 1,370 and 1,800 cyclists cycling against traffic are measured. For location 3, the match against Aston Villa stands out for the ingress. The counted value of 170 cyclists is significantly higher than the 44 and 64 of the other matches. This value can be traced back to the commuters who use this cycling path during the measurement period. Comparing the locations per inflow and outflow, it can also be seen that there are large differences at every location. Except for the third location, which has a higher egress than ingress. Reasoning for this can be found since there is a nearby food market that contains large fast food chains like McDonald's and Kentucky Fried Chicken.

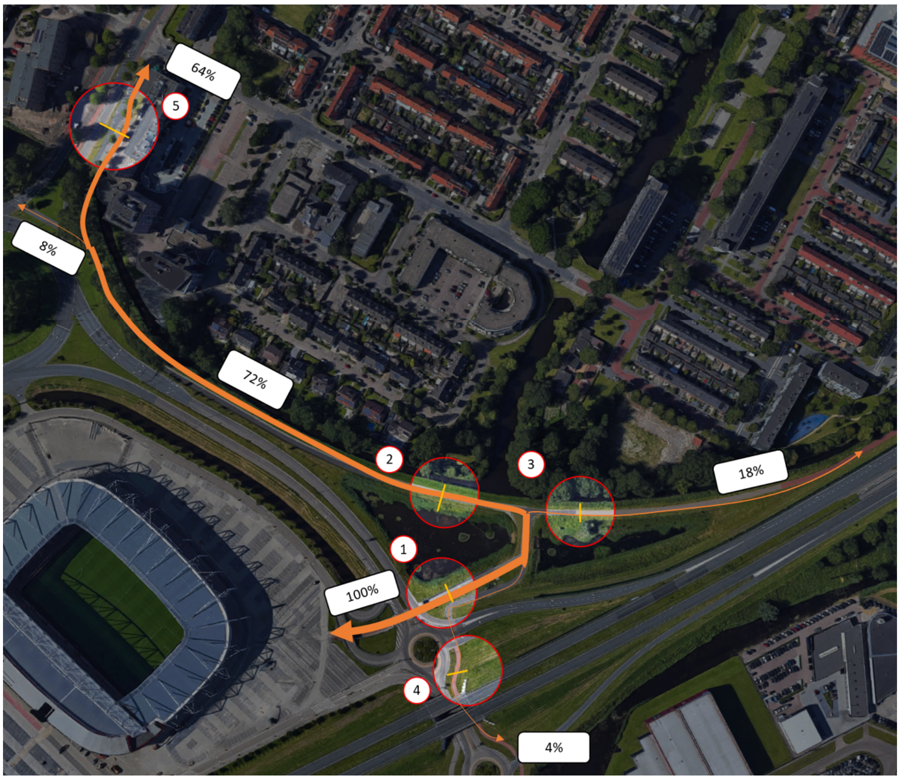

Figure 3.10: Locations of pneumatic tubes for revealed preference cyclist measurements

Table 3.3: Cyclist counting data

	Ingress			Egress		
	Heerenveen	**Aston Villa**	**NEC**	**Heerenveen**	**Aston Villa**	**NEC**
Location 1	2,157	2,625	2,256	1,179	1,581	1,673
Location 2	1,569	1,993	1,701	1,090	1,365	1,429
Location 3	360	543	445	474	655	565
Location 4	44	168	64	24	34	34
Location 5	1,374	1,792	1,521	929	1,266	1,253

Another reason for the difference between ingress and egress can be found in Figure 3.11. Within this figure, it can be seen that there are differences in patterns. The inflow starts building up fairly steadily before the event, from 90 to 40 minutes before kick-off. Afterwards, a somewhat continuous flow decreases 20-15 minutes before the event starts. A dramatic start can be seen for the outflow, which increases linearly and is similar to the three assessed events. This linear inflow takes approximately 15 minutes and shows the tunnel bottleneck. Since most supporters leave simultaneously, a large peak is expected. However, the slope of the egress line shows the tunnel's capacity. Over time, it can be seen that the outflow is becoming more constant when time increases. This tells that some supporters attend the supporters' cafes or the lounges at the stadium.

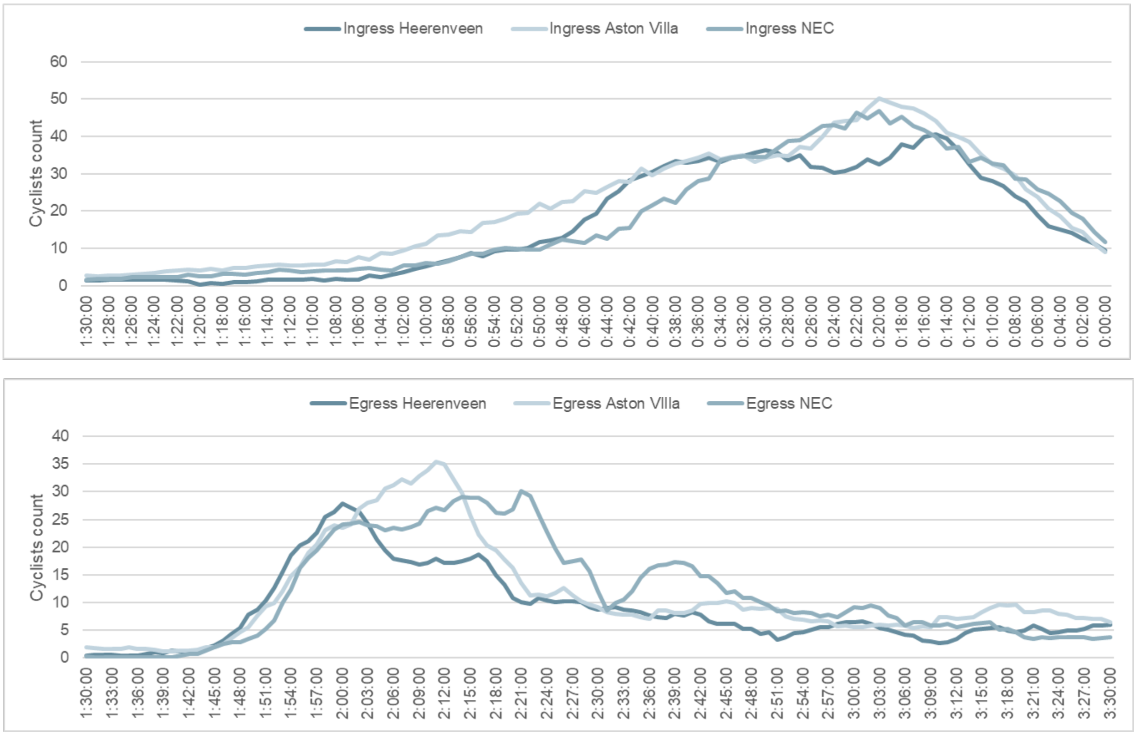

Figure 3.11: Ingress and Egress flow and time at pneumatic tube location 2

For these three matches, the attendance rate was 17,421, 16,633 and 18,773, respectively. When looking at the inflow of cyclists at the tunnel during inflow, an indication about the modal share can be given. For these matches, this modal share was 2,157, 2,625 and 2,256 respectively. When comparing this with the attendance rate, this leads to a share between 12 and 15 % of cyclists who visit the AFAS AZ Stadium by bicycle.

Pedestrians

Determination of the flow of pedestrians who visit the AFAS AZ Stadium via the Smaragdweg can be done in two ways. At first, the parking data (Figure 3.4), in combination with the average occupancy per vehicle, provides some insight into the modal share. Besides this information, measurements are done to measure the number of pedestrians going to the event. The parking data at first shows that 880 vehicles park within the residential area. Based on an average car occupancy (2.7), the number of pedestrians is 2,376. Adding this to the supporters who claim to come by foot (2.6%), approximately 3,000 supporters are expected to use the active mode tunnel.

In total, three zones are set up for the pedestrian sensor measurement. The first zone is the active mode tunnel. Followed by the sidewalk towards Alkmaar Centre and Heiloo as the second zone. At last, a zone is set together at the cycle path towards Heerhugowaard. Within these zones, radio transmitters are installed. Measurements were taken on the 26th and 30th of November for matches against FC Volendam and Zrinjski Mostar, respectively. The match on the 26th was an Eredivisie match played at 14:30. It could be seen that the crowd started arriving at the stadium at around 13:00, with the peak just 20 minutes before kick-off. The egress peak was found to be around 16:40. The second match was a group stage game for the UEFA Conference league, which took place at 18:45. For this event, the crowd started arriving at the stadium at around 17:30, with the peak around 15 minutes before kick-off. The egress peak was found to be around 20:50.

From the data analysis, it can be seen that, on average, people started arriving at the stadium about 90 minutes before the start of the match and continued to arrive for about 15 minutes after the match. Once the game has ended, people leave within 5-8 minutes. The egress period usually lasts about 45 minutes. Based on these two match days, during the ingress period, 80% of the crowd enters the active mode tunnel, comes from Alkmaar centre, and the rest (20%) arrives from the Heerhugowaard direction. In Figure 3.12, the graph for the ingress and egress for the event on the 30th of November 2023 is shown. The difference in inflow and outflow in terms of crowding can be obtained from the images. Moreover, with the constant egress flow, the capacity of the active mode tunnel can be obtained at about 200 movements per minute. Approximately 5,000 people are measured during the inflow on the 30th of November. Since this also includes cyclists, this number (2,500 from Table 3.3) must be extracted. This leads to approximately 2,500 pedestrians, of which (880 (Figure 3.4) × 2.7) 2,376 are parked in the residential area Overdie. This led to approximately 150 pedestrians attending the event. Calculating the ratio based on an attendance of 16,500 supporters leads to 0.8% of the supporters who walk to the venue.

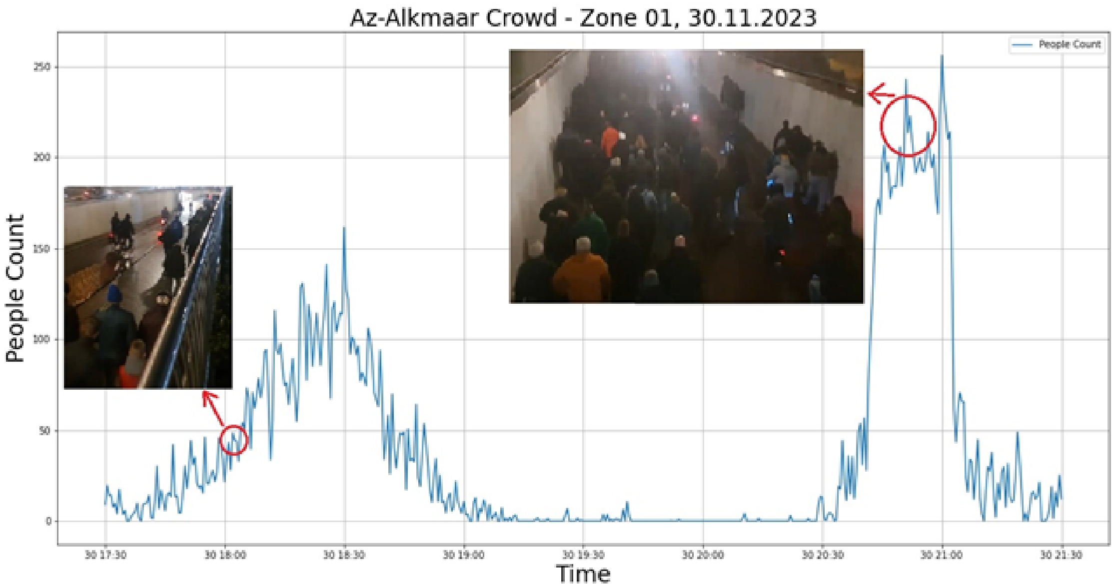

Figure 3.12: Ingress and Egress flow of pedestrians within active mode tunnel

3.3. Accessibility interventions

In this section, accessibility measures similar to those implemented by organisers of PSEs to mitigate accessibility disturbances are indicated. This is done within the first section of this chapter. Afterwards, the measures that apply to the AFAS AZ Stadium case were elaborated upon. This results in a list of measures to resolve the bottlenecks, as indicated in Table 1.1, at the AFAZ AZ Stadium.

3.3.1. General accessibility improvements

To determine general accessibility improvements, interviews have been held with different event organisers within The Netherlands. Fourteen football clubs have been interviewed to determine their mobility strategies. The interviews have been conducted with football clubs that own stadiums with a minimum capacity of 10,000 spectators. Within these interviews, topics are discussed, including their accessibility measures per mode and the arrival time patterns of supporters. Besides the interviews, the KNVB Supporters survey is used to gain insight into the supporter's accessibility assessment. These interviews are elaborated in Appendix B. This appendix shows the interviews and data from the KNVB (KNVB Expertise, 2023). These two research methods result in a list of mobility strategy measures. Within these interviews, the most frequent measures to increase accessibility are shown in Table 3.4. From this table, it can be seen that fan zones are applied for ten event organising entities. Whereas usage of traffic controllers is mentioned five times.

Table 3.4: Most frequently mentioned mobility strategies

Mobility strategy	Frequency
Fan zones	10
Traffic controllers	5
Transit operator agreements	5
Supporter buses	5
Event public transport	5
Happy hour	4
Secured bicycle stalling	4
Shuttle buses	4

Based on the modal split together with the score that accessibility has been given to the football clubs, effective measures are derived. Five main focus aspects of accessibility are derived from the analysis in Appendix B. The first aspect focuses on the overall accessibility. Strategies contributing to this specific aspect are an (online) application and increasing the turnstile capacity. To increase accessibility for car traffic, four effective measures are obtained: carpooling, folding signs, and conflict minimisation. Other indicated aspects focus on public transport, bicycles, and arrival time.

Table 3.5: Effective measures to increase accessibility

Aspect	Mobility strategy
Overall	- (Online) Application - Increased turnstile capacity
Car	- Carpooling - Folding signs - LED Signs - Conflict minimisation
Public transport	- Supporter buses - Transit operator agreements - Increased bus stops - Matchday timetables
Bicycle	- Secured bicycle stalling - Flexible bicycle sheds - Park + Bike
Arrival time	- On-field entertainment - Free seating areas - Beverages discount - Fan zones - Opening boardwalks

3.3.2. Accessibility improvements at AFAS AZ Stadium

This section proposes different solutions to improve accessibility around the AFAS AZ Stadium. These solutions are clustered in two main focus areas: infrastructural and service-related. Infrastructural-related solutions focus on changes which can be made to the spatial environment. An important aspect of this is that construction is involved in realising these solutions. Service-related solutions do not focus on any physical structures to improve accessibility. With these solutions, the focus is on the active help of AZ or the Municipality to help visitors reach the stadium. In Figure 3.13, the measures for improved accessibility are indicated. Within this figure, a distinction is made per mode of transport. Whenever a measure overlaps, it influences multiple transportation modes. A more detailed elaboration of the different measures is provided in Appendix C.

The proposed accessibility interventions influence the accessibility for some of the mentioned bottlenecks. As shown in Figure 3.13, the bottlenecks (Table 1.1) can be solved by different measures. Some bottlenecks can only be solved by taking specific actions per modality (e.g. improper use of exit ramp A9), whereas some can be solved by a modal shift (e.g. traffic congestion). The first mentioned bottleneck (Traffic congestion at the main arterials) can be solved by taking car-related measures such as putting up traffic signs. The lack of connectivity of the venue to Alkmaar station can be improved by implementing combi tickets. Table 3.6 shows the bottlenecks solved by the proposed accessibility measures. The measures related to public transport cover the traffic congestion and connectivity to Alkmaar train station during the inflow of the event. With combi tickets, a discount is provided for supporters to travel by public transport when they possess a valid entrance ticket to the venue. By increasing the frequency of transit within the public transport timetables, the connectivity to Alkmaar train station is also increased. Since more supporters are expected to use public transport, the traffic congestion at the main arterials is reduced. Supporters busses will pick up supporters from popular residential centres. This causes more supporters to travel with a shared vehicle instead of using it. A similar reasoning is valid for the implementation of carpooling. Another advantage of carpooling is that fewer vehicles are parked in residential areas. Redistribution of parking with park + bike or ticketing + parking measures solves traffic congestion and parking bottlenecks.

The application until turnstiles interventions tend to distribute the arrival time of supporters. By doing so, the pres-

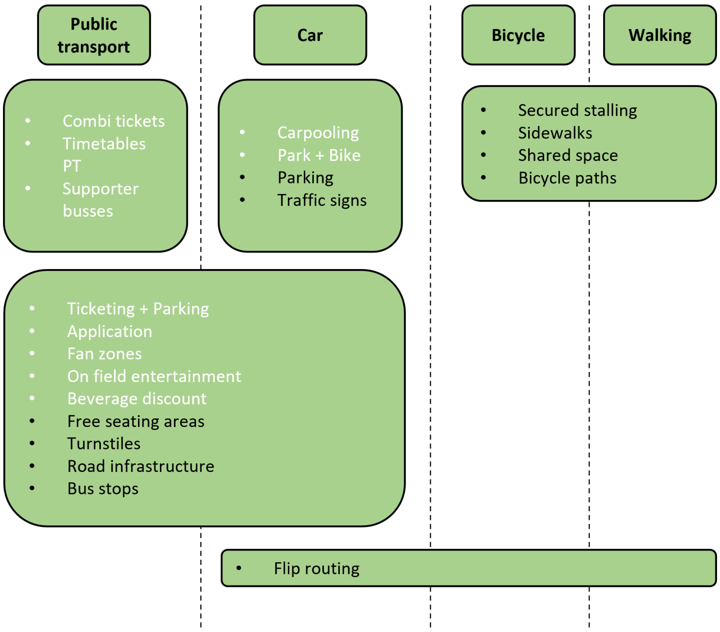

Figure 3.13: Interventions to improve accessibility at the AFAS AZ Stadium

Table 3.6: Accessibility interventions in relation to the arrival bottlenecks

	Traffic congestion at the main arterials	Parking of cars within residential area	Bicycle stalling before tunnel	Connectivity to Alkmaar train station	Improper use of exit ramp at A9
Combi tickets	✓			✓	
Timetables PT	✓			✓	
Supporters busses	✓				
Carpooling	✓	✓			
Park + Bike	✓	✓			
Ticketing + Parking	✓	✓			
Application	✓				
Fan zones	✓				
On field entertainment	✓				
Beverage discount	✓				
Free seating areas	✓				
Turnstiles	✓				
Bicycle paths			✓		
Secured stalling			✓		
Sidewalks			✓		
Shared space			✓		
Parking		✓			
Road infrastructure	✓				✓
Bus stops	✓			✓	
Traffic signs	✓				✓

sure on the infrastructure is spread more over time, reducing traffic congestion. While the aim of the interventions is similar, the implementation is very different. An application on their mobile phone can be introduced to nudge supporters to come earlier to the stadium and with a certain mode. Another measure is to create fan zones that offer a variety of entertainment before the main event. From the arrival time data, as shown in subsection 3.2.2, the supporters at the standing sections are earlier in the venue. From that perspective, adding the safe standing sections can offer solutions for traffic congestion. Accessibility interventions that can be implemented for active modes such as bicycles and pedestrians can be used as solutions for the discomfort experienced by bicycle stalls. With the bicycle path intervention, additional cycling routes are proposed. This way, the flow of cyclists will be more spread over the area instead of via only one active mode tunnel. A similar effect is obtained for the side-walks. However, this does not concern bicycles but pedestrians. Another intervention that provides a solution for another bottleneck is parking for cars. Creating more parking facilities at the Boeklermeer industrial area, fewer vehicles are expected to be parked within the residential area. Investing in the road infrastructure removes two bottlenecks (traffic congestion and exit ramp A9). These measures aim to create a permanent situation at the exit ramp of the away section on the Kooimeer junction. Making new bus stops around the venue will increase the stadium's connectivity to Alkmaar station. Also, since more supporters will use public transport, traffic congestion on the main arterials is reduced. Traffic signs at last also mitigate traffic congestion and improper usage of the A9 exit ramp. A more detailed explanation of these measures is shown in Appendix C.

Besides the bottlenecks for the inflow of supporters, four bottlenecks are mentioned for the outflow. To mitigate these bottlenecks, the accessibility interventions, as shown in Table 3.7, are derived. Besides contributing to the inflow, the supporters' buses also mitigate the early departure of supporters. Since these buses only depart after the event is finished, this will ensure supporters are present until the end of the event. Redistribution of ticketing in combination with parking causes the parking facilities to reduce egress time. Since conflicts for vehicles are reduced, the time it takes to get from the parking facilities is also reduced. Implementing fan zones, on-field entertainment, and beverage discounts can ensure supporters stay longer within the stadium. Therefore, any overcrowding at the active mode tunnel can be mitigated. Additionally, the supporters might have another incentive to stay until the end of the event instead of leaving the venue early. Investing in bicycle facilities and sidewalks will cause a geographical spread of supporters. This mitigates the disturbances at the active mode tunnel. Additionally, cyclists' improper use of the Smaragdweg roundabout is reduced since the pressure on the active mode tunnel is reduced. With the shared space within the active mode tunnel, the total throughput of supporters through the tunnel increases. Any overcrowding will be mitigated since the capacity of the tunnel is higher. Having additional parking or road infrastructure will decrease the egress time of the parking facilities. Since the amount of car-related conflicts is reduced, the outflow of vehicles will run smoother. This way it will take shorter to leave the parking facilities. Fewer supporters are likely to leave early since the outflow is quicker. The flipped routing intervention reduces the main conflict between the parking facility and the active modes. This way, room is created for cyclists to use the Smaragdweg roundabout; thus, the bottleneck for improper use is mitigated. Any overcrowding within the active mode tunnel is also mitigated by cyclists using this roundabout.

Table 3.7: Accessibility interventions in relation to the departure bottlenecks

	Overcrowding at active mode tunnel	Egress time of parking facilities	Early departure of supporters	Improper use of Smaragdweg roundabout
Supporters busses			✓	
Ticketing + Parking		✓		
Fan zones	✓		✓	
On field entertainment	✓		✓	
Beverage discount	✓		✓	
Bicycle paths	✓			✓
Sidewalks	✓			✓
Shared space	✓			✓
Parking		✓	✓	
Road infrastructure		✓	✓	
Flip routing	✓			✓

3.4. Conclusion

This chapter focuses on how the local stakeholders utilise the infrastructure during events at the AFAS AZ Stadium. First, the static surroundings of the 19,500 spectators' capacity venue are derived to gain understanding. The stadium is located between a national (A9), provincial (N242) and municipal road (Smaragdweg). In total, 2,857 parking lots are facilitated by the football club. Pedestrians and cyclists use a tunnel which crosses the Smaragdweg. The bicycle racks (2,250) are located between the tunnel and the stadium. Services which are offered to reach the stadium safely and efficiently are shuttle services and traffic controllers. There are three busses shuttle between Alkmaar station and the AFAS AZ Stadium. For vehicle guidance, a total of 25 traffic controllers are applied.

Utilisation of the infrastructure around the AFAS AZ Stadium is determined based on Figure 2.4. The analysis results are indicated within Figure 3.14. Starting with the trip generation, an average of 18,200 supporters attended the Eredivisie and UEFA Conference League matches. A ONE-WAY ANOVA test is performed to check whether there is a statistical difference within the trip distribution. Based on this test, the null hypothesis is accepted, which means there is no significant difference between the means. The time of day results show no significant difference in arrival time for these five events. Distribution of the arrival times shows similar trends; however, the time before kick-off changes between the events. The mode choice shows the mode shares from the KNVB Supporters survey as the collected data. From the table, there is a difference between the car users at first. The number of car users within the survey is lower than the lower bound in the data. The opposite is true for cyclists, who are over-represented in the survey. Car modal split is estimated through a study revealing 53.3% arriving by car, with 55-70% modal share. Half of these supporters come from Amsterdam/Haarlem via the A9, with the other 25% coming from the N242. For cyclists, measurements from selected matches show a 12-15% modal share. Of these visitors, almost 65% come from Alkmaar Centre and 10% from the direction of Heiloo. With approximately 20% arriving from direction Heerhugowaard. Pedestrian data obtained through radio wave sensors indicates that around 0.8% of supporters walk to the venue, with an average arrival time of 90 minutes before the match and a departure period lasting about 45 minutes after the game.

AFAS AZ Stadium infrastructure utilization

Trip generation / **Trip distribution** / **Time of day**

	Ajax	Feyenoord	Heerenveen	SS Lazio	RSC Anderlecht
Tickets sold	18,772	17,039	17,200	18,500	19,500
Average distance [km]	12.3	12.1	11.5	13.1	11.8
Standard deviance [km]	15.6	15.1	13.9	16.8	13.7
Arrival time [min:sec]	40:00	35:09	23:32	51:02	37:47

Mode choice

Mode share	KNVB Survey (KNVB Expertise, 2023a)	Revealed preference	
		Lower bound	Upper bound
Car	51.6%	55%	70%
Bicycle	37.8%	12%	15%
Public transport	5.6%	-	-
Walking	2.6%	0.8%	1.2%
Other	2.4%	-	-

Figure 3.14: Results of revealed preference data collection

To improve accessibility at the AFAS AZ Stadium, interviews are held with organisers of similar PSEs. From these interviews a generalised set of effective accessibility interventions is proposed. Five aspect groups for mobility strategies have been obtained. Two effective interventions are suggested to increase the overall accessibility (e.g., online application and increased turnstile capacity). Afterwards, specific interventions for cars, public transport, and bicycles are developed. Accessibility interventions for car traffic concern carpooling, folding, LED signs, and conflict minimisation. On the other hand, implementing supporter buses for supporters of different residential centres can provide solutions for public transport. Other public transport-related accessibility interventions relate to the number of bus stops and transit frequency. Also, having agreements between the PSE organiser and transit operator is an effective accessibility measure. For cyclists, the last three interventions are effective (e.g. secured or flexible bicycle stalls and park + bike). Another aspect of effective accessibility measures is the arrival time. By spreading the times that supporters arrive at the venue, the overall demand for the infrastructure is reduced. Five measures have been obtained: on-field entertainment, free seating areas, beverage discounts, fan zones and the opening of boardwalks. Additional accessibility interventions are derived besides the effective accessibility interventions used by similar PSE organisers. These interventions focus on geographically spreading the inflow and outflow of supporters. In the form of more bicycle-, pedestrian and car links towards the venue.

4
Mode choice attributes

Following the objective, this research examines mode choice using a discrete choice model incorporating determinants. More explicitly, this chapter aims to gain insight into factors that are known to influence mode choice. Following previous studies from De Witte et al. (2013), these categories can be divided into spatial, socio-demographic, socio-psychological and journey factors. This is shown in Figure 4.1. The spatial characteristics focus on the outside environment (Wang et al., 2016). While the journey characteristics encompass the modal route towards the PSE (De Witte et al., 2013). Musgrave et al. (2019) indicates that the socio-psychological encompasses how individuals perceive themselves and others. The socio-demographics factors refer to characteristics that collectively describe and categorise individuals (Ergin & Tezcan, 2022). The modes often assessed are cars, transit and walk/bike (Cummings et al., 2022; Di Martino et al., 2019; Kuppam et al., 2013; Kwoczek et al., 2014; Zheng et al., 2023).

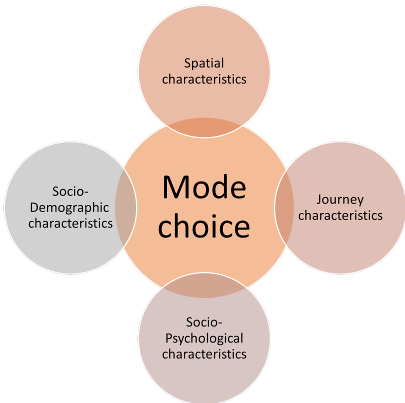

Figure 4.1: Mode choice attribute groups

4.1. Spatial characteristics

The spatial characteristics focus on the outside environment. Newman and Falcous (2012) provided various themes for research concerning sports competitions and attached mobility. By researching this field, insight can be obtained into the impact of time-space compressions on movement's spatial and temporal aspects. This study obtained two key groups that categorise the spatial characteristics. In Figure 4.2, these two groups (Event and Accessibility) are shown. Within this section, an elaboration of the mode choice factors within each group is given.

4.1.1. Event

Talaat and Rashwan (2018) has developed success factors for special event management. These factors are based on a well-known national event in Vietnam. ***Attraction*** to attend different kinds of events is based on the

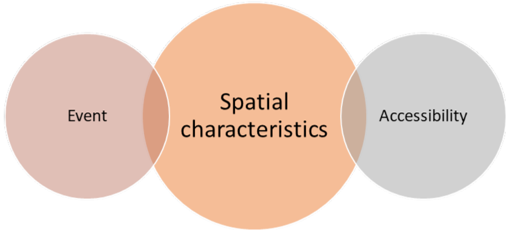

Figure 4.2: Mode choice attribute group: Spatial characteristics

uniqueness of the theme, quality of performance, diversification in activities and promotion. Media coverage and (inter-)national interests are also found by Talaat and Rashwan (2018) as factors contributing to the success of PSEs. Since this coverage only adapts to people at home, this is no factor for mode choice. Due to improper planning, the special events can lead to disruptive effects on our transportation infrastructure. Since the existing infrastructure and services are not equipped to handle extreme situations (Ergin & Tezcan, 2021; Kuppam et al., 2013; Kwoczek et al., 2014). To plan PSEs, Ergin and Tezcan (2021) and Kuppam et al. (2013) have proposed travel demand models based on the 4-step model and PSEs. In this model, the *size of the event* is a key factor in mode choice within trip generation (Kuppam et al., 2013). He states that the additional load on the road network cannot exceed the total capacity of the *venue type*. Therefore, this factor is also used within decision-making for mode choice. Within the literature, a variety of PSEs over the world has been reviewed from large *multi-/single day events* (Cummings et al., 2022; Ergin & Tezcan, 2022). For these events, the size of the event, the trips generated, and the modal decisions made by these events differ largely. For the venue type (single venue is researched) and single/multiple days (the sporting events only last for a period in a day), the used case study only focuses on one specific attribute. Therefore, these factors will not be researched in this study.

Proximity to an event which is discussed as the distance between one's origin and the event location plays a vital role within mode choice (Kuppam et al., 2013). It has also been found by Kuppam et al. (2013) that there is a difference in mode choice for the *event type* (sports, music, or other). Since this study only focuses on football-related events at the AFAS AZ Stadium, the type will not be considered for this research. Additionally, related to the market area of an event, visitors to PSEs make different mode choice decisions (Ergin & Tezcan, 2021; Kuppam et al., 2013). For the assignment step in the 4-step model, Kuppam et al. (2013) uses transit assignments to assign travellers to the transport network. Significant findings from this study are that accessibility is a crucial factor for *local-/regional events*, whereas, for national and multi-regional events, people are willing to tolerate lower levels of accessibility (Kuppam et al., 2013). The local/regional factor is also not considered because of the non-changing market area of the researched event. Comparing *professional with amateur events*, professional sporting events tend to attract home-based attendees from a wider geographical area (Kuppam et al., 2013). The Pro/Amateur event factor is also not considered since the study only focuses on events for professional football.

4.1.2. Accessibility

Before the start of an event, Skolnik et al. (2008) states that a general feasibility study is necessary. In this study, a traffic forecast should be made together with the impacted market area, parking demand, travel demand and roadway capacity. With this information, he claims that traffic agencies should take *measures* to mitigate the disruptive impacts of PSEs. Such arrangements can be to increase *parking availability* (Skolnik et al., 2008). In Cummings et al. (2022), multimodal simulation techniques are proposed into, around and from the venue. The analysis shows that assigned parking performs best since it reduces congestion significantly (Cummings et al., 2022). From the results of Cummings et al. (2022), it can be found that parking is a key influence on the mode choice and, thus, the performance of a PSE. Planning optimisation of these parking facilities has been studied by Zheng et al. (2023) for a case study in China. This study considers mainly the number of conflict points between vehicles and pedestrians. However, drivers naturally want to park their cars as close as possible to the venue, which increases the number of conflict points with pedestrians (Zheng et al., 2023). Other measures focus on the transit services and traffic management (Skolnik et al., 2008).

The way visitors experience their way to the PSE is formulated by Shahin et al. (2014) as *Convenience*. He stated that this factor greatly depends on how people travel and make modal decisions. Convenience in this context focuses on the ease and comfort of using one mode. Building on this, the ***comfort*** is another factor within mode choice. Shahin et al. (2014) stated that this comfort has two main components, physical and psychological. The physical part focuses on the infrastructure and effort needed when choosing a specific mode. In comparison, the psychological part leans towards mental boundaries to choose for any mode. Comfort and convenience are two very similar factors, and since convenience focuses on the perceived ease of accessing a PSE, this is neglected. *Safety* on the other hand, is also seen as an important factor within mode choice (Li et al., 2020; Shahin et al., 2014). When one does not feel safe travelling with a mode, the chances are lower that one will choose this mode.

Dalvi and Martin (1976) stated that accessibility is the *ease* of reaching an area of activity using a specific transport system. The way visitors to PSEs thus make their mode choice decisions greatly depends on the ease of using a transport system. With this definition of accessibility, three classifications for accessibility indicators have been derived by Bocarejo S. and Oviedo H. (2012) and Van Wee et al. (2001); Infrastructure-, Activities/land use- and People-based indicators. Infrastructure-based indicators examine the attributes of *infrastructural network* concerning its capacity and service level. This means it investigates the excellence of transportation amenities by analysing metrics such as road congestion levels and average travel speed. Such indicators evaluate the extent, *road density*, and *connectivity* infrastructure by considering factors such as length, density, and traffic volume during peak hours. However, by assessment of these accessibility indicators, the perspectives and capabilities of people are not taken into account. Since people are considered passive and the accessibility is only defined by how easily they can reach a destination (Curl, 2018). Road density is not mentioned since this will lead to unreliability in the results. Around the researched venue, however, there is a high density of roads without connections to the PSE location. Jamei et al. (2022) has stated that these conventional "objective" accessibility measurements have two main limitations. At first, these accessibility indicators assume that access is homogeneous among people. It thus neglects people's influence to overcome social, economic, and environmental barriers. Secondly, the conventional accessibility indicators fail to capture people's real experiences and preferences (Pot et al., 2021). By addressing the accessibility in comparison to people's behaviour, the quality of a location can be assessed more accurately (Morris et al., 1979). This relation between behaviour and accessibility is called perceived accessibility and has emerged as a heuristic for reflection, measurement and evaluation of accessibility opportunities for activities (Jamei et al., 2022; Pot et al., 2021). Pot et al. (2021) has proposed a model regarding the environment-behaviour relationship. This model focuses on the indicators derived by Van Wee et al. (2001), who showed a link between the environment and perceptions components (land-use, transport and temporal).

4.2. Journey characteristics

From an event management perspective, Fai (2019) studies the relationship between the sustainability of sports matches and (event) logistics. Sustainability in this study is defined by minimising the negative impacts of PSEs on stakeholders, organisers, society and the environment. They showed a statistically significant correlation between the sustainability of sports events and accessibility. Following the sustainability goals of the United Nations, accessibility for sports matches contributes to these goals (Fai, 2019; United Nations, 2015). Three groups have been derived to study the journey characteristics; Logistics, Natural and Event-related factors. An elaboration of the factors within the groups shown in Figure 4.3 is given in this section.

4.2.1. Logistics

The logistics discuss mode choice factors that play a role in the modal characteristics. These factors relate to often used variables such *travel time* (Ergin & Tezcan, 2021; Lin & Chen, 2017) and *travel cost* (Ergin & Tezcan, 2021; Lin & Chen, 2017; Shahin et al., 2014). Studies often use These two factors to demarcate the difference in making modal decisions. However, the *party size* by which people want to travel to a PSE is found by Musgrave et al. (2019) as an important factor. This factor jumps to mind since many people travel together to PSEs (Musgrave et al., 2019). This has also been found by Ergin and Tezcan (2022), who showed that most people (80%) attend PSEs together with someone else. By revealed preference data (i.e. video footage), it has been observed that there is an average car occupancy of 2.5 persons per car (Cummings et al., 2022).

The *distance* one travels to a PSE is formulated by Kuppam et al. (2013) as the origin from which one will travel towards the venue. The origins considered in this study are Home, Hotel or Work/Other related. Via origin choice models, the probability of origin type is formulated based on an MNL utility maximisation (Kuppam et al., 2013). Where Kuppam et al. (2013) used survey information to determine a demand-affected Origin-Destination matrix,

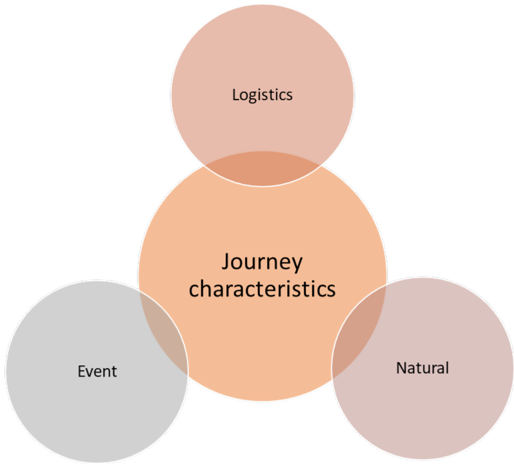

Figure 4.3: Mode choice attribute group: Journey characteristics

Kumar and Khani (2020) measured this matrix with revealed data. Due to the increase in demand, Kwoczek et al. (2014) showed that there is a direct correlation between PSEs and *congestion*. He indicated that there are two key waves in congestion. The first wave was caused by people who were going to the venue. The second wave is caused by people leaving after the main event. Since the congestion and, thus, delay differs amongst different modes, this also plays a role within mode choice. Closely related to congestion is the *queue waiting time* (Cummings et al., 2022). In this study, two different types of queues are introduced. The first kind of queue examined concerns the venue area's arrival rate. Visitors to the PSE travelling to the venue cause jams at bottlenecks. Whereas the second queue is occurring at the parking lots. At this location, visitors must find an available parking lot or have their tickets checked. At last, the queue for pedestrians at the gates is discussed (Cummings et al., 2022). However, the queue waiting time and congestion factors are not considered since extensive data collection has to be executed to obtain this information. This lies beyond the scope of this research.

For choosing shared modes such as public transport, the *punctuality* of these are of interest (Li et al., 2020; Shahin et al., 2014). Punctuality refers to the reliability towards predefined schedules, ensuring that vehicles consistently arrive and depart at the expected times. In the studies from Li et al. (2020), punctuality is measured from an experience point of view. The respondents in this study are asked how they feel about the punctuality of the public transport system in Xi'an, China. Within studies from Cummings et al. (2022), the *number of transfers* are also mentioned for mode choice. However, it will not be considered. For this factor, the passengers prefer options requiring fewer transfers as it reduces the likelihood of missed connections, minimises waiting times, and provides a more direct and convenient travel experience (Cummings et al., 2022). The number of transfers is not considered since the public transport facilities for the case study location are sub-optimal.

4.2.2. Natural

Factors which are often considered for *time-of-day* choices relate to *Weekend/Weekday* (Ergin & Tezcan, 2022), Time of day (Kuppam et al., 2013). Three time-dependent sections are mentioned when it comes to PSEs (e.g. pre-event, on-event and post-event) (Di Martino et al., 2019; Fai, 2019). The pre-event traffic relates to the set of streets utilised to reach the venue. While outbound traffic is the set of streets, people use to leave a venue (Di Martino et al., 2019). Ergin and Tezcan (2022) showed that fans arrive near the stadium 188 minutes before the start of the PSE. Also, he claims there is no significant difference between arrival time on weekdays and weekend days. However, Ergin and Tezcan (2021) found that average people attend the stadium 140 minutes before a game. It is also obtained that 120 minutes before an event only shows difference (Di Martino et al., 2019).

Kuppam et al. (2013) indicated that the *season* is also a factor within mode choice. Since there are changes within the *weather* conditions. The weather conditions can be aggregated and linked to the seasons. However, the weather conditions can also be investigated separately. In the study from Kuppam et al. (2013), PSEs studied are between September and May in the United States. The effect of the weather on mode choice is not considered in this study. This is because the weather factor exceeds the number of degrees of freedom of mode choice within this study.

4.2.3. Event

Besides the origin data, people also participate in pre-game *activity schedule* (Ergin & Tezcan, 2022). Ergin and Tezcan (2022) has studied the arrival time and location preferences of people who travel by car to these activities in Istanbul. The activity schedule is also not considered because the number of people participating in other activities before an event is minimal. The *purpose* to attend the PSE influences the activity schedule and, thus, the mode choice. Differences in purposes found by Talaat and Rashwan (2018) focus on the event, holiday, business and other reasons. Her study focuses on a multi-day event in Vietnam. From this study, it has been found that almost half of the visitors (48%) specifically come to the event because of the festival. An almost negligible amount (4%) of visitors come for business-related purposes. Other visitors attend the PSE for holiday purposes (Talaat & Rashwan, 2018). Since this study focuses on a multi-day festival held once a year, the results can differ from sports events. The *event frequency* within these events is significantly higher. In studies from Di Martino et al. (2019), PSEs cause non-recurrent congestion since their frequency is higher than once a week. However, there is a predictability for congestion since the activity schedule is predetermined. Event frequency is also not considered since there is a certain recurrence for the PSEs considered in this study.

The *predicted attendance* plays a huge role in the congestion and departure time window (Fernando, 2018; Kuppam et al., 2013). A higher demand for the infrastructure will be present for high-profile events with large crowds. Visitors change their mode choice and departure time window during events with high predicted attendance. The reasoning for this lies in the experience these visitors have regarding the congestion on event days (Fernando, 2018; Kuppam et al., 2013). Closely related to the predicted attendance and mode choice is the *start- and end time* of the PSE. Often used indicators to predict the congestion is 120 minutes before the event in a 5-minute interval. After the event, the outflow is measured for 60 minutes with a similar time interval (Di Martino et al., 2019).

It is believed that the decisions related to *departure time window* and mode of transportation have a direct impact on the distribution of event-generated demands over time (Lin & Chen, 2017). When looking at the model split following the for people who go to the venue directly, a modal split of public transport (71%), private vehicle (20%), private vehicle and public transport (5%) and walking (4%) is obtained (Ergin & Tezcan, 2021). The departure time is not considered decisive compared to the expected arrival time. Therefore the expected arrival time is a factor which is considered within mode choice. The four-step model is often called the 5-step model (de Dios Ortúzar & Willumsen, 2011). A time-of-day step is also considered in the model presented by Kuppam et al. (2013). This is mainly related to the *expected arrival time* since people who have paid for an event want to be at the location before an event has started.

Ticketing methods are discussed by Li et al. (2020) to also have an effect on mode choice. A distinction is made between tickets bought online and at the counter. He found that 80% of the tickets have been bought online for travelling by high-speed rail or airplane. It has been found that people have a significantly higher association with travelling to a location where the tickets can be bought easily (Li et al., 2020). Ticketing methods are not considered since there are no other alternatives to purchasing a ticket online in the case study. Another factor for mode choice is whether the visitors to PSEs are *visiting again* (Talaat & Rashwan, 2018). She found that when a venue is perceived as accessible and comfortable, visitors are more likely to return.

4.3. Socio-demographic characteristics

Socio-demographic factors, interchangeably referred to as socio-economic factors within the context of this study, hold a prominent position. This category of variables finds substantial presence in research focused on mode choice analysis. The decision-making process underlying mode choice is intimately intertwined with individual behaviours, which, in turn, exhibit a strong correlation with personal attributes and characteristics. Consequently, such an analytical approach offers valuable insights into diverse typologies of individuals, which wields considerable influence over the eventual determination of mode choice preferences. In Figure 4.4, two groups are shown by which the socio-demographics can be divided (Population and Attendance passport).

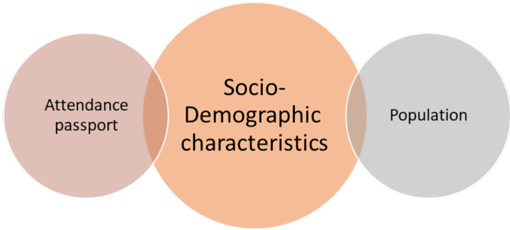

Figure 4.4: Mode choice attribute group: Socio-Demographic characteristics

4.3.1. Population

Different factors that describe behaviour on an aggregate level are used in focusing on the population. This starts with socio-economic (*age*, *income level*, *vehicle availability*, and *household size*) (Ergin & Tezcan, 2022; Kuppam et al., 2013) and private car ownership (Ergin & Tezcan, 2022; Shahin et al., 2014) indicators. Findings from the study of Shahin et al. (2014) show that people with a lower income are less likely to use a private vehicle to reach a specific venue. Moreover, the probability for visitors over 40 to reach a venue with a private vehicle is higher than for younger people. Usage also greatly depends on possessing a *licence*. Visitors with a driving license can travel by private car to PSEs (Jamei et al., 2022; Shahin et al., 2014). Jamei et al. (2022) also discussed that the *capabilities* of individuals with regards to using modes are of importance in mode choice. He argues that this is significant in the accessibility of PSE venues since the capabilities influence the relationship between people, land use and transportation. This study shows that older people have reduced capabilities to drive and are thus more easily triggered by public transport (Jamei et al., 2022).

Other variables introduced to the assessment of perceived accessibility concern *gender*. A connection between accessibility and transport choice has also been obtained by Scheepers et al. (2016). They researched the perceived accessibility of facilities (e.g. sports, etc.) in The Netherlands. Via surveys, the associations between walking, car and cycling are determined, taking conventional accessibility into account. Characteristics on a personal level which are covered are gender, age, *ethnicity*, *educational level*, household composition and physical activity. With regard to one's perception of their direct environment, focus on satisfaction, housing maintenance (e.g., distance between houses in my living environment is large enough, etc.), traffic safety, route availability, and parking facilities. This study concluded that if the perceived accessibility for cars is high, people are more likely to use a car. When perceived accessibility for public transport is high, people are more likely to walk or take a bike (Scheepers et al., 2016). Related to the educational level is the employment rate and income level. Within studies from Fai (2019), four kinds of employment groups are introduced; unemployed, employed, student and volunteer. Comparing this data with the income rates and usage of private vehicles and PT, it has been obtained that people who have a higher income are more likely to travel to PSEs by private car (Ergin & Tezcan, 2021; Jamei et al., 2022; Kuppam et al., 2013). This study's Factors for mode choice that are not covered focus on education, employment and income level. Since the organisers of PSEs do not use this information, this is not seen as a direct impact (Shahin et al., 2014). Moreover, ethnicity and capabilities are not considered. The household size, on the other hand, is also not measured since this does not directly influence the event organiser's business operations.

4.3.2. Attendance passport

Focusing on the attendance passport, different ticket sales characteristics are considered. An essential factor in this is the amount of people who attend the venue for the *first time* (Abkarian et al., 2022; Talaat & Rashwan, 2018). Search behaviour occurs since these visitors are less familiar with the environment and the surroundings. Therefore, these visitors take longer and are more vulnerable to cause congestion (Abkarian et al., 2022). Shahin et al. (2014) has shown a way to indicate this group of people by asking *the number of attended games*. With this information, the number of people who come to the venue for the first time can be made explicit. Closely related to the number of games is the number of visitors who possess a *season ticket* (Ergin & Tezcan, 2022; Musgrave et al., 2019). Since visitors to PSE who own a season ticket are familiar with the environment, they know the network's flaws. Therefore, their perception of attending an event is changing over time. It is deemed more difficult to reverse the modal decisions that season ticket holders make (Shahin et al., 2014). Next, the *ticket groups* available for purchase plays a role in mode choice. This is also closely related to the purpose of attending PSEs. Ergin and Tezcan (2021) has found that visitors who attend PSEs for business have a different arrival pattern than those who come for the main event.

4.4. Socio-psychological characteristics

Examining the impact exerted by psychological determinants upon individuals' selection of transportation modes can be categorised into two main groups (Figure 4.5). The first group (emotional) focuses on an individual perspective. Whereas the second group (interpersonal) focuses on the interaction between visitors of PSEs.

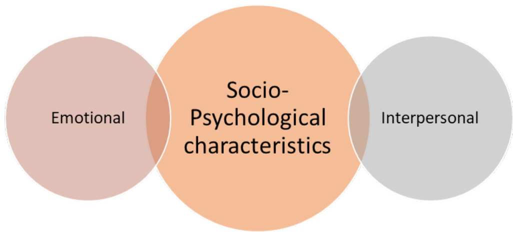

Figure 4.5: Mode choice attribute group: Socio-Psychological characteristics

4.4.1. Emotional

From an emotional point of view, the *habit* is seen as a significant variable for mode choice (Lättman et al., 2018). From this study, it has also been found that perceived accessibility significantly differs from conventional accessibility measures. This finding is also supported by other scholars in the field (Jamei et al., 2022; Pot et al., 2021; Scheepers et al., 2016). The way people who are visitors of PSEs are used to commuting plays a significant role in their mode choice. When considering modal alternatives, the option used often has a step forward compared to other alternatives (Lättman et al., 2018). Musgrave et al. (2019) and Newman and Falcous (2012) have also found that *lifestyle* plays a role within mode choice. Whenever one is committed to living a certain way, this is expressed within one's transport-related decisions, among other things (Musgrave et al., 2019). Lifestyle is not covered since this closely relates to habit. When one wants to live a certain way, one already lives up to this ideal (Newman & Falcous, 2012). This lifestyle and identity is then thus expressed in their behaviour Jamei et al. (2022), which is thus not covered in this research. Related to the lifestyle are individuals *beliefs* (Musgrave et al., 2019). He states that this factor affects modal choice from individuals without their cognitive knowledge. The *values* which someone tries to comply with is also mentioned by Musgrave et al. (2019) as a factor within mode choice. He states that the values an individual tries to comply with are a re-appraisal concerning certain problem behaviours.

While Shahin et al. (2014) opted for a modification of travel choice behaviour, the *Willingness* to change behaviour is not taken into account. The willingness to change is not for within this study since this is the foundation of the choice modelling model (Musgrave et al., 2019). In Musgrave et al. (2019), the travel behaviour of rugby fans is contrasted with the trans-theoretical model of change. This model examines the *attitude* and behavioural control of visitors to PSEs. From this study, it has been found that 92% of people travelling by car are not willing to change their travel behaviour. Travel mode choices belonging to this statement follow motives such as pre-game *Excitement* and *escapism* (Musgrave et al., 2019). Since these factors differ per match and are more related to behaviour and result of the event within the stadium rather than for mode choice, these factors are not considered for this study (Musgrave et al., 2019). Other definitions of perceived accessibility focus on ease of living a satisfactory life using the transportation system (Lättman et al., 2016), perceptions of the level of access to activities of choice (Lättman et al., 2018) and how people perceive the accessibility of destinations (Scheepers et al., 2016). Defining perceived accessibility can be seen as difficult since it encompasses *behavioural*, cultural and experimental dimensions (Jamei et al., 2022). Based on the study from Lättman et al. (2018), it has been observed that people use the mode of transport, which is satisfactory in terms of accessibility. Moreover, they have found that the overall cycling experience gives a higher sense of accessibility than other modes. However, it has also been found that perceived accessibility cannot be the sole measure of accessibility. It can only complement the conventional accessibility indicators (Lättman et al., 2018).

Other approaches to measure perceived accessibility use indicators such as perception of travel time (Curl, 2018), *satisfaction* within a distance range (Coppola & Silvestri, 2018) and whole-trip components (Cheng & Chen, 2015). However, it has been found that a great barrier exists between the end-users of infrastructure and policymakers. Since perceived accessibility can be perceived differently by end users compared to policymakers. Stakeholders may also prioritise certain actions that are considered essential but may not be viewed as necessary by communities. To achieve sustainable transportation with high levels of perceived accessibility, it is crucial to establish clear and honest communication between communities (i.e., users of the transportation systems) and stakeholders (Jamei et al., 2022). Following the reasoning of Musgrave et al. (2019), *pride* plays a unique role in sporting events. Since the venue visitors identify themselves with others who are like-minded, Therefore he argues that the form of personal *identity* is predetermined by the subculture associated with the event (Musgrave et al., 2019).

4.4.2. Interpersonal

Since most people travel in groups towards a PSE, a behaviour change is not only based on individual choices but also the *encouragement* and support of others (Musgrave et al., 2019). This way, the visitors of sporting events look towards the relations associated with the group they're travelling with. This form of *socialism* has a clear synergy with gaining group support (Musgrave et al., 2019). Via this way, the modal decisions made by individuals are highly dependent on the group identification and their *norms* (Musgrave et al., 2019). This form of group behaviour can be changed by acknowledging the categorisation in which sports fans identify and cause conformity.

Similar to traditional accessibility assessments, evaluating these experiences involves personal judgements of spatial access measured in terms of factors such as *resistance*, distance, time, and cost. Curl (2018), however, has stated that an individual's evaluation of their perceived accessibility typically goes beyond these factors also to consider availability, affordability and acceptability, which are based on whether the accessibility opportunities align with their needs. The perceived accessibility in studies of Lättman et al. (2016, 2018) is covered by a set of four key questions which respectively cover; an individual-, transport-, land-use and temporal component. The first question posted by Lättman et al. (2016) is 'It is easy to do (daily) activities with mode X', which covers the ease of reaching activities. This statement is theoretically supported by Dalvi and Martin (1976) and Preston and Rajé (2007), who states that the ease of reaching an activity is of the greatest importance. Within conventional accessibility, this is measured with mainly cost and time indicators (Preston & Rajé, 2007). Other determinants for perceived accessibility are found by Lättman et al. (2016) being perceived quality, safety feeling and travel frequency. Secondly, the question is the possibility of travelling' If mode X was my only mode of travel, I could continue living the way I want.'(Lättman et al., 2016). This question closely follows the potential of interaction definition of accessibility by Hansen (1959). The third question of Lättman et al. (2016) covers opportunities to travel to activities of interest, ' It is possible to do the activities I prefer with mode X'. The opportunities to travel are measured as a process indicator of perceived accessibility (Lättman et al., 2016). This question closely relates to the finding of Morris et al. (1979), claiming that it is senseless to go somewhere if one has no interest in getting there. The last question posted is 'Access to my preferred activities is satisfying with mode X', which measures an outcome indicator (Lättman et al., 2016). In this statement, satisfaction is measured, which is seen as significant in contrast to the possible assessment of travel experiences (Friman et al., 2013). Via these questions, a broad intention to measure perceived accessibility is obtained. With a Perceived Accessibility Scale from 1 to 7, the indicators are quantified (Joshi et al., 2015; Lättman et al., 2016). Other questions used for perceived accessibility concern age, trip purpose, frequency and service quality (Lättman et al., 2016).

In the studies from Musgrave et al. (2019), there is a high link between the social structure and physical *space*. The modal choice is an effect of the relation to the levels of control and this physical space. Notwithstanding the relation mode choice has with *cultural* needs. Whenever there is a collective identity amongst visitors to PSEs, this is influenced by the cultural background of the visitors (Musgrave et al., 2019). An example of cultural preference in combination with transport modal decisions relates to Dutch people attending events by bicycle. Cultural beliefs and norms are not considered since the cultural background is not measured.

4.5. Conclusion

This chapter aims to find modal choice factors by analysing the literature. This study found four categories in which the different characteristics can be divided (spatial-, journey-, socio-demographic- and socio-psychological characteristics). An overview of all factors is shown in Figure 4.6 and higher resolution in Appendix D. This image shows the (non-transparent) factors used in this study. Also, the factors which are neglected in this study are indicated transparently.

For the spatial characteristics, two key categories, Event and Accessibility, were identified as vital factors in this context. The Event category emphasises the attraction of an event and its proximity as influential factors. Accessibility included attributes like parking availability, comfort, and safety, which played crucial roles in mode selection. Additionally, the infrastructural network and the road density by which supporters travel to their venue. At last,

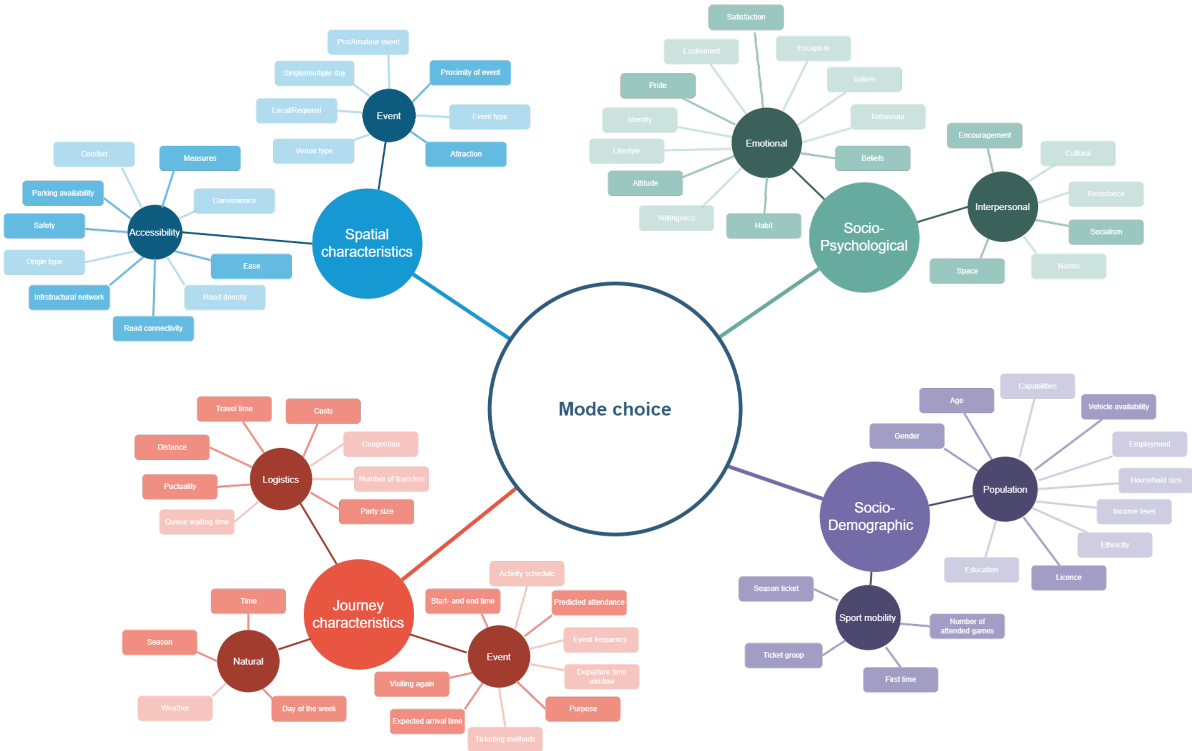

Figure 4.6: Conceptual model of mode choice attributes

the accessibility interventions taken by the organising body of a PSE are considered an influential factor for mode choice.

Journey characteristics consider three main factor groups, Logistics, Natural, and Event-related. Logistics factors like travel time, cost, and party size were discussed together with distance and reliability. Natural factors, including time of day, season, and day of the week, were found to impact mode choice. Event-related elements such as predicted attendance, event duration, and purpose of visiting an event play a role in modal choices. Factors like expected arrival time and revisiting also influence mode choice factors.

Socio-demographic factors provide valuable insights into individual typologies and substantially impact mode preferences. The Population group encompasses age, vehicle availability, household size and license, significantly influencing mode choices. Income, age, and possession of a driving license are associated with private car usage. The Attendance passport group examines ticket-related characteristics, including first-time attendees, attendance rate, season ticket holders and ticket groupings.

Socio-psychological characteristics influence modal choice for attending sports events through emotional and interpersonal factors. Emotional aspects, such as habit, pride, satisfaction and beliefs, shape individual decisions. Habitual preferences, rooted in past behaviour and mode familiarity, play a vital role. Interpersonal dynamics also contribute, with group influences affecting choices. Group encouragement, socialism and space also play a role within social contexts.

5
Stated preference experiment

In this chapter, the extent to which the observed mode choice attributes affect the modal choice behaviour is elaborated. Based on the interactions between these mode choice factors. Afterwards, the choice experiment elaborates on the choice levels within the SP survey. Afterwards, a pilot survey is held to estimate the priors of the utility function, which leads to a final choice experiment.

5.1. Choice attributes

Following the literature review (chapter 4), a large group of attributes influencing mode choice exists. To limit the amount of attributes within the discrete choice model, the relations between the individual attributes. Since the attributes influence each other, this reduces the number of variables to be examined. The relations between the attributes are shown within Figure 5.1. This figure presents four characteristic groups (Event-, Infrastructure-, Journey- and Visitor characteristics). The key determinants believed to have the highest impact on mode choice are found in these attributes. In between these attributes are arrows, which indicate which attribute influences the other. The colour and style of the arrow indicate whether the relations are tested within this study. The attributes of these relations are classified so that it becomes clear which attributes are used within this research.

The determinants which are found to have a direct influence on mode choice are party size (Musgrave et al., 2019), habit (Lättman et al., 2018), socio-demographics (Ergin & Tezcan, 2022) and satisfaction (Coppola & Silvestri, 2018). The party size by whom one wants to travel to events is dependent mainly on the extent to which a person enjoys having people around them (Gregariousness) (Musgrave et al., 2019). However, this also depends on how this person is encouraged by their environment to travel to events (Musgrave et al., 2019). Since it can be challenging to express how one's environment encourages one to travel by a specific mode, this is seen as an indirect decision variable. Moreover, it can be challenging to quantify the extent to which one enjoys the presence of other people. This is also seen as an indirect decision variable. However, this is a study since the party size with whom one travels is a key determinant. Socio-demographics is a determinant which is well covered within research. The most common visitor characteristics which are studied are the gender and age of the visitor (Ergin & Tezcan, 2021, 2022; Rudloff & Straub, 2021; Shahin et al., 2014).

Regarding habit, four key attributes (attitude, vehicle availability, number of attended games and ticket group) influence this determinant. The attitude one has towards certain modes is the only one not considered in this study. People can have pre-set opinions regarding certain modes while unfamiliar with these biases, thus forming an attitude towards a mode. This attribute is not considered since it is difficult to reflect on one's behaviour (Hyun et al., 2022). On the other hand, vehicle availability has a significant influence on the habit (Ergin & Tezcan, 2022; Kuppam et al., 2013). When more vehicles are available within a household, it is more likely that the household's inhabitants will use this mode of transport more often. Their possession of a driving licence is also an important part of using a vehicle and forming a habit (Jamei et al., 2022; Shahin et al., 2014). The number of games that the visitors to the event visit per season also plays a role in their mode choice habit. When people travel to the event often, they are familiar with the situation and thus the pros and cons of certain modes (de Haas et al., 2018). However, owning a season ticket significantly influences the number of events per season that these visitors attend. The fourth attribute is the ticket group (where one sits during the event). Since the different sections at the venue

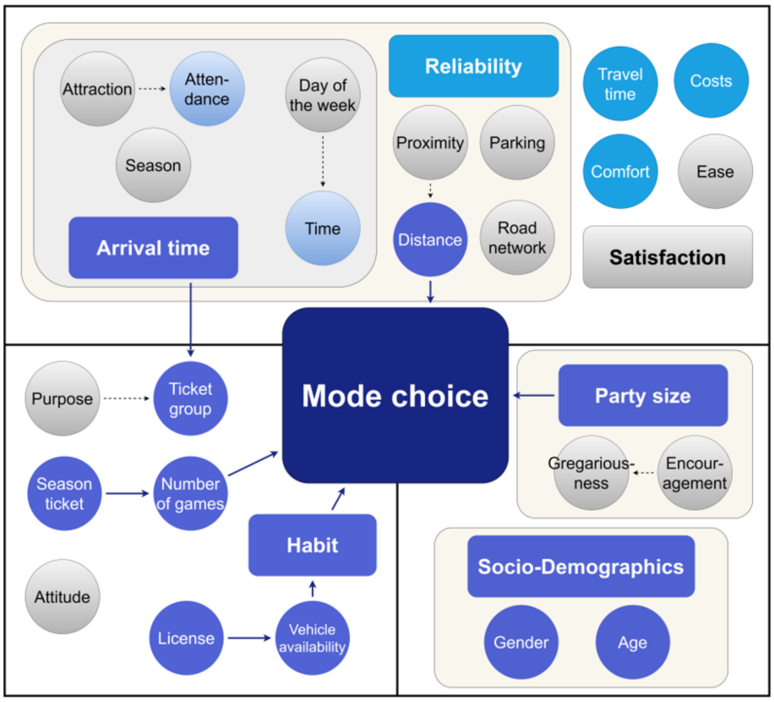

Figure 5.1: Conceptual model of survey blue arrows indicate relations being tested in this study

have different characteristics, such as the main stand, which includes parking around the venue, this influences the habit of mode choice. The ticket group to which visitors belong depends on their purpose for attending events. These relations are considered within this study.

The satisfaction one experiences when using a certain mode to travel to events is also a key determinant for mode choice. It is found that this is influenced by the reliability of the arrival time, infrastructure, and other journey characteristics. These characteristics include travel time, safety, ease and costs related to the journey to the venue. The reliability is influenced by the event's proximity to the individual. The distance between one's origin and the venue is measured to measure this proximity. Also, parking in the venue's environment plays a role in the road network. Since visitors do not value the road network as decisive within mode choice, this is seen as an indirect variable (Kwoczek et al., 2014; Van Wee et al., 2001). The time that the visitor to the event arrives at the venue also plays a role in the reliability. When one arrives earlier at the venue, the arrival time is more reliable (Di Martino et al., 2019). However, this arrival time depends on an event's start and end times. Which in itself depends on the day that the event is held. Regarding football matches in The Netherlands, the playing schedule is made by the KNVB. Each day has fixed time slots on the week- and weekend days (KNVB, 2022). Next to the event's starting time, does the predicted attendance play a role. When visitors expect that it will be busy around the stadium, they will aim to arrive earlier at the venue (Fernando, 2018). This is very much related to the attraction of the event which is occurring. For example, a football match which against a high-profile opponent versus an amateur team (Kuppam et al., 2013). Also, with its weather aspects, the season plays a role in this; however, due to time constraints, this factor will not be considered.

The scenario attributes form the basis for the discrete choice modelling. Due to time constraints, these factors are not considered, although they influence the mode choice significantly. Therefore, the predicted attendance and start- and end times are fixed during the mode choice estimation study. With the predicted attendance, a scenario with low predicted attendance will likely show later arrival times. Also, the disturbances (e.g. congestion) caused by the event will be experienced less. Therefore, a different modal split is expected to happen. Related to the event's start- and end time (e.g. 12:15 versus 14:30), it will result in a different arrival time pattern and mode choice. For the 12:15 event, supporters will likely leave their homes late since they will have to leave their origin early otherwise. Attributes which are considered are the decision variables. The four factors used are reliability, travel time, safety and costs. These factors are chosen since the solutions to improve accessibility at the AFAS AZ Stadium influence these factors directly.

5.2. Choice experiment

Within the choice experiment, the factors which influence mode choice are investigated. This section covers the design of the stated choice experiment at first. This part covers the selection of attributes and the range of these attributes. Afterwards, the pilot survey is elaborated, which forms the basis of the final choice experiment. The pilot choice experiment determines the priors for the final choice experiment. Finally, a choice experiment is discussed, which obtains data regarding mode choices and factors.

5.2.1. Design stated choice experiment

The choice experiment is based on the model shown in Figure 5.1. This image derives three kinds of factors that influence mode choice. The first factor is descriptive statistics, which describes behaviour on an aggregate level. The second factors are scenario attributes. These attributes are environmentally changing factors which cannot be influenced but change the modal behaviour. At last, the decision variables indicate the changing environments by which the measures from chapter 3 can be quantified. The first of sixteen factors, following Figure 5.1, considered for the descriptive statistics is licence. The way this question is asked focuses on whether the respondent possesses a licence for a car or moped or does not own a licence. This relates to the vehicle availability on the scale of none, 1, 2 or 3 plus vehicles. For the season ticket, a question is posted if the respondent possesses a season ticket. For the number of attended games per season, five categories are derived $(Never, 1{-}2, 3{-}7, 8{-}12, 13{+})$. The purpose of one attending events is asked from the perspective of the main event. Four pre-set answers are given together with one other option. The pre-set answers focus on no; the respondent only comes for the main event: Yes, it's a family outing; Yes, being with friends; and Yes, maintaining business relationships. This is followed by a question regarding the stand from where the respondents attend the event. These factors combined form the habit of the respondent who attends events at the AFAS AZ Stadium. To gain more insight into the habit, the mode of travel to the venue and their preferred mode of going to work/study are asked. For the party size, a scale from 0 to 10 is asked with an option of 10+. Socio-demographic indicators are also grouped starting with age, seven groups are derived $(18-25, 26-35, 36-46, ..., 65+)$. Gender is a three-option question with male, female and other. The respondent is asked to indicate their average arrival time based on a slider between 0 and 60 minutes before kick-off. Parking is based on whether they go to the event by car and the alternative parking options. The distance one has to commute towards the stadium is derived indirectly via their zip codes. At last, the ease and satisfaction will be obtained via a 5-point Likert (strongly disagree,..., strongly agree) based on statements from Pot et al. (2021).

The scenario attributes are factors which an individual cannot influence. The first attribute considered in this regard is the start- and end time of the event. The league's organising committee sets these times. The predicted attendance focuses on the event profile based on the opposition and competition profile. Due to this study's scope and time limits, a single event and time is chosen. For this study, a kick-off time of Sunday 14:30 is chosen against Ajax Amsterdam at the AFAS AZ Stadium. This match is selected due to its high profile and since it is often sold out, and thus, the infrastructure is most challenged. Moreover, Sunday at 14:30 is the preferred playing time of AZ.

Decision variables (costs, comfort, time and reliability) indicate the changing environments with the measures to increase accessibility. Since the time depends on distance, a total of six distances have been chosen by which the decision variables are altered. These distances are based on the cumulative distances from subsection 3.2.1. The six distances considered are 2, 3, 8, 13, 17 and 26 kilometres. These distances refer to 20%, 25%, 50%, 75%, 80% and 90% of the tickets sold respectively. The considered factors are shown in Table 5.1 based on these distances. This table illustrates the four primary modes with their associated scenarios. The levels within this table are derived based on the effects that the accessibility interventions (chapter 3) have on the decision variables. In Appendix C, the effects of each accessibility intervention are elaborated.
Within the table above, the choice scenarios are shown per mode. Travel time at first shows the base time to travel from door to door towards the AFAS AZ Stadium. For cars and cyclists, this entails parking and walking towards the stadium. Regarding public transport, it covers transfers and walking. Comfort is defined as the quantity of interactions with other traffic and the ease of reaching the AFAS Stadium. The comfort is described by a Likert 5 scale (Very uncomfortable, ..., Very comfortable). The first level (very uncomfortable) is described as having many interactions with other traffic and difficulty reaching the AFAS AZ Stadium. Uncomfortable within this study means a moderate number of interactions with other traffic and difficulty reaching the AFAS AZ Stadium. Moderately comfortable is a moderate number of interactions with other traffic and neutral regarding reaching the AFAS Stadium. Comfortable is an average number of interactions with other traffic and easy to reach the AFAS AZ Stadium. Being very comfortable means no interaction with other traffic and makes reaching the AFAS AZ Stadium easy. The

Table 5.1: Attribute levels of decision variables for stated choice experiment

	Car	Public transport	Bicycle	Walk
Travel time	· Base · 90% · 95%	· Base · Average car/pt · Car	· Base · -5 min	· Base
Comfort	· 3: Good · 4: Very good	· 2: Average · 3: Good · 4: Very good	· 2: Average · 3: Good	· 3: Good · 4: Very good
Costs	· Base · 75%	· Base · 75% · 50%	· €0,- · -€5,40	· €0,-
Reliability	· 2: Average · 3: Good	· 2: Average · 3: Good · 4: Very good	· 4: Good	· 4: Very good

costs are the overall costs to get to the stadium. For car traffic, this entails parking costs at AZ and gas facilities. Public transport costs concern the costs of buses and trains. The negative bicycle costs concern compensation in the form of a consumption voucher. Reliability is defined as the likelihood of being late for kick-off and the level of control one has over the arrival time. Highly unreliable is defined as an existing likelihood of being late for the start of the match while having no control over your arrival time. Unreliable means an existing likelihood of being late for the start of the match while having no direct control over your arrival time. Moderate reliability is an existing likelihood of being late for the start of the match while having personal control over your arrival time. Reliable, on the other hand, is a small likelihood of being late for the start of the match while having no control over your arrival time. Very reliable is defined as a small likelihood of being late for the start of the match while having personal control over your arrival time.

Within the base scenario, the set of six distances has varying characteristics for travel time and costs. These differences are shown in Table 5.2. The travel time, as indicated, presents the time it takes to get from door to door. Thus, the vehicle is alighted from its origin and arrives at the stadium site. For public transport, this also covers transfers and waiting time. Car traffic and bicycles include parking and walking to the venue. For costs, other aspects are considered. The costs for car traffic are based on buying a parking ticket 9.45 and petrol 0.12 per km. For public transport, the ticket prices are compared to the ticket prices of the bus operator. These are then incorporated into the overall costs.

Table 5.2: Base scenario for travel time and costs per mode

Distance	Car		Bicycle		Public transport		Walking	
	Travel time	Cost	Travel time	Cost	Travel time	Cost	Travel time	Cost
2	0:05	€ 9,66	0:08	€ -	0:25	€ 1,21	0:24	€ -
3	0:06	€ 9,80	0:12	€ -	0:29	€ 1,53	0:36	€ -
8	0:13	€ 10,50	0:32	€ -	0:36	€ 2,60	1:36	€ -
13	0:16	€ 11,20	0:52	€ -	0:44	€ 3,47	2:36	€ -
17	0:22	€ 11,80	1:08	€ -	0:59	€ 4,60	3:24	€ -
26	0:28	€ 13,00	1:44	€ -	1:03	€ 6,86	5:12	€ -

5.2.2. Pilot survey

Within the pilot survey, the priors of the decision variables within the choice model are estimated. This can be done by either a literature review or a pilot study. Since little research is done in this field, it is chosen to perform a pilot survey before the final survey. The pilot aims to gain insight into the magnitude of the relevance of the decision variables. By executing this pilot, dominant alternatives are eventually filtered. Moreover, the aim is to understand which variables have what size of fit with the data. A higher log-likelihood or a higher rho-square-bar means a better model fit. After this, MNL models are estimated for each category and all variables. The significance of the variables can be checked by looking at the p-value. If this is below 0.05, the variable is significant.

In this initial survey, an orthogonal design is employed, assuming that the attribute levels are uncorrelated across various profiles. For instance, very good comfort is combined with high and low prices. These correlations will be identified and controlled for in the subsequent survey design. The software Ngene is utilised to create the survey questions and profiles. A specific Ngene model (.ngs) has been crafted to generate alternatives for 250 choice sets in the pilot survey design (Appendix E). Since this choice set is large for a single participant to fill in, ten blocks have been created. Therefore, the total number of questions a single respondent receives is 25. An example of questions provided to the respondents is shown in Figure 5.2.

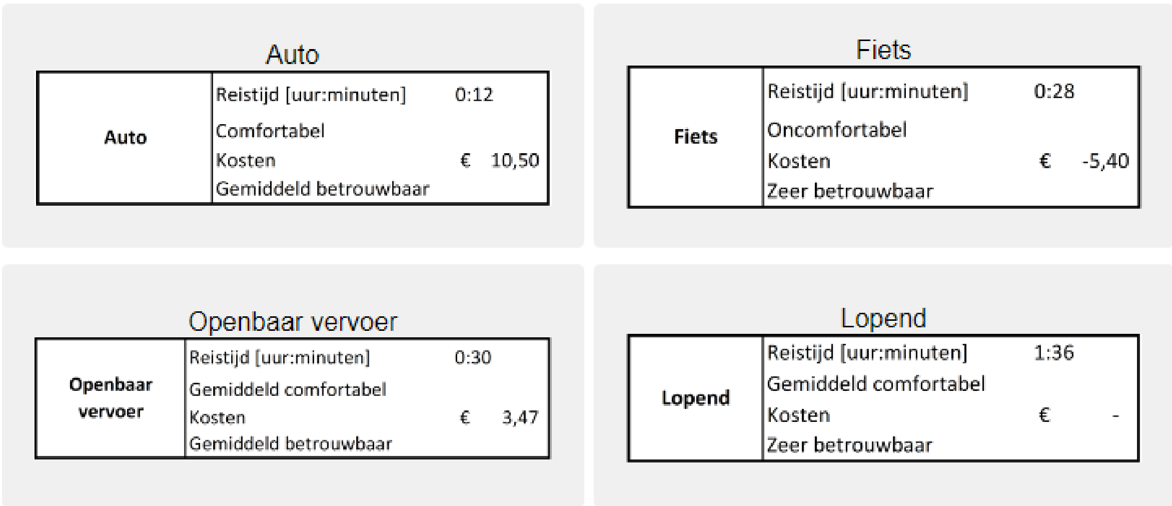

Figure 5.2: Example of question in pilot study

Based on the output of respondents from the pilot survey, the priors of the utility function can be estimated. The estimated utility functions are shown below. In this equation, an MNL is assessed. Within this function, the four attributes are noted with their dummy variable and Alternative Specific Constant (ASC). This factor indicates all aspects of an alternative that are not covered within the choice model. Only for the car, this factor is not used since this is the dominant alternative. The dummy variables are used to assess the categorical variables which are not numeric within the choice set. Using these dummy variables, the effect of each level within the set is represented within the model. This causes the model to be more accurate in its prediction. Moreover, a constraint is proposed so all modes are assessed equally. This last function shows that the distance of mode i is equal to the distance of mode j. By introducing this constraint, an example of an excluded option can be comparing 2 kilometres for cars with 13 kilometres for bicycles.

$$U_{car} = \beta_{TT} * TT_{car,D} + \beta_{Dummy_{car,comf,good}} * COMF_{car,good} + \beta_{Dummy_{car,comf,verygood}} * COMF_{car,verygood} + \beta_C * C_{car,D} + \beta_{Dummy_{car,R,average}} * R_{car,average} + \beta_{Dummy_{car,R,good}} * R_{car,good}$$

$$U_{PT} = ASC_{PT} + \beta_{TT} * TT_{PT,D} + \beta_{Dummy_{PT,comf,average}} * COMF_{PT,average} + \beta_{Dummy_{PT,comf,good}} * COMF_{PT,good} + \beta_{Dummy_{PT,comf,verygood}} * COMF_{PT,verygood} + \beta_C * C_{PT,D} + \beta_{Dummy_{PT,R,average}} * R_{PT,average} + \beta_{Dummy_{PT,R,good}} * R_{PT,good} + \beta_{Dummy_{PT,R,verygood}} * R_{PT,verygood}$$

$$U_{Bicycle} = ASC_{bicycle} + \beta_{TT} * TT_{bicycle,D} + \beta_{Dummy_{bicycle,comf,average}} * COMF_{car,average} + \beta_{Dummy_{bicycle,comf,good}} * COMF_{bicycle,good} + \beta_C * C_{bicycle,D} + \beta_{Dummy_{bicycle,R,verygood}} * R_{bicycle,verygood}$$

$$U_{Walk} = ASC_{walk} + \beta_{TT} * TT_{walk,D} + \beta_{Dummy_{walk,comf,average}} * COMF_{walk,average} + \beta_{Dummy_{walk,comf,good}} * COMF_{walk,good} + \beta_{C} * C_{walk,D} + \beta_{Dummy_{walk,R,verygood}} * R_{walk,verygood}$$

$$D_i = D_j \forall U \in i$$

Where:

U_i	= Utility of mode i
D	= Distance from the set of modes i and distances $2, 3, 8, 13, 17, 26$ in km
$TT_{i,D}$	= Travel time for mode i and distance D in minutes
$Dummy_{i,R,s}$	= Dummy variable of mode i of reliability R and scale s
$C_{i,j}$	= Costs of mode i and distance D
$Dummy_{i,comf,s}$	= Dummy variable of mode i of comfort $comf$ and scale s

By estimating the priors, an efficient design for the attribute level can be obtained in Ngene. Estimation of these priors is done via a Biogeme extension within Python. The results of the prior estimation are shown in Table 5.3. If the value of the prior within the utility function is negative, it has a repellent influence, and if it is positive, it has an attractive impact on the choice. In total, 525 scenarios were answered within the pilot survey. From the factors, it can be seen that the ASCs still play a prominent role in the priors. Also, the Robust t-tests can be seen as significant since their absolute values are higher than 1.96 for a 95% confidence interval. Comfort is the least important value for the other values following its estimated value and t-statistic. The p-value indicates whether the null hypothesis should be accepted or rejected. As a rule of thumb, a p-value higher than 5% suggests the significance of rejecting the null hypothesis. For this study, the null hypothesis which is formulated is that the means are statistically different from zero at a 95% confidence level. For the design of the final survey, these prior parameter values can be used to make an efficient design in Ngene. Within the model, a total of 24 parameters is estimated. From the model, a relatively low ρ^2 is calculated for the model (0.0433). This indicates that the model itself has little explanatory power. Since this model is the output for a pilot survey, this is accepted.
Following the table, it can be seen that the ASC for bicycles is positive. This indicates a preference for bicycles compared to cars when the choice attributes are equal. The same holds for the ASC for public transport. Walking, however, has a negative sign; thus, there is a preference to use the car when all attributes are equal. These ASCs have their t-test value in absolute sense above 1.96, which indicates they are significant. As expected, the costs have a negative value, which suggests the utility becomes less when the costs increase. However, it is seen as significant only for a bicycle. Since this pilot focuses on obtaining priors for the eventual choice model, the insignificant priors are kept within the model. The signs of the travel time by car and walking do not follow expectations. These values are expected to be negative since the utility decreases when travel time increases. At last, the dummy variables indicated within the model differ in statistical significance and power to reject the null hypothesis.

Table 5.4: Basic statistics from pilot survey

Respondents	n = 25
Gender	Male: 76%; Female 19%, Other 5%
Age	Average: 29 / Standard deviation: 14.5
Attended games	Never 48%, Rarely 14%, Regularly 14%, Often 19%, Always 5%
Party size	Average: 2,7 / Standard deviation: 1.6

Statistics about the pilot survey can be found in Table 5.4. In total, 25 respondents filled in the survey, meaning every block was filled in at least twice. On average, the supporters familiar with the environment on event days at the AFAS AZ Stadium are almost equal to those unfamiliar. Also, the party size by which supporters travel towards the stadium is 2.7 persons. Considering the statistics they influenced the result of the pilot survey. For gender, for example, women are more likely to opt for public transport and bicycles than men. Regarding the attended games, it can be noticed that the bicycle is a more preferred mode compared to the car for the low attendance rates. However, the group often perceives this as equal to a car. Public transport shows a similar trend with

Table 5.3: Prior estimation from pilot survey

	Value	Rob. t-test	Rob. p-value
ASC_{BIKE}	0.8230	4.240	2.231e-05
ASC_{PT}	0.7792	4.315	1.598e-05
ASC_{WALK}	-1.7170	-5.188	2.127e-07
$\beta_{COST,BIKE}$	-0.0760	-2.278	2.273e-02
$\beta_{COST,CAR}$	-0.0014	-0.016	9.869e-01
$\beta_{COST,PT}$	-0.0520	-0.493	6.221e-01
$\beta_{TT,BIKE}$	-0.0042	-0.680	4.968e-01
$\beta_{TT,CAR}$	0.0020	0.067	9.464e-01
$\beta_{TT,PT}$	-0.0067	-0.837	4.024e-01
$\beta_{TT,WALK}$	0.0002	0.055	9.557e-01
$\beta_{Dummy_{comfort,bike,average}}$	0.2796	2.219	2.646e-02
$\beta_{Dummy_{comfort,bike,good}}$	0.5434	3.952	7.761e-05
$\beta_{Dummy_{comfort,car,good}}$	0.0905	0.343	7.316e-01
$\beta_{Dummy_{comfort,car,verygood}}$	0.0244	0.093	9.261e-01
$\beta_{Dummy_{reliability,car,average}}$	-0.1610	-0.573	5.666e-01
$\beta_{Dummy_{reliability,car,good}}$	0.2759	1.114	2.651e-01
$\beta_{Dummy_{comfort,pt,average}}$	0.0211	0.135	8.926e-01
$\beta_{Dummy_{comfort,pt,good}}$	0.6943	4.674	2.956e-06
$\beta_{Dummy_{comfort,pt,verygood}}$	0.0637	0.459	6.465e-01
$\beta_{Dummy_{reliability,pt,average}}$	0.2589	1.798	7.213e-02
$\beta_{Dummy_{reliability,pt,good}}$	0.1285	0.895	3.709e-01
$\beta_{Dummy_{reliability,pt,verygood}}$	0.3917	2.582	9.831e-03
$\beta_{Dummy_{comfort,walk,good}}$	0.1615	0.337	7.362e-01
$\beta_{Dummy_{comfort,walk,verygood}}$	-1.8785	-2.971	2.970e-03

bicycles. However, within the often group, this modality decreases compared to cars. Walking always has a lower perception than all other modes. Age is not shown to have a significant influence on mode choice. However, when age increases, the frequency of choice for public transport decreases.

5.2.3. Final choice experiment

Based on the priors from the pilot survey, an efficient survey design is made in Ngene. For this survey, an efficient design is chosen. The necessary number of respondents with the expected margin of error is computed within this design. In Equation 5.1, the minimal number of required choice questions is shown (Choice Metrics Pty Ltd, 2014). A minimum of eight questions is necessary from the 24 parameters shown in the pilot survey and four alternatives. However, six questions are chosen per respondent to have a manageable survey. This number is chosen since it corresponds to the distances addressed within the choice metric.

$$\text{Minimum \# questions} = \frac{\text{\# parameters}}{(\text{Alternatives} - 1)} = \frac{24}{(4-1)} = 8 \tag{5.1}$$

In total, ten blocks of choice sets are opted for. With six choice sets per block, this leads to 60 unique choice sets. The efficient design is based on an MNL, optimised for the D-error (Choice Metrics Pty Ltd, 2014). The complete design of the survey within the choice sets can be found in Appendix E. Based on this information and the priors from the pilot study, a required sample size of $n = 735$ is necessary. A similar design of the choice sets as within the pilot survey is used within the final survey design. The question in Figure 5.2 shows the four modes: car, public transport, bicycle and walking. The time in minutes it takes to reach the AFAS AZ Stadium is 12, 30, 28 and 96 minutes, respectively. With the level of comfort reaching from uncomfortable to comfortable. Due to the use of an efficient design, the dominant alternatives are neglected. Corresponding to Figure 5.1, the attributes within the final survey design are indicated. The final design of the survey is shown in Appendix E.

5.3. Conclusion

In this chapter, the extent to which the choice attributes affect the modal choices is derived. This is obtained by first observing the relations between the choice attributes. The key determinants believed to have the highest impact on mode choice are found in these attributes. The attributes which are found to have a direct influence on mode choice are party size (Musgrave et al., 2019), habit (Lättman et al., 2018), socio-demographics (Ergin & Tezcan, 2022) and satisfaction (Coppola & Silvestri, 2018). Regarding habit, four key attributes (attitude, vehicle availability, number of attended games and ticket group) influence this determinant. The satisfaction that one experiences when using a certain mode to travel to events is also a key determinant for mode choice. It is found that this is influenced by the reliability of the arrival time, infrastructure, and other journey characteristics. These characteristics include travel time, safety, ease and costs related to the journey to the venue. The reliability is influenced by the event's proximity to the individual. The distance between one's origin and the venue is measured to measure this proximity. Also, parking in the venue's environment plays a role in the road network.

Based on the pilot survey, the average party size by which supporters travel towards the stadium is 2.7 supporters. For gender, for example, women are more likely to opt for public transport and bicycles than men. Regarding the attended games, it can be seen that the bicycle is a more preferred mode compared to the car for the low attendance rates. However, the group often perceives this as equal to a car. Public transport shows a similar trend with bicycles. However, within the often group, this modality decreases compared to cars. Walking always has a lower perception than all other modes. Age is not shown to have a significant influence on mode choice. However, when age increases, the frequency of choice for public transport decreases. From the factors, it can be seen that the ASCs still play a large role in the priors. The comfort is least significant for the other values following its estimated value and t-statistic. From the table, it can be seen that the ASC for bicycles is positive. This indicates a preference for bicycles compared to cars when the choice attributes are equal. The same holds for the ASC for public transport. Walking, however, has a negative sign; thus, there is a preference to use the car when all attributes are equal. As expected, the costs have a negative value, which indicates the utility becomes less when the costs increase. However, it is seen as significant only for a bicycle.

Based on the pilot survey results, an efficient design is derived. A minimum of eight questions per respondent is recommended following Equation 5.1. Minimising the D-error within the estimation model requires a sample size (n) of 735 respondents. Three main parts exist within the final survey design (Match-day experience): Choice modelling and descriptive statistics, as shown below.

Match-day experience	**Choice modelling**	**Descriptive statistics**
· Season ticket	· Scenario's	· Licence
· Length of season ticket		· Vehicle availability
· Number of attended games		· Habit
· Habit		· Age
· Satisfaction		· Gender
· Ticket group		· Distance
· Purpose		
· Party size		
· Ease		
· Arrival time		
· Parking		

6

Discrete choice model results

The outcome of the SP survey of the previous chapter is discussed in this chapter to obtain individuals' preferences to measure the effect that accessibility improvements have on modal choice behaviour. Firstly, the exclusion criteria are considered to filter inadequate answers. A sample $n = 2,218$ respondents have replied to the call to complete the questionnaire. However, since people < 18 years old cannot give informed consent, this group is filtered ($n = 144$). From the incentive of the survey's price, the time to complete the survey is also checked. The surveys were believed to be completed truthfully when it took longer than 120 seconds. This causes the sample to be reduced by another $n = 244$ answers. At last, unique answers are used, and thus, the duplicates are removed ($n = 22$). This leads to a final sample size of $n = 1,808$ answers. The descriptive statistics are discussed on section 6.1 based on the survey outcome. In this section, the relations from the conceptual framework are researched, and the statistical significance is proved. Afterwards, the choice model is estimated.

6.1. Descriptive statistics

This section highlights different characteristics of the sample from the survey. With this information, the representativeness of the survey results is tested. Additionally, a first idea of the mode choice behaviour of the sample is derived. At first, some socio-demographic characteristics of the sample are highlighted. Followed by the frequency of the visit with the ticket type relationship. Hereafter, the modal aspects of the sample are elaborated. Lastly, some insights are obtained into the choice set of the sample. The data discussed for the descriptive analysis is based on Figure 5.1. The key determinants within this figure are shown in purple. A statistical analysis is done to understand the results of these determinants and their relation. Statistical significance is tested with the chi-squared-, ANOVA- and Kolmogorov-Smirnov (KS) tests as presented in Appendix A.

Socio-demographics

A few key descriptive statistics are emphasised to assess if the sample accurately represents AZ supporters. A chi-square test will be utilised to examine if there is a significant distinction between the sample and the population. Within Table 6.1, the sample's descriptive statistics for age and gender are shown. Within Table 6.2, the arrival times from subsection 3.2.2 are compared to the population. From Table 6.1, the spread in age and gender from the sample can be observed. It can be seen that the majority of respondents are male, which is similar findings were obtained following the KNVB supporters survey (KNVB Expertise, 2023). Age groups are also presented against the survey from KNVB Expertise (2023). Within the KNVB survey, the largest sample is from supporters below 35. Whereas the supporters between 46 and 65 are over-represented within the survey sample compared to the KNVB Survey. Since these supporters are more likely to use cars, the share of car users from the sample is expected to be higher than in the KNVB Survey. Comparing the two surveys, it can be seen that the group 65+ has a similar share. Based on the comparison, the mode choice for cars might be expected to be higher within the sample since more people between 45 and 65 have a vehicle available. Moreover, they use their cars more than their bicycles compared to supporters between 18 and 25.

Table 6.1: Age and gender comparison from survey sample to KVNB Survey sample

	Sample		**KNVB Survey**
	Count	%	%
Gender			
Male	976	77	86
Female	286	23	14
Age			
18 - 25	130	10.3	32.9
26 - 35	154	12.1	21.1
36 - 45	214	16.9	11.0
46 - 55	340	26.8	13.7
56 - 65	259	20.4	10.9
65+	171	13.5	10.4

Arrival time data of the sample is compared to the arrival time of supporters during AZ versus Ajax on the 18th of September 2022. These results are shown in Table 6.2. From this table, it can be seen that the distribution within the sample follows a pattern similar to that of the population. Minor differences indicate that fewer supporters are present 60+ minutes before kick-off. Moreover, there are fewer peaks within the population compared to the sample. The origin distance is based on the Euclidean distance of the zip code area centroids and the stadium location. Five distance groups are introduced to check whether the sample corresponds to the population. Based on the table, it can be seen that the supporters who have their origin $< 2km$ are underrepresented within the sample. The groups $2-5, 5-10$ and $10-20km$ follow similar trends compared to the population (as discussed in subsection 3.2.1). Whereas the first group is underrepresented, the opposite is true for the group travelling $21+km$. It may, therefore, be expected that the mode choice for active modes (walking and cycling) is lower within the sample than within the population. Within Appendix A, the Chi-squared tests to check statistical significance between the sample and the population are shown.

Table 6.2: Arrival time and origin comparison of survey sample to population of AZ Supporters

	Sample		**Population**
	Count	%	%
Arrival time			
< 15 min	98	6.6	5.3
15 - 29 min	462	31.1	34.2
30 - 44 min	584	39.4	31.0
45 - 59 min	212	14.3	19.0
60+ min	128	8.6	10.5
Origin			
<2 km	110	9	19
2 - 5 km	248	21	17
5 - 10 km	335	26	28
10 - 20 km	274	22	21
21+ km	246	21	15

Visit frequency

This part focuses on the frequency by which the supporters visit the AFAS AZ Stadium based on the sample. This focuses on the description of the season ticket holders and the frequency by which they visit the AFAS AZ Stadium as shown in Figure 6.1.

Figure 6.1: Mode choice factors and relations for visit frequency

In the sample, there is a ratio of 63.9% season ticket holders and 36.1% who are not. Of these 63.9%, the majority is present at the Molenaar stand and the Ben-Side. The Alkmaarderhout-, and Victorie stands are underrepresented within the sample compared to the other two sections. Most of these season ticket holders have had their season ticket for over ten years (49.5%). Supporters with their season tickets for the first season are significantly smaller (6.7%). It can be seen that there is a relation between owning a season ticket and the number of games attended per season. Since 98.2% of the sample of 13 or more games are season ticket holders. Almost two-thirds of the supporters who attend 8 to 12 matches are season ticket holders. The statistical relationship is also computed in Appendix A. A statistically significant association between these variables is determined via the chi-squared test. A significant association is found since the P-value is < α when considering a 95% interval. Most of the supporters who visit the AFAS AZ Stadium less than seven matches per season are thus supporters who do not have a season ticket.

With the information about attended games and season ticket possession, something can be said about the modal split per group. As shown in Figure 6.2, there exists a difference in mode choice per attended games group. Another significant association is found via the chi-squared test between the number of attended games and the chosen mode of transport. When one supporter attends more matches per season, they are more likely to choose the bicycle. Significance is found since the chi value (76.49) is higher than the threshold of 24.996 for a freedom degree of 15 (Appendix A). From the figure itself, it can be seen that there is little difference between moped, public transport, walking, and the number of games attended. However, interesting findings can be made when comparing the car and bicycle with the visit frequency. It can be seen that the modal split of the car increases when the visit frequency decreases. An opposite finding can be made when comparing bicycles with the visit frequency. There, the modal split decreases when the visiting frequency decreases.

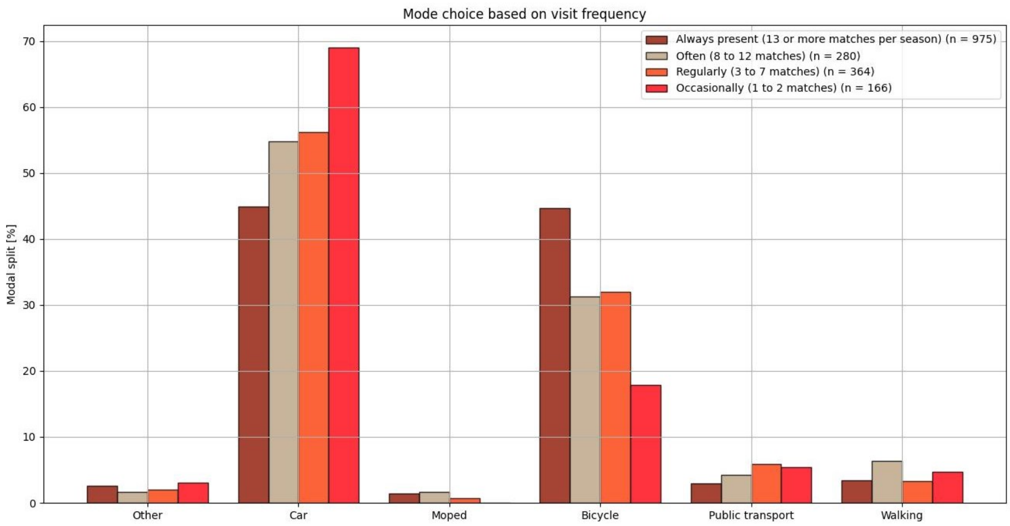

Figure 6.2: Bar graph depicting the mode choice according to frequency of visits in survey sample

The findings for the share of bicycle and car use compared to the visiting frequency can be related to one aspect. In Table 6.3, the visiting frequency groups are compared to the distance. From this table, it can be seen that supporters who attend games less frequently generally have a larger travel distance. The average distance supporters always present have to travel is 11.5 kilometres. While for occasional visitors, this lies on 30.9 kilometres. The significance of these values is computed with the ANOVA test (Appendix A). These results show a significant difference between the group means (P-value = 0.000). This thus implies the distance increases when the number of games decreases. Since this distance grows, so does the likelihood of choosing cars as a means of transport. This explains why the mode choice for a car increases when the visiting frequency decreases.

Table 6.3: Distance per visit frequency from origin to AFAS AZ Stadium in survey sample

	Always	**Often**	**Regularly**	**Occasionally**
Number of games	13+	8 - 12	3 - 7	1 - 2
Average [km]	11.5	14.8	21.2	30.9

Modal aspects

The modal aspects focus on the habit of supporters in combination with the availability of vehicles. Corresponding with Figure 5.1, the relations between the habit, mode choice and underlying factors are shown in Figure 6.3.

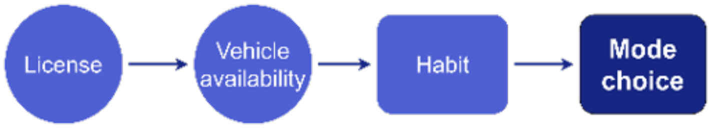

Figure 6.3: Mode choice factors and relations for modal aspects

The first relation is shown in Figure 6.4. This table highlights the relation between the modes the respondents use to travel to work/study and the mode choice towards the stadium. Respondents who commute by car are also more prone to come to the AFAS AZ Stadium by car. The majority (64,2%) of the 758 respondents who state they commute by car also travel to the AFAS AZ Stadium. This group is significantly larger than car commuters who use other modes such as bicycles (30,2%) and public transport (1,8%). Comparing commuters by car to bicycle shows that supporters who commute by bicycle are also more prone to use the bicycle to travel to the AFAS AZ Stadium. With 57,3% of bicycle commuters who also take a bicycle to the venue compared to 30,2% car commuters. Regarding public transport, a ratio of 12,9% of the 186 respondents indicate they use public transport for commuting as a mode of transport to the AFAS AZ Stadium. Based on the distance the respondents have to travel to the venue, the average travel distance is 23,3 km for car commuters and 5,0 km for cyclists. Based on this information, the difference in mode choice towards the venue can be explained. Little difference can be determined when looking at the distance per commuting mode and chosen mode to the AFAS AZ Stadium. This indicates that the average travel distance has little influence on the mode choice to the AFAS AZ Stadium. This can also be found in the ANOVA test (Appendix A). Following this test (F(816.7, 0.000)), there is a significant difference between group means. With a P-value of 0.000, the correlation observed is statistically significant for a 95% confidence level. Additionally, a KS test is performed. The lowest test statistic of KS = 0.082 indicates a substantial discrepancy between the two distributions.

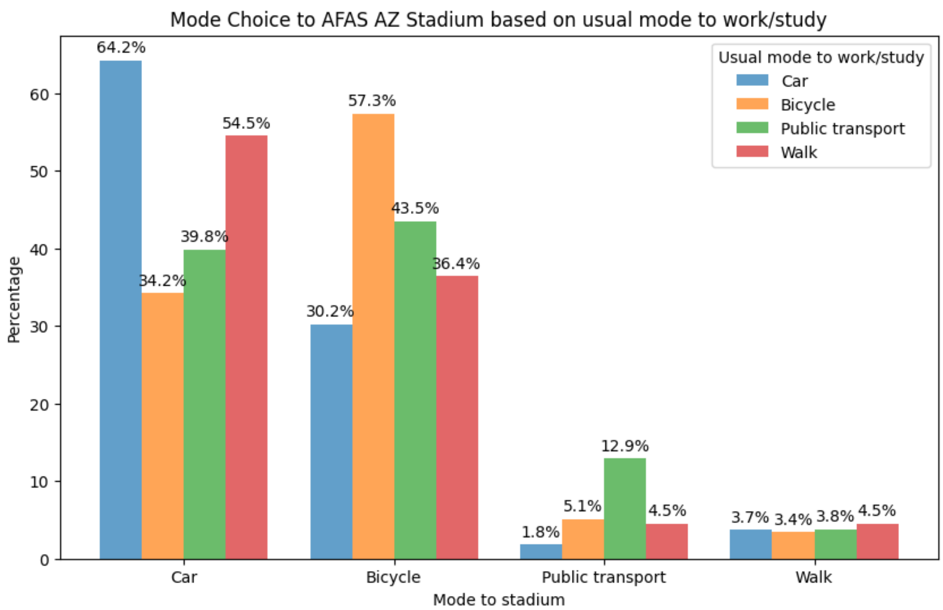

Figure 6.4: Bar graph showing usual mode choice to travel to work/study and mode choice travel to AFAS AZ Stadium from survey sample

Based on Figure 6.4, it can be seen that there is a correlation between the mode used for commuting and travel to the AFAS AZ Stadium. The next step is to check whether there is a connection between the mode of commuting and vehicle availability. From the sample, it can be observed that car commuters have more vehicles within their household than other commuters. Between cyclists and public transport users, there is lesser difference. Of the 63,7% of the respondents who commute by bicycle and go to the venue by bicycle, only 12,9% do not have a vehicle available in their household. This is similar to the people who cycle to work (10,4%). For similar car traffic, the same statement holds. Of the 758 respondents, 88,9% have one or two vehicles available within their household. A clear pattern between available vehicles and mode choice cannot be determined. Based on the chi-squared test, a P-value of 0.000 indicates a significant association between mode choice and vehicle availability. Looking at the relationship between owning a license and having a vehicle available within the household. It can be seen that the share of respondents who do not own a license and do not have a vehicle available is 39%. Whenever a vehicle is available within the household, the share of respondents who own a car increases. There is only a slight difference between having one or two vehicles available (94,2% and 95,7%). A statistical significance is present between these two variables as indicated with the chi-squared test (Appendix A). Based on this information, the conclusion can be drawn that supporters who do not own a license also don't have a vehicle available. Since the share of respondents who do not have a vehicle available is highest for bicycle and public transport, these modes of transport are preferred.

Travel pattern

For the travel pattern, three variables are discussed following the conceptual model (Figure 5.1). First, the relationship between arrival time and ticket group is discussed. Afterwards, the distance and mode choice distribution is elaborated. Followed by the mode choice in correspondence with the party size. In Figure 6.5, the aspects discussed regarding the travel pattern are indicated.

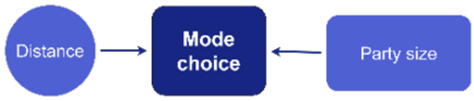

Figure 6.5: Mode choice factors and relations for travel pattern

From the distribution of the arrival times, it can be obtained that the supporters on the main (Victorie) stand are earliest within the stadium. Their average arrival time is stated to be approximately 35 minutes before kick-off. However, this stand's standard deviance (σ^2) is also highest at 15,5 minutes. This indicates that this stand has the most differences in arrival time. However, since this section has the smallest sample size, it might be underrepresented compared to the other sections. At the standing sections (Ben-Side), the average arrival time is 33 minutes, and the standard deviation is 15,1 minutes. From the figure, it can be seen that approximately 20% is within the stadium 50 minutes before kick-off. The stand with the slowest inflow is the Molenaar stand, with an average flow of supporters present 31,8 minutes before kick-off. The standard deviation of this stand is also lowest at 13,4 minutes. This means that the supporters of this stand arrive at the stadium within the shortest time frame. Two statistical tests are performed to test the significance of a KS test and ANOVA, as shown in Appendix A. At first, the KS statistic, higher than the critical value, indicates a substantial discrepancy between the distributions. While the ANOVA indicates, there is a significant difference between the mean arrival times per stand.

Another variable is the distance with the mode choice. This relation is shown in Figure 6.6. Before the data analysis, the sample is filtered at the 95th quantile of the data. Therefore, the outliers are removed from the sample. This has been set at the 75th quantile for walking since this sample had more outliers. This caused a final sample of 1.268 respondents. Respondents who, on average, have to travel furthest is public transport with a 26,5 km journey towards the AFAS AZ Stadium. While supporters who are walking have their origin within a 1,6 km radius of the venue. Car (18,5 km) and bicycle (3,9 km) are between these modes. The standard deviation of 17,9 km is the highest for public transport. This means the sample of 54 respondents is more spread than the other modes. Supporters by foot have a standard deviation of 1,4 km, which indicates that their travel distances are more equally distributed. Significance is tested by the KS test and ANOVA (Appendix A). The lowest test statistic of 0.076 is obtained from the KS test, indicating a substantial discrepancy between the distributions. From the ANOVA, F(16552.6, 0.000) is derived, indicating a significant difference between the average distance per mode.

Finally, the relationship between the number of people with whom someone travels to the stadium (party size) and the mode choice is discussed. In Figure 6.7, this relation is shown. The party size is indicated on the x-axis. On the y-axis is the percentage of the respondents. In this figure, it can be seen that most supporters travel with two or three others towards the venue. This percentage is the largest since most supporters indicate to come by car. The average party size lies highest for supporters who travel by bicycle (2,33). The standard deviation is also the highest for this group, with 1,72. However, the averages are relatively close between bicycle and car (2,27) and public transport (2,19). For pedestrians, the party size is the smallest, with 1,95 persons on average. As can be

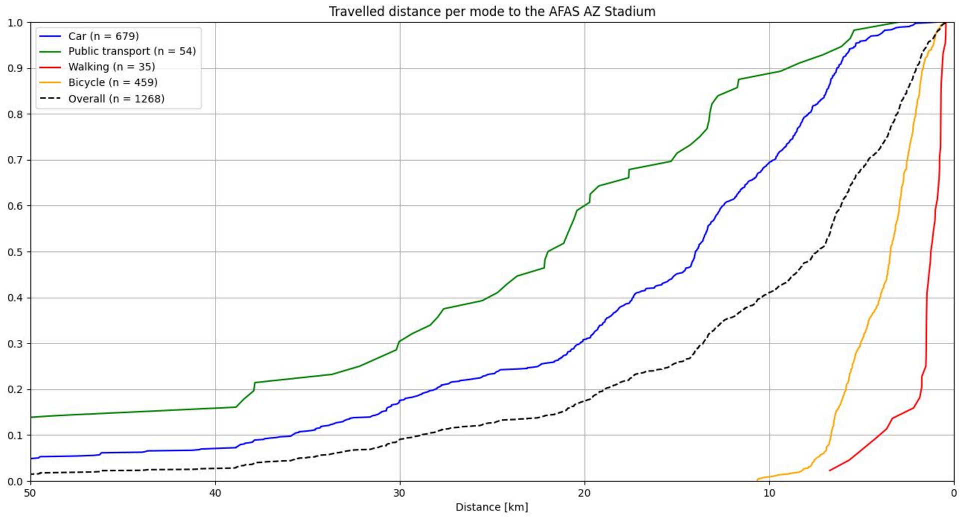

Figure 6.6: Cumulative distribution function of origin to AFAS AZ Stadium distance per the mode of survey sample

seen in the figure, there is a single peak present for car traffic, which causes a low standard of deviance (1.3). Based on the ANOVA statistical test from Appendix A, it is obtained that there is a significant difference between group means. The F(3.97, 0.04) indicates some variability between group means relative to the variability within groups. While the P-value of 0.04 suggests that there is sufficient evidence that there is a significant difference between the group means.

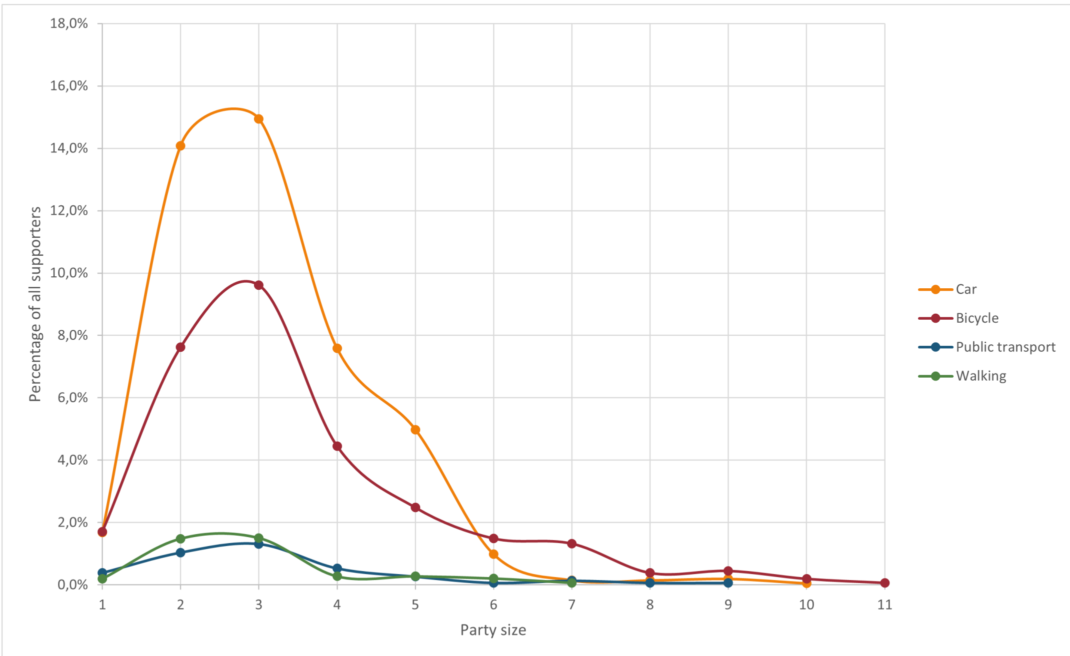

Figure 6.7: Mode choice concerning party size of survey sample

Choice frequencies

The choice frequencies are shown in Table 6.4. Based on this information, a modal portfolio can be derived (González et al., 2017). Within the first column of the table is the mode choice presented, which the respondents state. It can be seen that the public transport (n = 59) and walking (n = 59) modes are less opted for than car

Table 6.4: Choice frequencies per mode and distance of survey sample

Mode choice to stadium	Choice from choice set	2 km	3 km	8 km	13 km	17 km	26 km
Car (n = 756)	To Bicycle	36.1%	35.9%	26.7%	12.1%	14.9%	9.1%
	To Car	52.6%	56.0%	61.8%	76.1%	72.9%	76.6%
	To Public transport	4.9%	4.3%	10.0%	10.4%	11.2%	11.8%
	To Walking	6.4%	3.9%	1.5%	1.4%	1.0%	2.5%
Bicycle (n = 558)	To Bicycle	87.9%	86.9%	81.6%	61.2%	62.4%	48.8%
	To Car	4.9%	4.6%	7.6%	25.9%	20.4%	26.3%
	To Public transport	2.7%	3.5%	8.5%	10.4%	13.9%	22.7%
	To Walking	4.4%	4.9%	2.3%	2.4%	3.3%	2.1%
Public transport (n = 59)	To Bicycle	25.8%	46.2%	30.2%	20.7%	24.1%	3.8%
	To Car	8.1%	4.6%	6.3%	25.9%	16.7%	13.5%
	To Public transport	54.8%	44.6%	60.3%	46.6%	57.4%	80.8%
	To Walking	11.3%	4.6%	3.2%	6.9%	1.9%	1.9%
Walking (n = 59)	To Bicycle	10.0%	44.8%	23.7%	23.1%	22.9%	12.7%
	To Car	10.0%	15.5%	16.9%	34.6%	30.0%	34.5%
	To Public transport	0.0%	0.0%	0.0%	15.4%	7.1%	12.7%
	To Walking	80.0%	39.7%	59.3%	26.9%	40.0%	40.0%

(n = 756) and bicycle (n = 558). Therefore, the results of these two modes can be less accurate. Within the second column are the modes as presented within the choice scenarios. As described in subsection 5.2.3, each participant was presented with six choice scenarios. A modal choice is made based on, among other things, the distance between the origin and destination. The other columns show the percentage of choices for each distance and mode. For example, 52,6% of supporters who come to the stadium by car say they will travel by car when the distance is 2 km. A clear pattern can be seen for car users about the willingness to change mode. When the distance increases, they are less willing to change mode. Where the car was the opted mode in 52.6% of the times at 2 km, this increases to 76.6% at 26 km. When the distance increases, public transport is opted for more often, increasing from 4,9% to 11,8%. The opposite is true for the bicycle, which decreases from 36,1% to 9,1%. The willingness to change is even less for cyclists compared to the car for smaller distances. At 2 km, 87,9% of the time is the bicycle the opted mode of transport. Users of public transport and pedestrians are more willing to change than cyclists and car users. The amount of times the current mode is opted for again is occasionally less than 50%. Based on the chi-squared tests (Appendix A), a statistical significance between the stated mode choice and the modes from the choice scenario is determined. Moreover, there is statistical significance related to the distance and opted modes.

The respondents, therefore, show they are not always willing to change their current mode of transport. These findings align with the findings from Musgrave et al. (2019). From studies performed by Strömblad et al. (2022), two willingness to change groups are obtained (high and low willingness) to change their mode choice. Based on this study, different approaches for each category are needed to be implemented. Research has even found that habit is the strongest predictor for the willingness to change (Hoffmann et al., 2017). These studies are based on the finding that car commuters are more likely to use their car during non-commuting trips than other mode commuters (Rubin et al., 2014; Sharmeen & Timmermans, 2014). Nonetheless, numerous studies suggest that the selection of a transportation mode is influenced not only by rational decision-making but also by habitual patterns and past actions (Gardner & Abraham, 2008; Havlickova & Zamecnik, 2020; Lanzini & Khan, 2017; Sharmeen & Timmermans, 2014; Verplanken & Whitmarsh, 2021). Based on Table 6.4, a couple of willingness to change values are of interest. Starting with the fluctuation between transit users who are fluctuating over distance. Also, the increase in car usage when distance increases stands out. While the opposite is true for cyclists. At last, the respondents who are willing to walk 13 + kilometres.

Based on this last group, which opts for walking, a deeper analysis is done. In total, 101 respondents say they are willing to walk at least 13 kilometres in at least one scenario. Distributed over the three different distances, it has 42 respondents in a scenario with 13 kilometres, 50 for 17 kilometres and 48 for 26 kilometres. This also indicates that 39 respondents have stated that they are willing to walk for more than one distance. Almost one-third of the respondents who are willing to walk say they usually come to the stadium on foot. Most of these supporters have chosen the walking alternative in every situation. Interestingly, most people (60%) who have opted for this are older than 55 years. Also, 78% have said they are more than eight matches per season at the AFAS AZ Stadium. This group is kept within this study since it shows they are less willing to change their behaviour. Although it can be discussed, these respondents have understood the aim of this study. For people who usually come by other modes (n = 92), their willingness is higher. However, they have opted to do it more often for walking. Reasoning for this can be found in choosing a disproportionate option that cannot be achieved. These answers are still used within the choice model. However, this has a downside the choice model is likely to estimate walking along higher distances than in reality. Whether this is the case is presented in the following section.

6.2. Model estimation

Within this section, at first, the goodness of fit is discussed. A final estimation model for the utilities is derived based on the goodness of fit. This is followed by a sensitivity check of the estimated variables within the final model. At last, a validation is conducted to compute an estimation of the utilities from the model outcome. These utilities are expressed in a modal split compared to the revealed preference data. In Figure 6.8, the model estimation process is shown. The process is split into two groups. The first group focuses on the base model, whereas the second model focuses on the final model. Only the choice set variables (travel time, comfort, reliability and cost) are used for the base model. With this model, the first result of the choice set is obtained. At first, a generic approach is taken with an estimation of generic variables which are not dependent on the modality. Afterwards, the number of variables is increased by making these variables mode-specific. Afterwards, the descriptive statistics are added to increase the predictive power of the model in the final model. A similar approach is used by first adding generic variables to the choice model. Afterwards, these variables are made mode-specific. To increase the model's efficiency, the number of variables is reduced by looking at the significance of the estimated variables (steps 4 and 5). The correlation between the remaining variables is then tested during the sixth step. When no statistical difference exists in the variable correlation, the mode-specific variables are converted to generic variables.

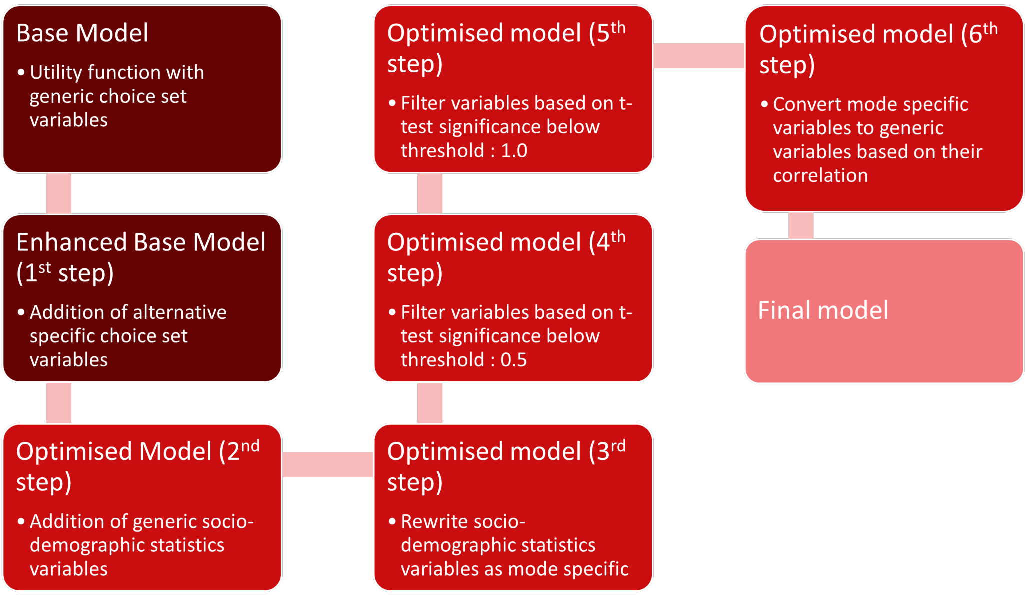

Figure 6.8: Step-wise workflow for MNL model estimation

6.2.1. Goodness of fit

MNL Base model

Within the base model, only the choice sets attributes are shown. This means only the variations in travel time, comfort, costs and reliability are used. At first, a model is derived which contains generic variables of the choice model. Afterwards, this model is improved by adding alternative-specific variables. This causes for the ρ^2 to increase from 6e-4 to 0.002. Therefore, the predictive power of the model increases. Based on this model, other attributes, such as descriptive statistics, are added. By adding these parameters afterwards, the predictive power of the model increases. The utility function for the base model per mode i is shown below in Equation 6.1. The variables and parameters of this function are described in Table 6.5.

$$U_i = ASC_i + \beta_{TT,i} * TT_i + \beta_{Dummy,i,rel} * R_{dummy,i} + \beta_{Dummy,i,comf} * COMF_{i,dummy} + \beta_{C,i} * C_i \quad (6.1)$$

Table 6.5: Utility function parameter explanation of base MNL model

Parameter		Description
i	:	Mode of choice [car, bicycle, public transport, walk]
U_i	:	Utility of mode i
$\beta_{TT,i}$	:	Alternative specific variable for travel time
$\beta_{Dummy,i,rel}$	:	Alternative specific dummy variable for reliability
$\beta_{Dummy,i,comf}$	:	Alternative specific dummy variable for comfort
$\beta_{C,i}$	:	Alternative specific variable for cost
TT_i	:	Travel time of mode i
$R_{dummy,i}$	:	Categorical variable for reliability of mode i
$COMF_{i,dummy}$	:	Categorical variable for comfort of mode i
C_i	:	Cost of mode i

From the utility function, it can be seen that there are dummy variables used for comfort and reliability. This is done since both the variables are categorical. Whereas the travel time and costs are continuous variables. In Appendix F, the results of the complete base MNL model are shown. The main results of the model estimation are displayed in Table 6.6. In this table, it can be seen there are, in total, fifteen parameters estimated. Based on a sample size of 9,000 answers, the model has a ρ^2 of 0.00154.

Table 6.6: Results of the base MNL model

Number of estimated parameters	:	15
Sample size	:	9000
Init log-likelihood	:	-9747.725
Final log-likelihood	:	-9747.725
Rho-square-bar for the init. model	:	0.00154
Akaike Information Criterion	:	19525.45
Bayesian Information Criterion	:	19632.02

The estimated variables are shown in Table 6.7. Based on the Rob. T-test the significance of the variables is tested. The ASCs for public transport and walking are above 1.96, indicating they are significantly different from the car. ASC is a collection point for variables not yet estimated in the model. The statistical significance is explainable since this is a simplistic representation of the entire model. However, the ASC for bicycles is not significant, which indicates the variables estimated in this model are significant within the model. The dummy variables for comfort show both minuses and plus signs. This is related to the base scenario versus the other scenario. Comfort for bicycles, for example, has a moderate level of comfort as a base. Within the alternative scenario, this is uncomfortable. The opposite is true for cars and public transport, where the other scenarios are improvements in the level of comfort. Travel time and costs are negative, as expected. This indicates the utility one experiences decreases when travel time or costs increase. The costs for bicycles, however, are not indicated as significant following this model, which is interesting. Costs for bicycles are expressed as a refund of money, as a reward when someone comes by bike. It can be the case that this is not interpreted as such and thus did not impact the choices made by people. However, it can also be discussed that it does not significantly affect the mode choice for bicycles. A similar discussion can be made about the costs of public transport. This dummy variable is also not significant following the t-test. When looking at the p-value, it indicates whether the observed difference is of statistical significance. The lower this value, the greater its significance is. Usually, a p-value of 0.05 is used as a benchmark. When using this value, it can be seen that some variables are not statistically significant. Three variables stand out: the dummy variable for walking and the bicycle costs.

Table 6.7: Variable estimation of base MNL model

	Value	Rob. Std err	Rob. t-test	Rob. p-value
$ASC_{Bicycle}$	0.145	0.17	0.854	0.393
ASC_{PT}	-1.76	0.169	-10.4	0
ASC_{Walk}	-2.07	0.192	-10.8	0
$\beta_{Dummy,bike,comf}$	-0.133	0.059	-2.25	0.0242
$\beta_{Dummy,car,comf}$	0.07	0.0568	1.23	0.218
$\beta_{Dummy,PT,comf}$	0.142	0.0758	1.87	0.0612
$\beta_{Dummy,walk,comf}$	-0.0238	0.103	-0.232	0.817
$\beta_{C,bike}$	-0.00272	0.00936	-0.29	0.772
$\beta_{C,car}$	-0.0408	0.0182	-2.25	0.0244
$\beta_{C,PT}$	-0.0617	0.044	-1.4	0.161
$\beta_{Dummy,car,rel}$	-0.138	0.0468	-2.96	0.00312
$\beta_{TT,Bike}$	-0.0316	0.00251	-12.6	0
$\beta_{TT,car}$	-0.0611	0.0109	-5.61	2.05e-08
$\beta_{TT,pt}$	-0.0285	0.00294	-9.7	0
$\beta_{TT,walk}$	-0.00987	0.000972	-10.2	0

Final MNL Model

By the addition of the socio-demographics, the predictive power of the model is increased. Since most variables are categorical, different dummy variables are used. The coding of these dummy variables is shown in Appendix F. The descriptive statistics with dummy variables added to the model concern gender, age, season ticket, attendance, habit, stand, license and vehicle availability. Besides these variables, three continuous variables are added distance, party size and arrival time. To estimate these variables, a base modality has to be considered as a reference. For this study, the car is used as the reference modality. Car is chosen since this modality is preferred to the other modes following the data analysis in chapter 3. This aligns with studies from Bekhor and Shiftan (2010) who claim that the alternative modalities should be compared to the dominant mode. This way, most answers are not considered, providing better insight in estimating the variables.

Within the second step, the generic descriptive variables are added to the model. By doing so, the ρ^2 increases to 0.143 with 44 estimated variables. This shows that the model fits better to the data set than without the descriptive variables. However, this is not surprising since the number of variables has increased from 15 to 44. When adding more parameters by making the descriptive variables mode specific, this ρ^2 increases further to a 0.202 value. Adding more parameters, however, can cause overfitting of the model. Increasing the complexity of the model in the third step results in a total of 105 parameters. Therefore, the AIC and BIC values are checked to compare this overfitting. The lower the values of these two criteria, the better the model is. To overcome the problem of overfitting, the insignificant variables are neglected within the model. A two-step approach is used to test whether removing these variables is effective. Step 4 removes only the insignificant variables with a t-test lower than 0.5 in absolute terms. Afterwards, the variables with an absolute t-test statistic between 0.5 and 1.0 are neglected from the study. This results in the total number of variables reducing from 105 to 86 and afterwards to 75, respectively. However, the model fit improves within the model together with the AIC and BIC values, which decrease. This indicates the model's predictive power increases when the insignificant attributes are removed. Between the fourth and fifth steps, the model fit does not increase. Therefore, it is chosen to not further remove parameters based on their significance. Within the final step, the correlation between the mode-specific variables is tested. When the t-test statistics values are below a threshold of 1.96, the mode-specific variables are merged into a generic variable. This was done for the age levels 26-35, 36-45 and 46-55 and the moped licenses. Making these variables generic, the ρ^2 decreases to 0.374 slightly. However, the AIC increases, whereas the BIC decreases. This indicates that it has some influence on the goodness of fit. In Table 6.8, an overview of the ρ^2 with the AIC and BIC for each step process is shown.

Looking at the parameter estimation, as shown in Table 6.10, it can be observed that there are only a few parameters that are not significant anymore. Factors which are not significant for a 95% confidence interval are the age groups 26 - 36 and 65+ for bicycles and gender for public transport and walking. However, these variables are significant for a 30% (TU Delft (2022): t-statistic = 1.03) confidence interval. The smallest t-test statistic variables are the comfort level for walking and bicycle-specific dummy variables for 3+ vehicles available. A small t-test

Table 6.8: MNL Choice model results per step

Step	#Parameters	ρ^2	AIC	BIC
Base	7	0.166	20831.69	20881.42
1	15	0.219	19525.45	19632.02
2	44	0.322	16999.66	17312.28
3	105	0.376	15766.57	16512.59
4	86	0.376	15730.43	16341.46
5	75	0.376	15719.48	16252.35
6	66	0.374	15749.3	16218.23

statistic for the comfort level for walking can be discussed as there is no difference for pedestrians within the level of comfort. This discussion is also made by (Bardutz & Bigazzi, 2022). He showed little difference between the users' classes for speed- and comfort-seeking pedestrians at mass events. A small sample size can explain the second since the number of respondents with 3+ cars was smaller than the other levels. Since all descriptive variables are measured for the car, the results should be interpreted as such. Based on the negative sign of the ASC values, it can be concluded there is a negative factor to use the other modes. This can be expected since the car is the dominant mode to travel to the AFAS AZ Stadium.

Age also negatively impacts choosing modes other than the car. Since all age variables are negative, it gives a lower utility than a car. It has to be noted, however, that the variable fluctuates when supporters are above 60 years. Since the estimated parameter for public transport (-0.792) is much lower than for bicycles (-0.009). This indicates that this age group is less willing to use public transport to travel than the bicycle. This finding is underpinned by the study from Böcker et al. (2017), which showed that elderly people prefer riding a bicycle for trips compared to public transport. The assumption of this is that this group has a bicycle available. Regarding the Dutch context, this is seen as a valid assumption (United Nations, 2018).

The attendance rate shows two key findings. At first, the utility of choosing public transport becomes higher when supporters are not always present. This indicates this group of supporters is more willing to use transit to get to the stadium. Harz and Sommer (2022) showed a positive influence on going to an event-related venue by public transport. Especially when this event has good connections to the origins (e.g. hotels). The second finding indicates walking and cycling have less utility for supporters who attend matches more than seven times per season. Since cycling comes second in the modal split and an attendance of seven plus is the highest sample, a negative sign of these variables can be expected. If they were positive, it can be expected cycling would be the dominant mode of transport.

Habit shows to impact the utility of a mode positively. This indicates a significant relation between the means of transport that people are used to commuting with and their travel pattern to the AFAS AZ Stadium. Especially the supporters who often cycle to their work and use public transport more quickly than taking a bicycle. And are more willing to use these modes compared to cars. For the mode choice, a similar conclusion can be drawn. Since all these values are relatively high, ranging between 0.5 and 3.8, the usual mode of transport plays a role in the choices made by supporters. This finding is broadly discussed within transport choice modelling (Aarts et al., 1997; Asgari & Jin, 2020; Lättman et al., 2018; Musgrave et al., 2019). From Aarts et al. (1997), the respondent who highly depends on their habits uses fewer attributes regarding the trip that had to be made. In addition, strong-habit individuals were more selective in using the information of the characteristics of choice options than weak-habit individuals. Besides these findings, the habit acts as a barrier toward behavioural changes (Asgari & Jin, 2020).

At last, the vehicle availability shows negative and positive signs. For example, the group that has three or more vehicles available gets a lower utility for using other modes than the car. While the group who has no vehicle available gets a higher utility when taking other modes than the car. This is in line with findings from Ergin and Tezcan (2022). In this study, it has been shown that there is a dis-utility for supporters of Turkish football clubs to use public transport when they have a vehicle available. The other way around this thus means that people who don't have a vehicle available have a lower likelihood to use a car to attend matches (Ergin & Tezcan, 2021, 2022; Kuppam et al., 2013). Also, the travel time has a negative influence on the utility of supporters. This indicates that the utility decreases when the travel time increases.

Table 6.9: Parameter estimation for MNL choice model estimation step process 6

	Value	Rob. Std err	Rob. t-test	Rob. p-value
ASC BIKE	-0.404	0.214	-1.884	0.060
ASC PT	-2.339	0.232	-10.071	0.000
ASC WALK	-2.608	0.272	-9.599	0.000
B Age dummy 1 bike	-0.094	0.082	-1.149	0.251
B Age dummy 2	-0.268	0.076	-3.529	0.000
B Age dummy 4	-0.159	0.069	-2.289	0.022
B Age dummy 5 PT	-0.792	0.144	-5.503	0.000
B Age dummy 5 bike	-0.098	0.085	-1.160	0.246
B Arrival time PT	-0.007	0.003	-2.363	0.018
B Arrival time bike	-0.009	0.002	-4.713	0.000
B Arrival time walk	-0.012	0.004	-3.001	0.003
B Attendance dummy PT 2	0.339	0.158	2.136	0.033
B Attendance dummy PT 3	0.349	0.184	1.894	0.058
B Attendance dummy PT 4	0.738	0.353	2.087	0.037
B Attendance dummy bike 1	-0.155	0.078	-1.992	0.046
B Attendance dummy bike 2	-0.172	0.093	-1.845	0.065
B Attendance dummy walk 1	-0.261	0.161	-1.624	0.104
B Attendance dummy walk 2	-0.498	0.176	-2.825	0.005
B COMFORT BIKE DUMMY	-0.175	0.068	-2.571	0.010
B COMFORT CAR	0.068	0.066	1.028	0.304
B COMFORT PT DUMMY	0.188	0.083	2.278	0.023
B COMFORT WALK DUMMY	0.005	0.113	0.042	0.967
B COST BIKE	-0.005	0.011	-0.451	0.652
B COST CAR	-0.056	0.021	-2.626	0.009
B COST PT	-0.103	0.049	-2.119	0.034
B Distance bike	-0.003	0.001	-2.335	0.020

Table 6.10: Parameter estimation for MNL choice model estimation step process 6

	Value	Rob. Std err	Rob. t-test	Rob. p-value
B Gender dummy PT	-0.170	0.092	-1.853	0.064
B Gender dummy walk	0.091	0.125	0.723	0.470
B Habit dummy PT 1	0.323	0.095	3.415	0.001
B Habit dummy PT 2	0.766	0.119	6.457	0.000
B Habit dummy bike 1	0.293	0.066	4.412	0.000
B Habit dummy bike 2	0.390	0.097	4.001	0.000
B Habit dummy walk 2	-0.452	0.218	-2.073	0.038
B License dummy 2	1.217	0.419	2.903	0.004
B License dummy bike 1	0.139	0.113	1.232	0.218
B Mode choice dummy PT 1	1.507	0.093	16.232	0.000
B Mode choice dummy PT 2	0.506	0.257	1.971	0.049
B Mode choice dummy PT 3	3.214	0.188	17.123	0.000
B Mode choice dummy bike 1	2.629	0.073	36.028	0.000
B Mode choice dummy bike 2	1.021	0.172	5.939	0.000
B Mode choice dummy bike 3	1.518	0.193	7.886	0.000
B Mode choice dummy walk 1	1.614	0.142	11.375	0.000
B Mode choice dummy walk 2	3.815	0.175	21.859	0.000
B Mode choice dummy walk 3	1.985	0.306	6.491	0.000
B RELIABILITY CAR DUMMY	-0.187	0.055	-3.393	0.001
B Season ticket dummy PT 1	0.190	0.096	1.974	0.048
B Season ticket dummy PT 3	0.110	0.156	0.703	0.482
B Season ticket dummy bike 3	0.157	0.079	1.986	0.047
B Season ticket dummy walk 3	0.485	0.146	3.315	0.001
B Stand dummy PT 2	-0.403	0.141	-2.854	0.004
B Stand dummy bike 1	-0.130	0.061	-2.132	0.033
B Stand dummy bike 2	-0.395	0.096	-4.104	0.000
B Stand dummy walk 2	-0.195	0.187	-1.046	0.295
B Stand dummy walk 3	0.388	0.144	2.692	0.007
B TT BIKE	-0.039	0.003	-13.949	0.000
B TT CAR	-0.067	0.012	-5.565	0.000
B TT PT	-0.032	0.003	-10.143	0.000
B TT WALK	-0.012	0.001	-11.073	0.000
B Vehicle availability dummy PT 1	-0.120	0.083	-1.443	0.149
B Vehicle availability dummy PT 2	-0.351	0.170	-2.064	0.039
B Vehicle availability dummy PT 3	0.580	0.185	3.125	0.002
B Vehicle availability dummy bike 2	-0.010	0.113	-0.091	0.927
B Vehicle availability dummy bike 3	0.505	0.165	3.069	0.002
B Vehicle availability dummy walk 2	-0.844	0.335	-2.521	0.012
B Vehicle availability dummy walk 3	1.150	0.227	5.060	0.000

6.2.2. Sensitivity analysis

A sensitivity analysis of the final MNL model is done within this section. This analysis first tests whether the model provides reliable and thrust-worthy outcomes. The sensitivity is tested by using sections of the entire sample size. Three levels of the complete sample size are compared to the results of the model presented in the previous section. Components taken from the sample are 50-, 75- and 90% of the sample. The results of the β-estimation are shown in Figure 6.9. To determine whether the values significantly differ, a t-test is performed, comparing each of the beta values of the random sample to the beta value found in the entire dataset. The critical value is 1.96 with α= 0.05. Computing the overall t-statistic of the obtained β values of the samples shows whether the model provides accurate variable estimations. These test statistics are calculated as -1.518, -0.581 and -0.998 for the 50-, 75 and 90% samples. Therefore, it can be concluded that the model provides accurate estimates for the estimated β variables.

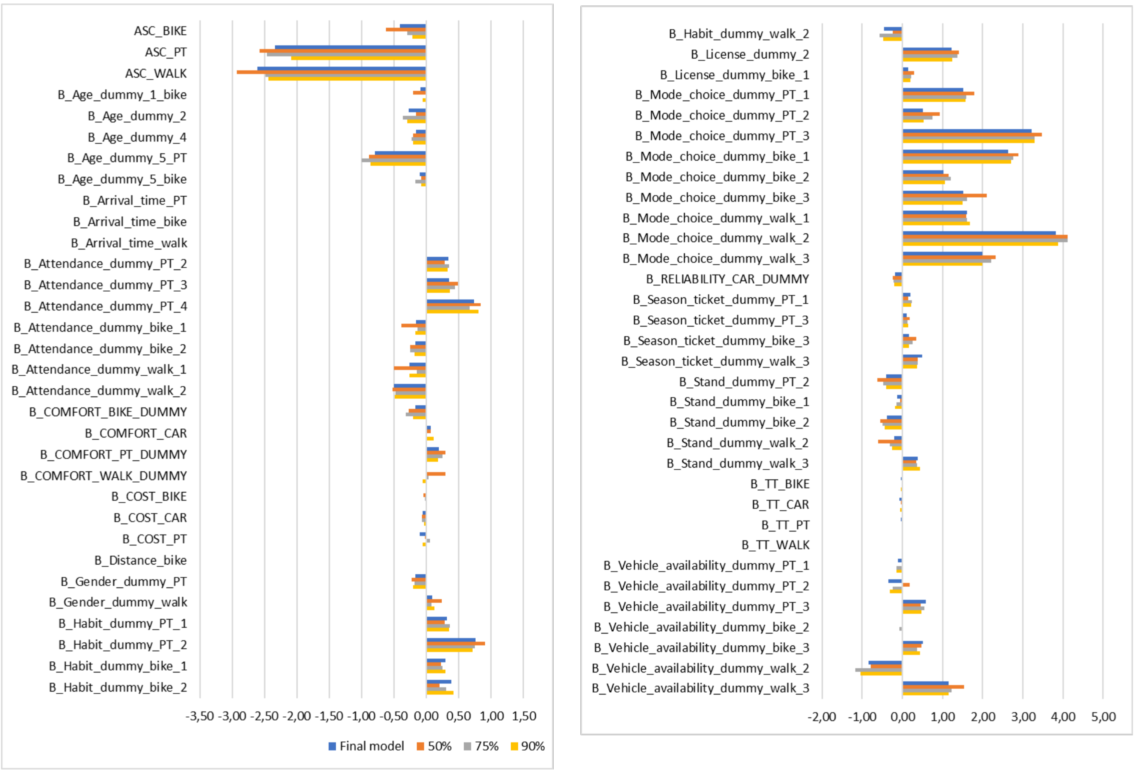

Figure 6.9: Sensitivity analysis of the estimated parameters in the final MNL choice model

It can be seen that all the variables obtain similar positive or negative signs. However, the magnitude of some of the variables changes. Some key findings regard the dummy variable for the level of comfort of walking. Within the 50% sample, this dummy variable positively influences the utility function. Whereas this is close to zero in the full sample. Similar findings are obtained for the cost variable of cycling. This variable estimate has a higher dis-utility within the smaller sample sizes than in the overall sample. Reasoning for this can be found since not all the choice alternatives are covered within the reduced samples. Therefore, the changes within the choice sets (e.g. level of comfort of walking) are not considered equally.

Other variables which are part of the descriptive statistics are vehicle availability, stand and gender. Regarding vehicle availability, the estimated variables for bicycle and public transport of the group with three or more vehicles available show the highest variability. The utility of taking these modes when one has more than three cars available stays negative. Comparing the entire sample to the other three samples, the dis-utility increases for public transport. The opposite is true for the bicycle, where the dis-utility decreases when comparing the entire sample to the other samples. Estimating the dummy variable for walking at the Victorie stand shows the sample deviation. Comparing the 50% sample to the entire sample shows the dis-utility of walking decreases within the entire sample. This can be explained by the other half of the choice set containing more supporters at the Victorie stand. The estimation of the gender dummy variable for walking is discussed lastly. The utility of walking for women seems to decrease when the sample size increases.

6.2.3. Validation

Within this section, the model outcomes are compared to the data of chapter 3. Multinomial logistic regression will be used to calculate the modal split. Within Equation 6.2, the formula is shown to calculate e the probability (P) of choosing mode (i). The validation of the model is done firstly by comparing the outcome of the base scenario to the data discussed in chapter 3. Afterwards, the influence of different descriptive statistics on the modal split is discussed and elaborated.

$$P_i = \frac{e^{U_i}}{\sum_{i=1}^{n}\left(e^{U_i}\right)} \tag{6.2}$$

Based on the base conditions as discussed in chapter 5, the modal split is calculated. This results in the modal split per distance group. Calculate the modal split within the choice model by setting all descriptive parameters to zero. This means the dummy variables within the utility function are not all considered within the model. By doing so, the model's results will be less accurate; however, the time it takes to process the results decreases. The null scenarios of the descriptive statistics are all derived based on the largest sample. Therefore, the modal share calculation of these groups is most justified. The figure below shows the mode share for the group of male visitors aged between 18 and 25 years. This group is well aware of the surroundings since they have a season ticket for longer than ten seasons and are always present. They often come to the stadium by car and are seated at the Molenaar stand. To commute to work/study, this group also takes the car. From the figure, it can be seen that the majority of this visitor group comes by bicycle and car. A clear trend is visible when distance increases, the share of cyclists decreases, and car users increases. For public transport and walking, the share stays somewhat similar. However, a slight increase in public transport usage can be determined. Noted has to be that the group of cyclists and pedestrians does not converge to zero since some supporters have stated they will use these modes to travel to the venue.

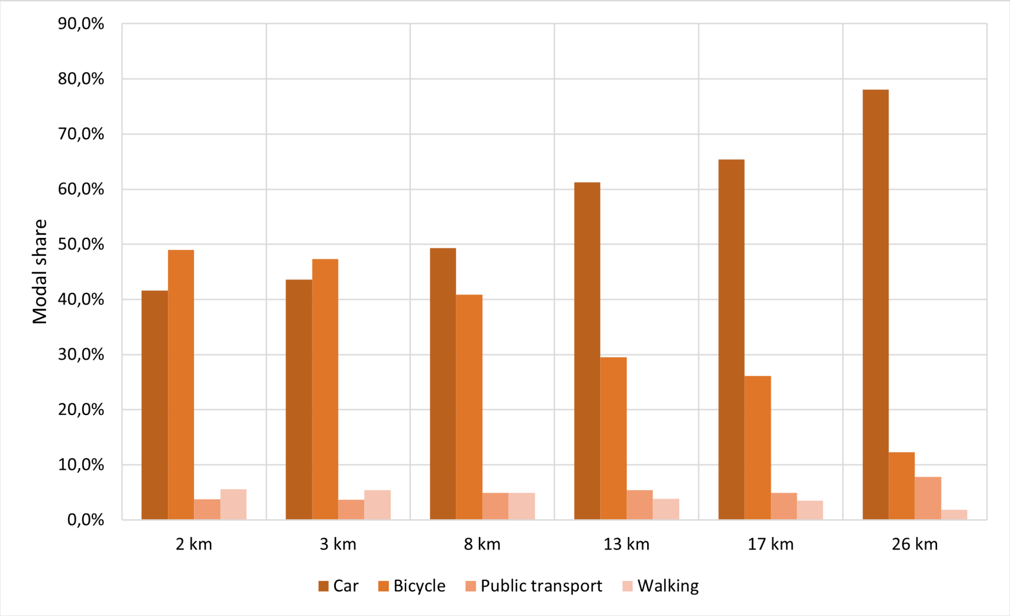

Figure 6.10: Calculated mode choice probability in base scenario

For the base group, the modal split is calculated based on the modal shares per distance. It can be seen that 20% of the supporters come from a two-kilometre radius. For three kilometres another five percent of tickets sales are added. The other regarded distances within the choice model (8, 13, 17 and 26 kilometres) have an additional ticket sale percentage of 25, 25, 5 and 10 respectively. Based on the ticket sale ratio per distance and the modal share, a modal split is calculated for this group in Table 6.11. This modal share is compared to the stated modal split within the survey. A modal split can be derived since the respondents have indicated by which mode they usually go to the stadium. Based on this comparison, it can be seen that there is little difference between the modal share of the group and the modal split from the survey. The highest deviation is a reduced number of cyclists, only 3.1 percent.

Table 6.11: Calculated modal share from MNL compared to revealed modal split in base scenario

	Calculated modal share	Modal split	Difference
Car	54.7%	52.8%	1.9%
Bicycle	35.9%	39.0%	-3.1%
Public transport	5.1%	4.1%	0.9%
Walking	4.4%	4.1%	0.2%

After calculating the modal share for the null group, the variables are altered. The variables are altered per choice distance, and the differences in the modal split are discussed. This way, the results of the final modal are examined.

Starting with the first distance (2 kilometres), altering between males and females only influences the probability of walking instead of public transport. This change can be explained since women have a higher utility for walking than for public transport. When age increases, the probability of cycling decreases from 49.1% to 34.5% in the age group 36 - 45.

For the distance group of 8 kilometres, the changes in mode choice probability for the variables attendance and mode choice are compared. Based on the model, it is estimated that more supporters will opt for active modes such as cycling than they have no season ticket. Looking at the variable parameter, this can be explained since either cycling or walking gives a higher utility for someone without a season ticket than someone with a 10+ year-long season ticket. Supporters who are regularly at the stadium, as opposed to the ones who are always present, are more likely to choose the car or public transport. However, when a visitor is only occasionally at the venue, the probability of choosing a car or a bicycle is almost similar. Since the last group only visits the stadium once or twice every season, they are more willing to choose public transport. This gives them a higher utility when looking at the estimated parameter value.

Considering the regular mode choice for the group who is always present, this gives the largest changes in mode choice probability. Simultaneously, this has the highest willingness to pay for people. The willingness to pay for one mode of the car can be calculated by dividing the beta of the current mode choice by the cost variable of the mode. For example, dividing the beta estimate of bicycle choice (2.63) of cost for a bicycle (-0.005) gives a willingness to pay of -526. This shows that supporters who use the bicycle as a means of transport are not very willing to choose for car. The supporters who usually travel by public transport are more willing to pay for bicycles, with -4.90 as their willingness to pay. This indicates that the public transport group will change to cycling when the costs increase by 4 euro and 90 cents. Altering the regular mode choice to the venue also shows to have a large impact on the mode choice probability. Changing the regular mode choice to walking shows that there is a higher probability one will walk even though it is a 96-minute walk.

At the last distance group of 26 kilometres, the habit and vehicle availability are alternated. For the habit of commute mode, the variable estimation shows a higher utility is obtained when other than cars are used. Except when one is usually walking towards the venue, and their willingness is against public transport. This will result in a lower utility and thus a lower probability this group will opt for public transport. Little changes within the mode choice probability when someone has a car available. However, when someone has no vehicles available, the choice probability decreases, especially walking increases. This can be seen by the willingness to pay since the other mode users will gain utility if they choose to walk.

6.3. Conclusion

In this chapter, the extent to which decision factors affect the modal choice behaviour is determined. This forms the basis to predict the probability of modal choice for visitors of the AFAS AZ Stadium. In total, the SP survey is filled in by 2,218 respondents. This group is reduced to a final sample of 1,808 respondents by validating the results and using exclusion criteria. Of this group, it can be seen that the majority of respondents are male (77.0%). The supporters between 46 and 65 are overrepresented (47.2%) within this survey. Therefore, it can be expected that the mode choice for cars is higher since more people between 45 and 65 have a vehicle available. The differences between the stated and obtained arrival times are similar. The supporters with their origin < 2km towards the venue are underrepresented within the sample. From the sample, a ratio of 63.9% owns a season ticket. Of this percentage, the majority is at the Molenaar stand and the Ben-Side. The Alkmaarderhout-, and Victorie stands are underrepresented within the sample compared to the other two sections. Almost half of the stated season ticket holders have had their season ticket for over ten years. Based on the sample, it can be seen that the modal split of the car increases when the visit frequency decreases. An opposite finding can be made when comparing bicycles with the visit frequency. The findings for bike and car use share compared to the visiting frequency can be related to the respective average distances. The average distance increases when attendance reduces. There also exists a correlation between the mode used for commuting and travel to the AFAS AZ Stadium. Supporters on the main (Victorie) stand are earliest within the stadium, followed by the Ben-Side.

To quantify these findings, different choice models have been derived. At first, a generic approach is taken with an estimation of generic variables which are not dependent on the modality. Afterwards, the number of variables is increased by making these variables mode-specific. Afterwards, the descriptive statistics are added to improve the model's predictive power in the final model. From the final MNL model, negative ASC values are obtained. It can be concluded there is a negative factor to use the other modes. This can be expected since the car is the dominant mode to travel to the AFAS AZ Stadium. Age also has a negative impact on choosing other modes than the car. The analysis of t-test statistics highlights the smallest values for comfort level in walking and bicycle-specific dummy variables for 3+ vehicles available. The small t-test for the bicycle variable is attributed to a small sample size with 3+ cars. Age has a negative impact on choosing modes other than cars, especially for those above 60, with public transport less favoured than bicycles. The attendance rate reveals higher utility for public transport when supporters are not always present, suggesting a greater willingness to use transit. Conversely, walking and cycling have lower utility for those attending matches more than seven times per season, aligning with cycling being less dominant in this scenario. Habit positively impacts mode utility, indicating a significant relationship between commuters' usual means of transport and their travel patterns to the stadium. This aligns with existing transport choice modelling discussions, emphasising the role of habit as both a preference and a barrier to behavioural changes. Vehicle availability impacts utility, with three or more vehicles preferring cars, while those without vehicles prefer other modes. Travel time negatively influences supporter utility, indicating decreased utility with increased travel time.

7 Multi-Criteria Decision Making

The BWM method is used to assess the discussed solutions. Within BWM, weights in the value function are calculated based on expert judgment. This chapter first examines the attributes used to evaluate the alternatives. The stakeholders are asked to rank these attributes based on their perspectives. Ranking of these attributes and weights results in the relative importance of the weights in section 7.3. Afterwards, the performance of the alternatives is scored within the performance matrix. At last, the assessment of these alternatives is based on the relative importance of the attributes in section 7.4.

7.1. Attributes

Attributes are needed to obtain the ranking of the alternatives. The relevant stakeholders then weigh these attributes in this study. To gain a broad view of the alternatives, six attributes are considered. These six attributes are shown in Figure 7.1. These attributes are derived from the interviews held with stakeholders.

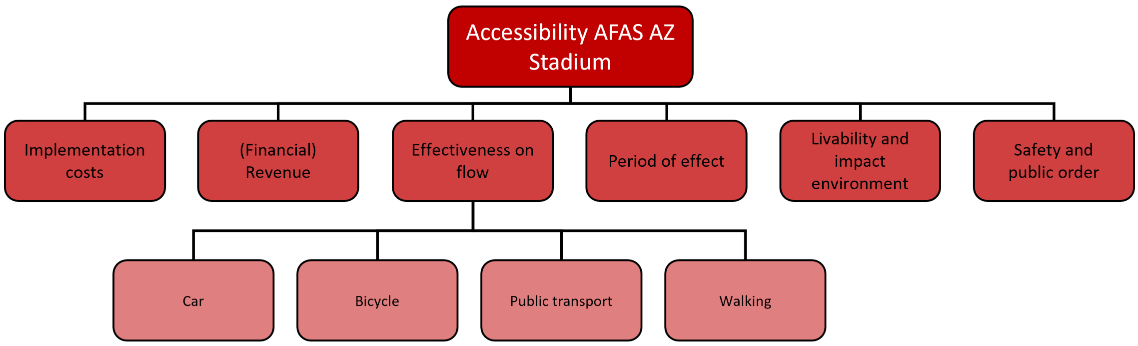

Figure 7.1: Attributes used for multi-criteria decision making

The first attribute which is measured concerns the *effectiveness of the measure on flow*. The choice model (chapter 6) is used to assess the effectiveness. A new modal split is computed by the changes the alternatives bring to the choice set variables (comfort, travel time, costs and reliability). Comparing the changed modal split to the original one shows how the measure affects supporters' choices. Based on this change, the rating is given. Since the overall modal split does not directly provide insight into the effectiveness, this measure is split into four modalities. Therefore, a second attribute level is derived to assess the importance of the four modes (Car, bicycle, public transport and walking). With these second-order attributes, the relative importance of each mode is quantified. The calculated mode choice probability shows whether the choice probability will change. Based on this change, a score on a Likert 5 scale will be given. This means that an alternative which causes a higher mode choice probability will score well. Meanwhile, the alternatives cause reduced mode choice probability scores badly. Scales in which the mode choice probabilities and the Likert 5 scale are divided is shown below:

- $++$: Mode, choice probability $>$ 7.5%
- $+$: 2.5% $<$ Mode choice probability $\geq$ 7.5%

- $/$: -2.5% $<$ Mode choice probability $\geq$ 2.5%
- $-$: -2.5% $<$ Mode choice probability $\geq$ -7.5%
- $--$: -7.5% $<$ Mode choice probability

The second and third attributes are focused on costs. Firstly, the costs focus on the direct *costs* attached to the measure's implementation. Normally, these costs will be expressed in terms of monetary value. However, to safeguard the scope of this research, a Likert 5-scale is used. In this scale, a bandwidth of very expensive to very cheap is opted for. As an example, the additional road infrastructure will have high implementation costs. Whereas the on-field performances will be free to implement. The bandwidth of this Likert scale then increases from free to very cheap, relatively cheap, relatively expensive and expensive, respectively. For the *(financial) revenues*, the opposite of the costs is considered. Due to the changes in services or infrastructure, the supporters' behaviour will be adopted. For example, developing a fan zone will enhance early arrivals. Since the supporters are at the venue earlier, they are more likely to have extra beverages. This will cause an increase in revenue. The scale of these revenues ranges from none to a very high increase in revenue. In between steps are the subtle increase in revenue, marginal revenue increase and significant increase in revenue.

The *period in which the effect of the measures is visible* is another attribute in the decision set. The impact of some of the measures on accessibility can be directly visible. While the impact of some of the measures may involve the supporters to be 'educated'. This involves a behaviour change which takes longer to have an impact. The supporter busses, for example, will not be directly full when they are introduced. This will need some time to be found by the supporters of AZ. Whereas an extra off-ramp of the stadium site will show direct changes in the egress of supporters. ++ will score measures that directly impact the accessibility of the AFAS AZ Stadium. Long-term investments and behavioural changes are expected to take over five years and thus are scored with a –. The measures which involve some implementation and thus the effects are visible within six months are scored with a +. In between these are the effects, which take a full season and approximately two seasons. The measures taking time for the supporters to be educated expected to take at least two or three years to reach their potential.

Livability and impact on the (build) environment is considered as fifth attribute. This attribute considers the measures' negative and positive effects on the venue's surroundings. Also, whether the measures can be used permanently (when there is no event) is considered. When a measure costs money but can be used permanently, it is easier to implement the specific measure. This, in combination with the positive or negative influences a solution has on the surroundings. The measures will be scored using a Likert 5-scale with '–' and '++'. The minuses have a very bad impact on the livability of the environment and have no contribution to non-event days. The pluses, on the other hand, show the measure has a very positive impact on livability. This also means the measure can also be used during non-event days. In between these rankings are the measures with low, medium, and high contributions to the livability and impact on the built environment on non-event days.

At last, *safety and public order* are considered. This factor is considered since safety aspects are highly considered for football-related events in terms of fan behaviour. In recent years, different incidents have put safety and public order under a microscope. Recent examples of recent troubles have been seen during AZ - Legia Warshaw (NOS, 2023b), AZ - West Ham United (NOS, 2023c), AZ - NEC (De Gelderlander, 2021) and Ajax - AZ (NOS, 2023a). This safety aspect focuses on whether additional security efforts in the form of security or police are necessary. If, due to the measure, less deployment of personnel is required, this will score very well. Whereas deployment of extra personnel is required, this will score less. No changes to the usage of stewards/police will result in a net score of 0. An example showing that more safety measures are necessary involves extending the safe-standing sections. While the alternatives where traffic flows around match days are organised differently, this will reduce stewards' deployment. The attribute levels are shown in Table 7.1. Based on the Likert 5 scale, the level of each attribute is indicated.

Table 7.1: Decision attribute levels for multi-criteria decision making

Likert scale	Costs	Revenue	Period	Livability	Safety
++	Free	Very high increase	Direct	Used non event days	No safety personnel
+	Very cheap	Significant increase	Less six months	High contribution non event days	Less safety personnel
0	Relatively cheap	Marginal increase	One year	Medium contribution non event days	No impact
-	Relatively expensive	Subtle increase	Two years	Low contribution non event days	Slight increase
–	Expensive	None	Three years	No contribution non event days	Increase of safety personnel

7.2. Performance

The performance of the proposed measures on the decision attributes is discussed in this section. At first, the mode choice probability (based on the effects of the measure on the choice attributes from chapter 3) is calculated with the choice model (chapter 6). The mode choice probabilities per measure are shown in Table 7.2. This table shows that the estimated effects of the measures influence the probability one chooses a modality. Therefore, the differences between the measures can be easily obtained. Analysing the service-related measures, it stands out that the first three measures benefit public transport. The introduction of supporter busses greatly impacts the mode choice, with a seven per cent higher probability this mode will be chosen. Reasoning for this can be found that the travel time of the supporters busses is estimated to be similar to car traffic. Compared to the other measures, public transport travel time is reduced; however, the time it takes by public transport is still longer than for cars. Costs for public transport are shown to have some effect on the mode choice probability; however, this is marginal. Since differences in reliability are shown to be insignificant for public transport, an increase in this for the public transport timetables does not affect the mode choice probability. After the public transport-related measures, a cluster of carpooling, park + bike, and ticketing + parking can be distinguished. In those measures, the mode choice probability for the car is increased. The probability that supporters opt for other modes, especially bicycles, decreases. Reasoning for this effect change can be obtained by the decreased travel cost for carpooling and P+B. Since the P+B measure halves the travel costs towards the venue, the increase in probability can be discussed. However, decreasing travel time and increasing comfort and reliability also positively affect the likelihood of mode choice. The other service-related measure focuses on having supporters earlier at the venue site. Since this causes higher reliability for car traffic, the mode choice probability for this modality increases.

The infrastructure-related measures have a similar approach. The first two mentioned measures; free seating areas and turnstiles, cause a change in arrival time pattern. Therefore, the reliability of getting to the stadium site increases. This causes a higher probability of supporters choosing cars. Adding bicycle paths and secured bicycle stalls increases the probability of supporters opting for the bicycle. Especially since these increase the comfort of the active modes. Between these two measures, the travel time and costs differ. However, this only shows a marginal impact on the mode choice probability. Since the differences between the mode choice probability between both measures are relatively low. Investing in sidewalks and implementing shared space similarly affect the mode choice probability. The increased level of comfort for both active modes can be discussed. Since this is similar to the previous bicycle-related measures, the differences in probability are relatively low. The shared space investment, however, has a higher travel time for bicycles, which lowers the likelihood of opting for this mode. This is very much in contrast with additional parking facilities. By implementing this measure, supporters are more likely to choose a car. The increase in car probability mainly originates in bicycles since this amount is significantly decreasing. Investing in car-related infrastructure does not necessarily impact the costs but does influence the travel time and level of comfort and reliability. However, since the costs are perceived as more important, this will cause the probability of choosing a car within the parking measure to be higher than in the road infrastructure measure. Although the road infrastructure measure also influences public transport, this causes a slightly higher choice probability. Redirecting the routes before and after the event affects the comfort level for all modes except public transport. As a result, the probability that supporters will opt for the bicycle increases since the comfort level for this modality is perceived as more important. Having additional bus stops only influences the travel time for the car and public transport and the level of comfort for the last group. However, the probability of choosing a bicycle increases when looking at the result. This can be reasoned by the additional travel time of the car. With a higher travel time, more supporters on the verge of altering their choice will opt for the bicycle. Lastly, investing in traffic signs positively influences car choice likelihood. The effectiveness of this measure is shown to be slightly higher than that of the measures that focus on the arrival time of supporters.

Table 7.2: Change in mode choice probability due to accessibility interventions AFAS AZ Stadium

		Car	Bicycle	Public transport	Walking
Baseline		54.7%	35.9%	5.1%	4.4%
Service	Combi tickets	-1.2%	-0.8%	2.2%	-0.1%
	Timetables PT	-0.4%	-0.7%	1.2%	-0.1%
	Supporters busses	-4.2%	-2.4%	7.0%	-0.4%
	Carpooling	8.2%	-6.0%	-1.2%	-1.0%
	Park + Bike	10.9%	-8.0%	-1.6%	-1.3%
	Ticketing + Parking	8.0%	-6.8%	0.0%	-1.1%
	Application	4.3%	-3.2%	-0.6%	-0.5%
	Fan zones	4.3%	-3.2%	-0.6%	-0.5%
	On-field entertainment	4.3%	-3.2%	-0.6%	-0.5%
	Beverage discount	4.3%	-3.2%	-0.6%	-0.5%
Infrastructure	Free seating areas	4.3%	-3.2%	-0.6%	-0.5%
	Turnstiles	4.3%	-3.2%	-0.6%	-0.5%
	Bicycle paths	-4.5%	5.5%	-0.5%	-0.5%
	Secured stalling	-3.3%	4.0%	-0.4%	-0.4%
	Sidewalks	-3.1%	3.7%	-0.3%	-0.2%
	Shared space	-2.3%	2.9%	-0.3%	-0.3%
	Parking	9.8%	-7.2%	-1.5%	-1.2%
	Road infrastructure	2.8%	-3.2%	1.0%	-0.5%
	Flip routing	-1.5%	2.5%	-0.5%	-0.5%
	Bus stops	-9.4%	4.7%	3.9%	0.8%
	Traffic signs	5.9%	-4.3%	-0.9%	-0.7%

Checking the effect of other groups on the mode choice probability shows the robustness of the results in Table 7.2. Since the habit effects are most significant, a change from normal car usage is discussed. The differences between a usual mode choice for bicycles are tested towards three measures. The tested and compared measures are the application, bicycle paths, and road infrastructure. Alternations of this lead to a different mode choice probability, which is significantly higher in favour of bicycles. However, the effects of these measures are similar to when someone usually drives by car. All directions in positive and negative terms have stayed equal. Although the magnitude has changed slightly. Adding cycle paths has caused fewer cyclists, whereas road infrastructure has a higher effect on bicycle choice probability. A relatively lower effect can be seen for the arrival time measures. Similar findings are made when considering the usual public transport users. However, the effects on the probability of public transport choice are higher than for bicycles. Adding new cycling paths has a higher effect on the probability of public transport than the others. This thus means the relative change is marginally higher.

Besides the effectiveness of flow, the other decision attributes' performance is discussed. As shown in Table 7.3, all decision attributes besides flow effectiveness are rated. Rating of the attributes is done based on a comparable Likert 5 scale ($--, -, 0, +, ++$). By doing this, the effects of the performances of the different attributes can be compared. The costless measures are rated highest, starting with the cost of implementing a measure. The measures that do not cost anything to implement are the combi tickets for public transport, carpooling, redistribution of ticketing and parking, application, on-field entertainment, and flipped routing. Although the discussion can be raised that the tickets, in combination with public transport, need to be paid for by the organising body, this study considers an appreciation in the form of visibility and exposure. Therefore, the direct implementation costs will be equal to zero. The ticketing and parking itself can also be discussed as not being cost-free since some revenue streams might be missed. However, by charging the same price for parking, this will be reduced to a minimum. In addition, the same infrastructure will also be utilised, which does not require new investments. Implementing a new application also entails additional costs. However, since a new application is under development. As a result, a traffic extension of this app will not entail any direct additional costs. One very cheap measure is the beverage discount before and after the event. Since this is expected to entail a higher sale of beverages, this must also be purchased. More measures, such as the increased PT timetables, fan zones, turnstiles, sidewalks, shared space and traffic signs, are relatively cheap. Having additional busses which transport supporters to and from the stadium site cause for additional costs. These costs, however, can be minor since exposure can be part of reducing the implementation costs. Minor investments that alter the public space are covered in the fan zones, shared space and traffic signs. Relatively expensive measures include supporter busses, P+B, free seating areas, secured stalling, parking and bus stops. All these measures involve some investment which has to be made. A similar exposure model for the supporters busses can be opted for for the public transport timetables. However, this is likely more difficult since a transport authority does not operate these supporter busses. Measures which involve a high implementation cost are the bicycle paths and road infrastructure investments. The related costs will be higher since this entails infrastructural and separate crossings.

Looking at the revenue streams, different conclusions can be drawn. A large amount of the measure does not impact the revenue generated by the organised event. However, the measures which cause the adaptation of the arrival time will also directly affect the revenue generated. Adding fan zones, which aim to change the supporters' visit purpose from a football-related event to a night out, will likely improve the revenue. In a lower context, the organisation of the supporters has a similar effect on the revenue stream. Selling beverages within these busses and using the drop-off area as a place of interest in the form of a small fan zone can generate an increase in revenue. A marginal increase in revenue can be generated by the extension of the free seating sections and the application. Due to the higher consumption in the standing sections, a marginal increase in revenue can be expected. By introducing a loyalty program within the application, a similar effect is expected to be created. The measures that cause a subtle additional revenue generation are on-field entertainment, discounts, and additional turnstiles. For on-field entertainment, a collaboration with sponsors can be opted for, which might increase the revenue generated by these bodies. Under the assumption that more beverages are sold when they are discounted, an increase in revenue can also be counted. However, the bottom line is expected not to be too high. Having more turnstiles causes supporters to be at the venue earlier, thus giving them more time to purchase merchandise or beverages. Noted has to be, however, that removal of the queues can also lead to a later arrival time pattern.

Afterwards, the period over which the effects become visible is compared to the proposed measures. A difference between the measure group (service or infrastructural) can be seen from Table 7.3. Whereas the service-related measures often entail a behavioural change from visitors, the infrastructural measures force these changes. Examples that are expected to influence the accessibility of the AFAS AZ Stadium directly are the increase in turnstiles, additional bicycle paths, and road infrastructure. However, the routing, which is flipped after the event and shared space, is believed to show direct changes to the accessibility. Measures which need one or two matches to be understood accordingly and to have the visitors get used to the measures are secured bicycle stalls and car parking measures. For the car parking measures, the new parking facilities can be indicated by clearly indicating the location of these new parking spaces in advance sales. A similar approach can be used for the bicycle stalls to make this happen. Measures likely to take one full season are the fan zones, other arrival time measures, and traffic signs. Since these involve a small adaptation of supporter behaviour, these effects are expected not to take very long. The period increases to have the effects reach their full potential for more complex behavioural changes. Trying to nudge supporters to take public transport as a traffic mode without direct (monetary) rewards can be especially time-consuming.

Whenever a measure is likely to impact the surroundings and environment permanently, the feasibility of this measure increases. However, the service-related measures do not contribute to the venues' surroundings when there is no matchday. Apart from the park and bicycle facilities which are located around the city. External organisations can also utilise these facilities when there is a need. Small contributions can be discussed for public transport and carpooling. By having more people get used to these modes of transportation and vehicle sharing, they are expected to be more willing to use these forms of transport. Overall, it can be seen in Table 7.3 that the infrastructural measures have a higher impact on livability. Although the free seating areas and turnstile measures only focus on event days, changes in the road infrastructure can be used permanently. The secured bicycle stalls will not be manned during non-event days; however, since these are gated stalls, the perception of safety will be higher. Therefore, they can also be used outside event days. There is no direct use for the flipped routing and traffic signs during non-event days. Especially when no events exist, the routing around the stadium site will not be altered. Therefore, an option must remain to use the existing access ramp at the Smaragdweg roundabout. For access and egress of the Boeklermeer industrial estate, the additional bicycle and road infrastructure can prove to have additional benefits.

At last, the measures' safety and public order aspects are rated. Since it is obligatory for all measures to be safe, this is expressed in terms of additional safety personnel needed to be deployed. Most measures do not influence safety and are scored with zero. Three measures from Table 7.3 show a positive influence on public order and safety. Since the application contains personnel information, any violation of rules can be traced back more quickly. The increase in turnstiles causes lesser movement around the stadium. Similar reasoning can be found for road infrastructure and flipped routing. The measure which causes the deployment of safety personnel is increased standing sections. In relation to an expected increase in (alcoholic) beverage consumption, the supporter's busses also show a slight increase in personnel. For the fan zones and beverage discounts, a similar reasoning can be found to have a slightly higher increase in safety measures.

Table 7.3: Performance of proposed accessibility interventions at the AFAS AZ Stadium on decision attributes

		Costs	Revenue	Period	Livability	Safety
Service	Combi tickets	++	–	-	-	0
	Timetables PT	0	–	–	-	0
	Supporters busses	-	+	-	–	-
	Carpooling	++	–	–	-	0
	Park + Bike	-	–	–	0	0
	Ticketing + Parking	++	-	+	–	0
	Application	++	0	-	–	+
	Fan zones	0	++	0	–	-
	On-field entertainment	++	-	0	–	0
	Beverage discount	+	-	0	–	-
Infrastructure	Free seating areas	-	0	+	–	–
	Turnstiles	0	-	++	–	+
	Bicycle paths	–	–	++	++	0
	Secured stalling	-	–	+	-	0
	Sidewalks	0	–	++	+	0
	Shared space	0	–	++	+	0
	Parking	-	–	+	0	0
	Road infrastructure	–	–	++	++	+
	Flip routing	++	–	++	-	+
	Bus stops	-	–	-	0	0
	Traffic signs	0	–	0	-	0

7.3. Attribute weights

The representatives from the stakeholders have ranked the attributes based on section 7.1. For every stakeholder, the results of the BWM method and the corresponding weights are shown in Appendix G. The main findings of this ranking are discussed within this section and presented in the next section. Based on the results from the municipality of Alkmaar, the traffic department rates safety and public order as the most important. The revenue generated with the measure is considered the lowest importance. For the modalities, the traffic department gives the highest priority to cyclists compared to the other modes. The supporters association of AZ has indicated they find safety and public order of the highest importance. It can be discussed as surprising that they find the measure's effectiveness on the flow of least importance.

Besides the municipality, AZ is another key stakeholder in this research. Within AZ, five different perspectives have been researched. A holistic overview is created based on the different perspectives related to their departments. Departments interviewed are marketing, catering, safety, maintenance and board of directors. From the marketing department, it can be seen that there is a strong favour that the measures directly impact fan behaviour and accessibility. Surprisingly, the costs do not seem to have that much of a priority. This also comes forward, looking at the relative weight of the implementation costs for catering and maintenance. The revenues, however, are the most important attributes for these departments. Within the safety department, it might be obvious that safety and public order are considered most important. The period of the effects and livability are rated equally important. The financial revenues have the lowest importance for this department. In contrast, the board of directors have indicated that costs and safety are equally important. Followed by the increase in revenues and impact on the environment. The period is indicated by the directors as least important.

From the other stakeholders, additional perceptions are considered in determining the relative attribute weights. Based on the interpretation of Rijkswaterstaat, the measure's effectiveness on flow is considered the most important. Especially the flow of cars is regarded as the most critical attribute for improving the accessibility of the AFAS AZ Stadium. Another relatively important factor considered is safety and public order. The effectiveness of flow for walking is seen as the least important. This corresponds with the expectations since this authority is responsible for main highways and water corridors. The Province of North Holland is expected to have relative weights similar to Rijkswaterstaat. However, the province has indicated that the period in which the effects can be seen has a higher priority. The effectiveness of a measure on flow is considered low, which can be discussed as unexpected. However, the province has indicated that they don't experience much disturbance due to events at the AFAS AZ Stadium. A broader interest is obtained from the answers given by the safety region. Little priority was indicated between the different attributes. However, the lowest relative weight has been assigned to the flow effectiveness for cars and revenue generated by the measure. Looking at the police have indicated that safety and public order are of the highest importance at the AFAS AZ Stadium. Similar findings have been obtained by the municipality of Heiloo (second-hand municipality). This municipality has a similar significance for the period as the safety and public order.

7.4. Assessment

Based on the attribute weights and the stakeholders, Equation 2.6 is calculated. This computation derives a ranking of the top six measures per stakeholder. From the traffic department of the municipality, flipped routing (3,59) and road infrastructure (3,48) come out on top. Closely followed by shared space (3,42) and sidewalks (3,34). It has to be noted that these values are relatively close to each other. Therefore, a slight change within attribute rating or effect on flow effectiveness can cause different results. The frequency by which the measures are mentioned is indicated in Table 7.4.

Table 7.4: Frequency of mentioned accessibility intervention at Municipality of Alkmaar

Stakeholder	Measure	Frequency
Municipality of Alkmaar	Shared Space	4
	Road Infrastructure	3
	Sidewalks	3
	Bicycle Paths	3
	Turnstiles	3
	Flip Routing	2

Within AZ, different departments are asked for their perception of the attributes. The departments considered are the marketing, catering, maintenance and safety. The marketing department prefers to invest in road infrastructure (3,88), followed by bicycle paths (3,61). This comes out since these measures directly affect accessibility and can be of use permanently. Catering, on the other hand, has a strong preference for fan zones (3,54), which is followed by application (3,05) and supporters busses (2,96). A strong preference for fan zones is determined because of the revenue generated by the measure. A similar finding was obtained from the maintenance department, which has fan zones (3,73), supporters busses (3,73), and applications (3,02). Supporters busses and applications came forward since both measures affect the revenue stream. The safety department at AZ showed an equal preference towards additional road infrastructure (3.67) and flipped routing (3.65). The other measures that have a preference are shared space (3.40), turnstiles (3.35), and sidewalks (3.29). The frequency by which the measures are mentioned is indicated in Table 7.5.

Table 7.5: Frequency of mentioned accessibility intervention at AZ Alkmaar

Stakeholder	Measure	Frequency
AZ Alkmaar	Flip Routing	4
	Application	3
	Shared Space	3
	Sidewalks	3
	Turnstiles	3
	On-field Entertainment	3
	Road Infrastructure	2
	Fan Zones	2
	Bicycle Paths	2
	Supporters Busses	2
	Ticketing + Parking	2
	Free Seating Areas	1

From the other six stakeholders, the following measures have been mentioned. Additional investments within road infrastructure and flipped routing have come forward for all stakeholders. Afterwards, the shared space came forward six times, only for Rijkswaterstaat. This was not one of the six best measures. Investments in the sidewalks were the third most mentioned measure. However, this was not mentioned for the supporters association of AZ and Rijkswaterstaat. Investments within the bicycle paths and the application were mentioned three times. Followed by the increase in turnstiles (twice) and parking (once). Looking at the differences between the measure scores, the road infrastructure has a score of 3,67 compared to the second (turnstiles), which has 3,42. This is mainly because of the permanent impact, which can apply to road infrastructure. For the Province of North Holland, scores are more similar. This indicates that a slight change of variables can cause varying results. A similar finding can be made for the safety region, in which the highest measure is shared space (3,55) and the fifth is road infrastructure (3,43). Police, on the other hand, have a stronger preference for road infrastructure (3,63) and flipped routing (3,53). For external municipalities and the supporters association, the scores are also very similar to each other. The frequency by which the measures are mentioned is indicated in Table 7.6.

Table 7.6: Frequency of mentioned accessibility intervention at other stakeholders

Stakeholder	Measure	Frequency
Other stakeholders	Road Infrastructure	6
	Shared Space	6
	Flip Routing	6
	Turnstiles	5
	Sidewalks	5
	Bicycle Paths	4
	Application	3
	Parking	1

To show the overall preference of the stakeholders, a similar BWM method is used between stakeholders. At first, the most important stakeholders and least important stakeholders are determined. For this study, the most important stakeholder is determined to be AZ, and the least important is its supporters association. This group is chosen since they will not directly impact any measure implementation. The municipality of Alkmaar has a relative importance within this study, similar to AZ. A similar study is done within the different interviewed departments of both these parties. At AZ, the most important group is the board of directors. This group is followed by the safety department, amongst whom the playing permit is mostly dependent. The board of directors is considered reasonably more critical than the safety department for this study. Comparing the directors to catering and marketing, their interests are strongly more dependent. Maintenance is said to be the least important, with the directors being strongly more important. For the municipality of Alkmaar, the alderman and the municipal government are believed to be the most important group for this study. This is followed by the safety department, which is between as important and reasonably more important. In the traffic department, the importance is strongly more important. Between the safety region of North Holland and Alkmaar police, it is believed there is no difference in importance. AZ and the municipality of Alkmaar, however, are seen as reasonably more important than these stakeholders.

The same counts for the Province of North Holland and Rijkswaterstaat, in which the main stakeholders have a strongly more important impact on the study result. Lastly, the main stakeholders are considered much more important than the external municipalities. Table 7.7 shows this relative importance which these stakeholders have based on the BWM method.

Table 7.7: Relative importance of stakeholders consulted within this study

AZ	**Directors**	0,13
	Safety	0,05
	Marketing	0,03
	Catering	0,03
	Maintenance	0,02
Municipality of Alkmaar	**Council**	0,17
	Safety	0,09
	Traffic	0,04
Rijkswaterstaat		0,07
Province		0,07
Safety region		0,11
Police		0,11
External municipalities		0,05
Supporters association		0,03

7.5. Conclusion

Within this chapter, the solutions for improving the perceived accessibility of the AFAS AZ Stadium are ranked via MCDM. To do this, the Best-Worst Method (BWM) is applied. To rank the different solutions, the attributes need to be determined first. To differentiate the accessibility alternatives, six attributes are derived (implementation costs, financial revenue, effectiveness on flow, period of effect, livability and environmental impact and public order). A new modal split is calculated via the choice model to measure the effectiveness of flow. Implementation costs focus on the direct costs attached to the measure's implementation. Whereas the (financial) revenues, the opposite of the costs, are considered. Regarding the period of effect, the measures' impact on accessibility is discussed. The livability focuses on the measures' negative- and positive effects on the venue's surroundings. Safety and public order aspects are highly considered for football-related events in terms of fan behaviour.

Performance of the accessibility interventions is done by a Likert 5 scale. The effectiveness of flow is measured per mode. A low score is given for a mode when it caused a reduction of 7.5%. The opposite is true when a transport mode opts for more than 7.5%. It has the highest score. For costs, this ranges between free and expensive. For revenue, the Likert scale lies between a very high revenue increase and no additional revenue. The period of change is measured either directly or within the years. Livability usage during non-event days is measured with no contribution to permanent usage. Safety at last ranges between no use of safety personnel and increased safety personnel. Carpooling, Park and Bike, Ticketing + Parking and the parking measures can cause extra use of cars. Whereas the bicycle paths, secured sheds and bus stops cause for an increase in bicycles. Bus stops and supporter busses are examples of measures which score well for public transport. On average, the service-related measures have lower costs and higher revenues. However, the period of the effect and the impact on livability on average is higher for the infrastructural measures.

From the stakeholders, the relative importance of the attributes is derived. Based on the results from the municipality of Alkmaar, it can be seen that the traffic department rates safety and public order as the most important. Meanwhile, in the marketing department at AZ, it can be noticed that there is a strong favour that the measures directly impact fan behaviour and accessibility. Within the safety department, it might be evident that safety and public order are considered most important. Based on the interpretation of Rijkswaterstaat, the measure's effectiveness on flow is regarded as the most important. Looking at the police have indicated that safety and public order are of the highest importance at the AFAS AZ Stadium.

Taking the relative importance of the stakeholder and multiplying this with the relative importance of the attribute, the scores are computed. From Table 8.2 the scores of the measures are shown. This table demonstrates that investments in road infrastructure and flipped routing are the most feasible measures. Scoring of these measures has a higher importance on increasing accessibility of the AFAS AZ Stadium than shared space (3,35), sidewalks (3,29), bicycle paths (3,22) and turnstiles (3,14).

Table 7.8: Scores of the measure based on the relative importance of the stakeholders

Ranking	Measure	Score
1	Flip routing	3,50
2	Road infrastructure	3,43
3	Shared space	3,35
4	Sidewalks	3,29
5	Bicycle paths	3,22
6	Turnstiles	3,14
7	Application	2,97
8	Parking	2,90
9	On-field entertainment	2,79
10	Secured stalling	2,71
11	Ticketing + Parking	2,70
12	Combi tickets	2,69
13	Fan zones	2,64
14	Traffic signs	2,63
15	Carpooling	2,58
16	Bus stops	2,53
17	Beverage discount	2,44
18	Park + Bike	2,33
19	Timetables PT	2,32
20	Supporters busses	2,27
21	Free seating areas	2,25

From Table 8.2 is can be seen that the scores are relatively close. Implementation of one measure can impact the effect of another measure. Therefore, there could be co-option opportunities to implement certain mobility interventions. For example, any change in road infrastructure might have additional effects due to changing the driving direction between access and egress of the event. Since the parking facility's egress is distributed clockwise, the proposed on-ramp on the N242 can be used more efficiently. By completing clockwise egress, more room becomes available for pedestrians and cyclists. This creates possibilities for investments in sidewalks and bicycle paths. More room becomes available since the main conflict is mitigated at the Smaragdweg roundabout. Changing the infrastructure to facilitate the additional space for active modes could enhance the use of these modes. Also, investing in additional turnstiles means fewer queues at the venue's entrance. This way, accessibility by different modes can be perceived better. Any ingress-related bottlenecks might then be less valuable.

8 Conclusion

This research focuses on finding effective interventions to improve accessibility for visitors attending planned special events (PSEs). With a specific focus on the modal choice behaviour of visitors at the AFAS AZ Stadium. This is formulated within the following main research question:

What effective accessibility improvements can be applied to enhance accessibility for visitors attending planned special events, with a specific focus on their modal choice behaviour for the AFAS AZ Stadium?

To structurally answer the main research question and reach the goal, a set of sub-questions are derived. The first question focuses on the existing infrastructure and around the AFAS AZ Stadium and its usage over space and time during events. The goal is to determine supporters' flow and arrival time patterns. Together with the requirements of the stakeholders involved in event organisation and potential accessibility interventions are discussed (section 8.1). Afterwards, the modal choice behavioural aspects are mentioned by stakeholders, and the literature is questioned in the third research question (section 8.2). In section 8.3 and section 8.4, the preferences and experiences of individuals are derived to measure the effect of the accessibility improvements. Obtaining the accessibility and decision factors applicable to these accessibility improvements is the goal for the fifth sub-question. At last, the ranking of the derived solutions for improving the perceived accessibility of the AFAS AZ Stadium is done in section 8.5.

8.1. AFAS AZ Stadium

The first two sub-questions which are answered within this section are: *How do local stakeholders around the AFAS AZ Stadium utilise the infrastructure during PSEs and what criteria for accessibility do they follow?* and *Through which accessibility improvements can the experienced disturbances be mitigated focusing on similar PSE organisers who enhance accessibility for PSEs at their venue?*. The stakeholders' requirements in event organisation are researched for the AFAS AZ Stadium. These requirements focus on the available infrastructure and public facilities within the transportation characteristics. Followed by the usage of these facilities by the visitors within the visitor characteristics. Visitor origin information is provided based on the ticket sales of five events in the 2022-2023 season. These matches were played between AZ and Ajax, Feyenoord, Lazio Roma, SC Heerenveen, and RSC Anderlecht, respectively. On average, 18,200 supporters attended these Eredivisie and UEFA Conference League matches. To check whether it can be concluded that there is no statistical difference between the origin information, a ONE-WAY ANOVA test is performed. Based on this test, the null hypothesis is accepted, which tells us there is no significant difference between the origin data means. The average distance supporters travel to the events is 12.3 kilometres, with 15.0 kilometres being the average standard deviation.

Besides the origin information, arrival time data is obtained based on the turnstiles at the AFAS AZ Stadium. This data is obtained for the same matches as for the origin data. However, only season ticket holders are considered for this analysis for privacy reasons. Against Lazio, half of the supporters entered the stadium 51 minutes before kick-off, while this was only 23,5 minutes against Heerenveen. Supporters on the Ben-Side were the first ones to be at the stadium, especially against Lazio, when they were present 57 minutes before kick-off. On the other stand, the arrival time, on average, lies closer. Via a ONE-WAY ANOVA test, it was found that there is no significant difference in arrival time for these five events.

To check the modal preferences of the visitors at the AFAS AZ Stadium, two main data streams are used, namely the KNVB Supporter survey and Revealed preference data. From the sample obtained within KNVB Expertise (2023), the stated mode choice is observed for 51.6% car, 37.8% bicycle, 5.6% public transport, 2.6% walking and the other 2.4% for other modes. Revealed preference studies host different methods for cars, cyclists and pedestrians. Starting with car traffic, a study is performed with parked vehicles around the AFAS AZ Stadium on event days. From this study, it has been found that an additional 880 vehicles are parked within the residential areas when an event is played. On the stadium site, approximately 2,200 vehicles are parked. Considering an average occupancy of 2.9, this leads to 8,850 supporters (53.3%) who come to the event by car. In addition, publicly available highway flow data is obtained for the A9. In combination with origin data from TomTomMove, it is obtained that 40% of the visitors come from the A9. Approximately 1,550 vehicles travel from this freeway to the event. Taking a 10% uncertainty into account, this leads to a range between 3,480 and 3,880 vehicles which travel to the event. The modal share of cars, therefore, lies between 55% and 70%. For cyclists, measurements have been taken on events against SC Heerenveen, Aston Villa, and NEC in the 2023-2024 season. Five locations have been chosen to install pneumatic tubes. For these matches, this modal share was 2,157, 2,625 and 2,256 respectively. When comparing this with the attendance rate, this leads to a share between 12 and 15% of cyclists who visit the AFAS AZ Stadium by bicycle. Pedestrians are measured via radio wave sensors. Three zones have been set up, one of which lies in the active mode tunnel. Measurements have been taken for matches against FC Volendam and Zrinjski Mostar in the 2023-2024 season. The data analysis shows that, on average, people started arriving at the stadium about 90 minutes before the match and continued to arrive for about 15 minutes after the start. Once the match has ended, people leave within 5-8 minutes. The egress period usually lasts about 45 minutes. Approximately 5,000 people are measured during the inflow against Zrinjski Mostar. Since this also includes cyclists, an average of 2,500 has to be extracted. This leads to approximately 2,500 pedestrians, of which 2,376 are parked in the residential area of Overdie. This led to approximately 150 pedestrians who attend the event. Calculating the ratio based on an attendance of 16,500 supporters leads to 0.8% of the supporters walking to the venue.

Within Table 8.1, the differences between the data obtained by the KNVB Supporters survey and the revealed data are shown. From this table, it can be seen that a difference exists between the car users at first. The number of car users within the survey is lower than the lower bound in the data. The opposite is true for cyclists, who are over-represented in the survey.

Table 8.1: Result of observed modal share compared to KNVB Expertise (2023)

	KNVB Survey	**Revealed preference**	
		Lower bound	**Upper bound**
Car	51,6%	55%	70%
Bicycle	37,8%	12%	15%
Public transport	5,6%	-	-
Walking	2,6%	0.8%	1.2%
Other	2.4%	-	-

8.2. Mode choice attributes

This section aims to find what choice attributes are mentioned in the literature regarding modal choice behaviour. Four categories are found in which the different mode choice-related characteristics can be divided (spatial-, journey-, socio-demographic- and socio-psychological characteristics).

For the spatial characteristics, two key categories, Event and Accessibility, were identified as vital factors in this context. The Event category emphasises the attraction of an event and its proximity as influential factors. Accessibility included attributes like parking availability, comfort, and safety, which played crucial roles in mode selection. Additionally, the infrastructural network and the road density by which supporters travel to their venue. At last, the accessibility interventions taken by the organising body of a PSE are considered an influential factor for mode choice.

Journey characteristics consider three main factor groups: Logistics, Natural, and Event-related. Logistics factors like travel time, cost, and party size were discussed together with distance and reliability. Natural factors impact mode choice, including time of day, season, and day of the week. Event-related elements such as predicted attendance, event duration, and purpose of visiting an event play a role in modal choices. Factors like expected arrival time and revisiting also influence mode choice factors.

Socio-demographic factors provide valuable insights into individual typologies and substantially impact mode preferences. The Population group encompasses age, vehicle availability, household size and license, significantly influencing mode choices. Income, age, and possession of a driving license are associated with private car usage. The Attendance passport group examines ticket-related characteristics, including first-time attendees, attendance rate, season ticket holders and ticket groupings.

Socio-psychological characteristics influence modal choice for attending sports events through emotional and interpersonal factors. Emotional aspects, such as habit, pride, satisfaction and beliefs, shape individual decisions. Habitual preferences, rooted in past behaviour and mode familiarity, play a vital role. Interpersonal dynamics also contribute, with group influences affecting choices. Group encouragement, socialism and space also play a role within social contexts.

8.3. Stated preference experiment

A stated preference (SP) survey is done to answer the fourth sub-question partially. This method elaborates on the extent to which the choice attributes affect the modal choice behaviour per accessibility improvement by which the probability of modal choice is predicted for visitors of the AFAS AZ Stadium. Accessibility- and decision factors (Choice attributes, choice sets and choice alternatives) apply to visitors of the AFAS AZ Stadium. At first, the choice attributes from the literature study are derived based on the relations between the individual attributes. The key determinants believed to have the highest impact on mode choice are found in these attributes. The determinants which are found to have a direct influence on mode choice are party size (Musgrave et al., 2019), habit (Lättman et al., 2018), socio-demographics (Ergin & Tezcan, 2022) and satisfaction (Coppola & Silvestri, 2018). Regarding habit, four key attributes (attitude, vehicle availability, number of attended games and ticket group) influence this determinant. The satisfaction that one experiences when using a certain mode to travel to events is also a key determinant for mode choice. It is found that this is influenced by the reliability of the arrival time, infrastructure, and other journey characteristics. These characteristics include travel time, safety, ease and costs related to the journey to the venue. The reliability is influenced by the event's proximity to the individual. The distance between one's origin and the venue is measured to measure this proximity. Also, parking in the venue's environment plays a role in the road network. Via the stated choice experiment, the effect of these attributes is quantified.

Based on the pilot survey, the average party size by which supporters travel towards the stadium is 2.7 supporters. For gender, for example, women are more likely to opt for public transport and bicycles than men. Regarding the attended games, it can be noticed that the bike is a more preferred mode compared to the car for the low attendance rates. However, the group often perceives this as equal to a vehicle. Public transport shows a similar trend with bicycles. However, within the usual group, this modality decreases compared to cars. Walking always has a lower perception than all other modes. Age is not shown to have a significant influence on mode choice. However, when age increases, the frequency of choice for public transport decreases. The factors reveal that the alternative specific constants (ASCs) still play a significant role in the priors. Comfort is the least essential value for the other values following its estimated value and t-statistic. Following the table, it can be seen that the ASC for bicycles is positive. This indicates a preference for bicycles compared to cars when the choice attributes are equal. The same holds for the ASC for public transport. Walking, however, has a negative sign; thus, there is a preference to use the car when all attributes are equal. As expected, the costs have a negative value, which indicates the utility becomes less when the costs increase. However, it is seen as significant only for a bicycle.

8.4. Discrete choice model estimation

The extent to which decision factors affect the modal choice behaviour is determined by predicting the probability of modal choice for visitors of the AFAS AZ Stadium. This complements the answer to the fourth sub-question: *To what extent do the choice attributes affect the modal choice behaviour per accessibility improvement by which the probability of modal choice is predicted for visitors of the AFAS AZ Stadium?* This forms the basis to predict the probability of modal choice for visitors of the AFAS AZ Stadium. In total, the SP survey is filled in by 2,218 respondents. This group was reduced to a final sample of 1,808 respondents by validating the results and using exclusion criteria. Of this group, it can be seen that the majority of respondents are male (77.0%). The supporters between 46 and 65 are overrepresented (47.2%) within this survey. Therefore, it can be expected that the mode choice for cars is higher since more people between 45 and 65 have a vehicle available. The differences between the stated and obtained arrival times are similar. The supporters with their origin < 2km towards the venue are underrepresented within the sample. From the sample, a ratio of 63.9% owns a season ticket. Of this percentage, the majority is at the Molenaar stand and the Ben-Side. The Alkmaarderhout-, and Victorie stands are underrepresented within the sample compared to the other two sections. Almost half of the stated season ticket holders have had their season ticket for over ten years. Based on the sample, it can be seen that the modal split of the car increases when the visit frequency decreases. An opposite finding can be made when comparing bicycles with the visit frequency. The findings for bike and car use share compared to the visiting frequency can be related to the respective average distances. The average distance increases when attendance reduces. There is also a correlation between the mode used for commuting and travel to the AFAS AZ Stadium. Supporters on the main (Victorie) stand are earliest within the stadium, followed by the Ben-Side.

From the final MNL model, negative ASC values are obtained. It can be concluded that there is a negative factor in using the other modes. This can be expected since the car is the dominant mode to travel to the AFAS AZ Stadium. Age also has a negative impact on choosing other modes than the car. The attendance rate shows two key findings. At first, the utility of selecting public transport becomes higher when supporters are not always present. The second finding indicates walking and cycling have less utility for supporters who attend matches more than seven times per season. Habit has been shown to impact the utility of a mode positively. This indicates a significant relation between the means of transport that people are used to commuting with and their travel pattern to the AFAS AZ Stadium.

8.5. Multi-Criteria Decision Making

Via MCDM, the last two sub-questions are answered: *Which accessibility- and decision factors are applicable for visitors of the AFAS AZ Stadium?* and *How do the accessibility improvements score on the decision factors of the AFAS AZ Stadium?* The solutions for improving the perceived accessibility of the AFAS AZ Stadium are ranked. To do this, BWM is applied. First, the decision attributes need to be determined to rank the different solutions. To differentiate the accessibility alternatives, six attributes are derived (implementation costs, financial revenue, effectiveness on flow, period of effect, livability and environmental impact and public order). A new modal split is calculated via the choice model to measure the effectiveness of flow. Implementation costs focus on the direct costs attached to the measure's implementation. Whereas the (financial) revenues, the opposite of the costs, are considered. Regarding the period of effect, the measures' impact on accessibility is discussed. The livability focuses on the measures' negative- and positive impact on the venue's surroundings. Safety and public order aspects are highly considered for football-related events in terms of fan behaviour.

Carpooling, Park and Bike, Ticketing + Parking and the parking measures can cause extra use of cars. Meanwhile, the bicycle paths, secured sheds, and bus stops cause an increase in the number of bicycles. Bus stops and supporter busses are examples of measures which score well for public transport. On average, the service-related measures have lower costs and higher revenues. However, the period of the effect and the impact on livability on average is higher for the infrastructural measures.

From the stakeholders, the relative importance of the attributes is derived. Based on the results from the municipality of Alkmaar, it can be seen that the traffic department rates safety and public order as the most important. Meanwhile, in the marketing department at AZ, it can be seen that there is a strong favour that the measures directly impact fan behaviour and accessibility. Within the safety department, it might be obvious that safety and public order are considered most important. Based on the interpretation of Rijkswaterstaat, the measure's effectiveness on flow is considered the most important. Looking at the police have indicated that safety and public order are of the highest importance at the AFAS AZ Stadium. For this study, the stakeholders are also ranked. AZ and the Municipality of Alkmaar are seen as the most dominant stakeholders. Followed by the Safety region and Police.

Based on this relative importance, the overall scores of the measures are calculated. The scores are computed by taking the relative importance of the stakeholder and multiplying this with the relative importance of the attribute. From Table 8.2 the scores of the measures are shown. Within this table, it can be seen both investments in road infrastructure and flipped routing come forward as the most feasible measures. Scoring of these measures has a higher importance on increasing accessibility of the AFAS AZ Stadium than shared space (3.35), sidewalks (3.29), bicycle paths (3.22) and turnstiles (3.14).

Table 8.2: Scores of the accessibility interventions based on the relative importance of the stakeholders

Ranking	Measure	Score
1	Flip routing	3,50
2	Road infrastructure	3,43
3	Shared space	3,35
4	Sidewalks	3,29
5	Bicycle paths	3,22
6	Turnstiles	3,14
7	Application	2,97
8	Parking	2,90
9	On-field entertainment	2,79
10	Secured stalling	2,71
11	Ticketing + Parking	2,70
12	Combi tickets	2,69
13	Fan zones	2,64
14	Traffic signs	2,63
15	Carpooling	2,58
16	Bus stops	2,53
17	Beverage discount	2,44
18	Park + Bike	2,33
19	Timetables PT	2,32
20	Supporters busses	2,27
21	Free seating areas	2,25

9 Discussion and recommendations

In this chapter, the results are discussed with the main limitations. Afterwards, some points for further research are highlighted. Offering additional perspectives beyond the existing research in the field, some of the discoveries align with the information presented in the literature review. In contrast, others diverge from the studies conducted at the outset of this project.

9.1. Limitations

Limitations of this research focus on the adaptability of this study to other cases. For example, the estimated choice model is not necessarily applicable at the Johan Cruijff ArenA instead of the AFAS AZ Stadium. The sample of respondents from the survey comes from channels which supporters of AZ access. When looking at the results, the majority possesses a season ticket, which shows these supporters already have a bias regarding mode choice. With this situational bias, the mode choice might differ for the same supporter when visiting other events.

Estimation of the choice model is done via an MNL model. However, a drawback of this model is the assumption of independence alternatives. Which states that the relative odds of choosing one alternative over another remain constant regardless of the presence or absence of other alternatives. This assumption can be unrealistic in many real-world scenarios and lead to model misspecification. However, better estimation results might be obtained using other models, such as the Nested- or Mixed Logit. In the nested logit model, alternatives are grouped into nests, and individuals first choose a nest and then select an alternative within that nest. This hierarchical structure allows for correlations among alternatives within the same nest. Therefore, the nested logit model provides more flexibility in capturing the correlation among alternatives and avoids some of the limitations of the MNL model. The mixed logit model allows for individual-specific parameters instead of assuming fixed coefficients for all individuals, as in the MNL model. The mixed logit model introduces random parameters that vary across individuals according to a specified distribution. This flexibility allows for capturing heterogeneity in preferences across individuals.

The survey itself is assembled with NGene and Biogeme software. Within NGene, a pilot survey is held at first. In this survey, the ranges for comfort and reliability have been reduced to minimise the degrees of freedom. Afterwards, a pilot survey was held with twenty choice sets per respondent. This amount of choice is rather large, influencing the answers given. With a lower amount of questions, the results can be expected to be more reliable. However, this causes a larger sample size to obtain some reliable results. When the final choice set is derived, the D-value is minimised within NGene. Usually, the S-value is determined to be the lowest since this leads to the lowest error of the model. This causes a difference in the choice set and thus can lead to varying results. In the final choice set, only reliability for car traffic can be altered. This can be the effect of the choice attribute being insignificant. However, the differences in accessibility interventions can, therefore, not be measured when they increase reliability. The definition of comfort within this survey focused on the amount of interactions with other traffic. This definition, however, can be interpreted differently with mode-specific characteristics. This might lead to supporters choosing public transport sooner since this gives them a higher perceived comfort as an example. The choice scenario focuses on AZ-Ajax at the AFAS AZ Stadium. By having this event on a Sunday at 14:30, supporters might opt for different modes than other matches. This limitation might lead to a result that might favour cars more during less attractive events since attendance is expected to be lower at these events. Additionally, considering the seasonality can also cause changes in mode choice. Due to weather conditions such as heavy rain, snowstorms, or extreme heat, certain modes can become less attractive. For example, people may prefer using cars or public transportation instead of walking or cycling to stay dry, warm, or comfortable during adverse weather conditions.

Estimation of the mode choice probability is estimated using the dominant categorical variables. By doing this, only the mode choice for specific groups is determined. For example, the share of public transport is larger for female visitors. Therefore, the effects of the interventions on public transport will be greater for female visitors. Large effects are expected when the main mode is different. When the usual mode of travel is changed to bicycle, many more supporters are expected to use bicycles. The effects of any bicycle-friendly measure will then be more visible. The effects of the accessibility measures on the choice variables are derived based on expert judgment. Therefore, the actual effect might differ, especially in reducing travel time. Solving congestion can decrease travel time, which might be higher than is used within this study. This can cause the mode choice probability for the car to be higher. The estimation of mode choice is based on uni-modal trips. This means that the first- and last miles of the different modes of transport are not considered. The effects of this might be interpreted in a way which does not comply with the study outcomes. Since only a few supporters use walking as a single transport option, the active mode tunnel is used frequently. To measure this, preference studies are held for cars, bicycles, and pedestrians to estimate the mode choice preferences at the AFAS AZ Stadium. Measurements of these modes took place at different events. Therefore, the modal split cannot be determined accurately. Also, not all modes are covered since the effects of public transport are not considered. Radio wave sensors for pedestrian measurements have a downside to being vulnerable to vandalism. Since some of the sensors occasionally went missing, the results might be shifted.

Measurement of the effectiveness of a measure to increase accessibility is done by looking at the modal split. This way, a mode scores better when more supporters make use of this mode. In terms of assessment of the perceived accessibility, it might be useful to implement some measures and ask supporters about their accessibility score. Different representatives of the stakeholders are consulted to estimate the relative weight of the decision attributes. However, these representatives are not necessarily decision-makers. Therefore, the consistency criterion is not always matched. This causes a factor of randomness in the obtained relative importance. Moreover, not all stakeholders are consulted since it is discussed they do not have a direct influence on the implementation of an intervention. The final obtained ranking of solutions is not tested for sensitivity. By altering the performance of the measure, the score will be changed. The amount of times the measure will still be at the same place shows how robust the conclusion is. Also, the weights obtained by the stakeholders can be altered to test the robustness.

9.2. Future research

For future research, a similar structure is used. New research can be done for two applications (i.e. academically and for the case study). Future academic research can focus on using other mode choice estimation models. As an example, Nested- and Mixed Logit functions can be used. The difference between these methods is that the parameters are estimated differently. Within ML, they are taken randomly from a distribution, while for MNL, the parameters are estimated using data (Brownstone & Train, 1998). The existing MNL model can be further elaborated by adding another step. Within the last step of the model, some insignificant parameters came forward. Within further steps, these parameters can be neglected. The correlation matrix can also be consulted to check which parameters show a high correlation. Additionally, a sensitivity of the choice coefficients can be done to test the robustness of the model. The various visitor profiles can be altered within this sensitivity to test the attribute levels and modal share changes. When using the nested logit, the modes can be divided into two main nests. The first nest that can be distinguished is the active mode nest, which contains walking and cycling. Where the second nest contains motorised vehicles (i.e. public transport and cars). Based on these nests, two utility functions can be specified. The probability of choosing each nest relative to all other nests can be determined within the first utility function. Afterwards, the probability of choosing the individual mode within that nest is determined in the second nest.

Within this study, the natural aspects are not considered. Some of these aspects are weather- and seasonal-related considerations. The existing study can be extended with further research to investigate the effect of these aspects on mode choice. Since it might be expected that the supporters are less likely to choose the bicycle during extreme weather conditions (i.e. heavy rain) compared to an average day in spring. These seasonal experiments can be taken via stated- or revealed preference. However, it might be difficult for the respondents to put themselves in a situation where bad weather is indicated while the sun is shining in real-time. Therefore, a revealed preference study can provide a more reliable outcome. The downside of this revealed preference is that this method has higher costs than another survey. The tests must be present for at least one full calendar year to test the seasonality. Additionally, since there are only a few matches per season, the chance might arise that not all weather conditions are covered. For example, there might be a time when there was no heavy rain during the matches. Similar arguments can be given to test the effect of event starting time and excitement. There might be reasons, such as European football, why certain playing times are not utilised during a season. To measure the number of visitors coming by foot and car during at least one season, it might be expected that most scenarios are covered.

Besides using other estimation methods, the obtained stated preferences can be validated with the results of the revealed preference study. By calibrating these choice parameters, a more reliable result can be obtained. In addition, testing the willingness of the entire sample size (instead of only one group) can be done. By doing so, some differences in adaptability between statistically significant groups could be obtained. This study focuses on the mode choice preferences of visitors at the AFAS AZ Stadium. However, it can also be extended for a more holistic view of visitors to events within The Netherlands. Therefore, the survey can be slightly configured to make it more generally applicable. Via this way, any differences between different supporters in terms of willingness to adapt mode choice can be determined.

For the AFAS AZ Stadium case study, further research is recommended for a more in-depth elaboration of the top six solutions. This can be done by using guidelines for design. Also, the performance matrix, which is now filled in based on a Likert 5 scale, can be done using the correct units. As an example, costs and revenues can be expressed in monetary values. Macro- or microscopic simulation models can be used for flow effectiveness. With these simulation techniques, the effects of the measures are indicated more clearly. A sensitivity analysis for the assessment can be done to make the result more reliable. This way, the results can be defended better, and any bias can be filtered. Within this study, any new (shared) mode of transportation is neglected. These modes, such as shared bicycle systems, could be of interest. Future research can also focus on using e-scooters as a mode of transport to the AFAS AZ Stadium. To get all the stakeholders willing to collaborate with potential changes to the stadium environment, a plenary session can be held to bring everyone on the same page.

References

Aarts, H., Verplanken, B., & van Knippenberg, A. (1997). Habit and information use in travel mode choices. *Acta Psychologica*, *96*(1), 1–14. https://doi.org/https://doi.org/10.1016/S0001-6918(97)00008-5

Abkarian, H., Tahlyan, D., Mahmassani, H., & Smilowitz, K. (2022). Characterizing visitor engagement behavior at large-scale events: Activity sequence clustering and ranking using gps tracking data. *Tourism Management*, *88*, 104421. https://doi.org/https://doi.org/10.1016/j.tourman.2021.104421

Ambühl, L., Menendez, M., & González, M. C. (2023). Understanding congestion propagation by combining percolation theory with the macroscopic fundamental diagram [Cited by: 0; All Open Access, Gold Open Access]. *Communications Physics*, *6*(1). https://doi.org/10.1038/s42005-023-01144-w

Asgari, H., & Jin, X. (2020). Incorporating habitual behavior into mode choice modeling in light of emerging mobility services. *Sustainable Cities and Society*, *52*, 101735. https://doi.org/https://doi.org/10.1016/j.scs.2019.101735

AZ Alkmaar. (2021). *Over ons*. Retrieved March 2, 2023, from https://www.az.nl/nl/meer/club/over-ons?category=historie

AZ Fanpage. (2006). *Afas stadion*. Retrieved March 2, 2023, from https://www.azfanpage.nl/afas-stadion/

Balezentis, T., Siksnelyte-Butkiene, I., & Streimikiene, D. (2021). Stakeholder involvement for sustainable energy development based on uncertain group decision making: Prioritizing the renewable energy heating technologies and the bwm-waspas-in approach. *Sustainable Cities and Society*, *73*, 103114. https://doi.org/https://doi.org/10.1016/j.scs.2021.103114

Bardutz, E., & Bigazzi, A. (2022). Communicating perceptions of pedestrian comfort and safety: Structural topic modeling of open response survey comments. *Transportation Research Interdisciplinary Perspectives*, *14*, 100600. https://doi.org/https://doi.org/10.1016/j.trip.2022.100600

Basu, R., & Sevtsuk, A. (2022). How do street attributes affect willingness-to-walk? city-wide pedestrian route choice analysis using big data from boston and san francisco [Cited by: 7]. *Transportation Research Part A: Policy and Practice*, *163*, 1–19. https://doi.org/10.1016/j.tra.2022.06.007

Bekhor, S., & Shiftan, Y. (2010). Specification and estimation of mode choice model capturing similarity between mixed auto and transit alternatives. *Journal of Choice Modelling*, *3*(2), 29–49. https://doi.org/https://doi.org/10.1016/S1755-5345(13)70034-4

Bierlaire, M. (2018). A short introduction to pandasbiogeme. https://transp-or.epfl.ch/documents/technicalReports/Bier20.pdf

Bocarejo S., J. P., & Oviedo H., D. R. (2012). Transport accessibility and social inequities: A tool for identification of mobility needs and evaluation of transport investments [Special Section on Theoretical Perspectives on Climate Change Mitigation in Transport]. *Journal of Transport Geography*, *24*, 142–154. https://doi.org/https://doi.org/10.1016/j.jtrangeo.2011.12.004

Böcker, L., van Amen, P., & Helbich, M. (2017). Elderly travel frequencies and transport mode choices in greater rotterdam, the netherlands. *Transportation*, *44*, 831–852. https://api.semanticscholar.org/CorpusID:155851280

Brink Verkeer. (2022). Mobiliteitsplan oranje koningsdag 2022.

Brownstone, D., & Train, K. (1998). Forecasting new product penetration with flexible substitution patterns. *Journal of Econometrics*, *89*(1), 109–129. https://doi.org/https://doi.org/10.1016/S0304-4076(98)00057-8

Bularda, J. (2022). Parkeeronderzoek afas az stadio.

Burns, P., Mules, T. J., Hatch, J. H., & for South Australian Economic Studies., C. (1986). *The adelaide grand prix : The impact of a special event / edited by j.p.a. burns, j.h. hatch, t.j. mules*. The Centre for South Australian Economic Studies [Adelaide].

Cheng, Y.-H., & Chen, S.-Y. (2015). Perceived accessibility, mobility, and connectivity of public transportation systems. *Transportation Research Part A: Policy and Practice*, *77*, 386–403. https://doi.org/https://doi.org/10.1016/j.tra.2015.05.003

Choice Metrics Pty Ltd. (2014). Ngene 1.1.2 user manual reference guide. https://www.choice-metrics.com/NgeneManual130.pdf

Coppola, P., & Silvestri, F. (2018). Estimating and visualizing perceived accessibility to transportation and urban facilities [Assessing wider impacts of transportation policies]. *Transportation Research Procedia*, *31*, 136–145. https://doi.org/https://doi.org/10.1016/j.trpro.2018.09.051

Cummings, C., Abkarian, H., Zhou, Y., Tahlyan, D., Smilowitz, K., & Mahmassani, H. S. (2022). Simulating large-scale events as a network of heterogeneous queues: Framework and application. *Transportation Research Record*, *2676*(1), 192–203. https://doi.org/10.1177/03611981211035755

Curl, A. (2018). The importance of understanding perceptions of accessibility when addressing transport equity: A case study in greater nottingham, uk. *Journal of Transport and Land Use*, *11*(1). https://doi.org/10.5198/jtlu.2018.1003

Dalvi, M., & Martin, K. (1976). The measurement of accessibility: Some preliminary results. *Transportation*, *5*(1), 17–42. https://doi.org/10.1007/BF00165245

Darcy, S., & Harris, R. (2003). Inclusive and accessible special event planning: An australian perspective. *Event Management*, *8*, 39–47. https://doi.org/10.3727/152599503108751685

De Gelderlander. (2021). Strafrechtelijk onderzoek naar ongeregeldheden bij az - nec. https://www.gelderlander.nl/home/strafrechtelijk-onderzoek-naar-ongeregeldheden-bij-az-nec~afa92b3a/

de Haas, M., Hoogendoorn, R., Scheepers, C., & Hoogendoorn-Lanser, S. (2018). Travel mode choice modeling from cross-sectional survey and panel data: The inclusion of initial nonresponse [Transport Survey Methods in the era of big data:facing the challenges]. *Transportation Research Procedia*, *32*, 268–278. https://doi.org/https://doi.org/10.1016/j.trpro.2018.10.049

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. https://doi.org/https://doi.org/10.1016/j.tra.2013.01.009

de Dios Ortúzar, J., & Willumsen, L. (2011). *Modelling transport*. Wiley. https://books.google.nl/books?id=qWa5MyS4CiwC

Demir, S. T., Bryde, D. J., Fearon, D. J., & Ochieng, E. G. (2015). Three dimensional stakeholder analysis - 3dsa: Adding the risk dimension for stakeholder analysis [Cited by: 7; All Open Access, Green Open Access]. *International Journal of Project Organisation and Management*, *7*(1), 15–30. https://doi.org/10.1504/IJPOM.2015.068002

Di Martino, S., Kwoczek, S., & Rossi, S. (2019). Predicting the spatial impact of planned special events (Y. Kawai, S. Storandt, & K. Sumiya, Eds.), 102–117.

Ergin, M., & Tezcan, H. (2021). Planned special event travel demand model development. *International Journal of Engineering, Transactions B: Applications*, *34*, 336–347. https://doi.org/10.5829/ije.2021.34.02b.05

Ergin, M., & Tezcan, H. (2022). Joint logit model approach to analyze soccer spectators' arrival time and location preferences for interim activities in istanbul. *International Journal of Engineering, Transactions B: Applications*, *35*, 613–625. https://doi.org/10.5829/ije.2022.35.04a.01

Fai, E. E. A. J. L. S. H. K. E. N. L. K. (2019). Event logistics in sustainability of football matches. *International Journal of Supply Chain Management*, *Vol 8, No 1 (2019): International Journal of Supply Chain Management(IJSCM)*. http://ojs.excelingtech.co.uk/index.php/IJSCM/article/view/2920/1476

Federal Highway Administration. (2007). Managing travel for planned special events handbook: Executive summary. https://ops.fhwa.dot.gov/publications/fhwahop07108/plnd_spcl_evnts.pdf

Fernando, R. (2018). The impact of planned special events (pses) on urban traffic congestion. *ICST Transactions on Scalable Information Systems*, *6*, 159624. https://doi.org/10.4108/eai.13-7-2018.159624

Friman, M., Fujii, S., Ettema, D., Gärling, T., & Olsson, L. E. (2013). Psychometric analysis of the satisfaction with travel scale [Psychology of Sustainable Travel Behavior]. *Transportation Research Part A: Policy and Practice*, *48*, 132–145. https://doi.org/https://doi.org/10.1016/j.tra.2012.10.012

Gardner, B., & Abraham, C. (2008). Psychological correlates of car use: A meta-analysis. *Transportation Research Part F: Traffic Psychology and Behaviour*, *11*(4), 300–311. https://doi.org/https://doi.org/10.1016/j.trf.2008.01.004

Glock, J.-P., & Gerlach, J. (2023). Berlin pankow: A 15-min city for everyone? a case study combining accessibility, traffic noise, air pollution, and socio-structural data. *European Transport Research Review*, *15*. https://doi.org/10.1186/s12544-023-00577-2

González, M. J. A., van Oort, N., Cats, O., & Hoogendoorn, S. P. (2017). Urban demand responsive transport in the mobility as a service ecosystem: Its role and potential market share. https://api.semanticscholar.org/CorpusID:45554211

Google Earth. (2023). Google earth version 9.

Hall, C. (1989). The definition and analysis of hallmark tourist events. *GeoJournal*, *19*. https://doi.org/10.1007/BF00454570

Han, A. F., Wong, K., & Ho, S. (2018). Residents' perceptions on the traffic impact of a special event: A case of the macau grand prix [Cited by: 7]. *Asia Pacific Journal of Tourism Research*, *23*(1), 42–55. https://doi.org/10.1080/10941665.2017.1399916

Hansen, W. G. (1959). How accessibility shapes land use. *Journal of the American Institute of Planners*, *25*(2), 73–76. https://doi.org/10.1080/01944365908978307

Harris, L., & Brown, G. (2010). Mixing interview and questionnaire methods: Practical problems in aligning data. *Practical Assessment Research Evaluation*, *15*, http://pareonline.net/pdf/v15n1.pdf.

Harz, J., & Sommer, C. (2022). Mode choice of city tourists: Discrete choice modeling based on survey data from a major german city. *Transportation Research Interdisciplinary Perspectives*, *16*, 100704. https://doi.org/https://doi.org/10.1016/j.trip.2022.100704

Havlickova, D., & Zamecnik, P. (2020). Considering habit in research on travel mode choice: A literature review with a two-level methodology. *Transactions on Transport Sciences*, *11*(1), 18–32. https://doi.org/10.5507/tots.2020.004

Hinz, O., Schlereth, C., & Zhou, W. (2015). Fostering the adoption of electric vehicles by providing complementary mobility services: A two-step approach using best–worst scaling and dual response. *Journal of Business Economics*, *85*, 921–951. https://doi.org/10.1007/s11573-015-0765-5

Hoffmann, C., Abraham, C., White, M. P., Ball, S., & Skippon, S. M. (2017). What cognitive mechanisms predict travel mode choice? a systematic review with meta-analysis. *Transport Reviews*, *37*(5). https://doi.org/10.1080/01441647.2017.1285819

Holmgren, J., & Ivehammar, P. (2020). Mode choice in home-to-work travel in mid-size towns: The competitiveness of public transport when bicycling and walking are viable options [Recent Advances and Emerging Issues in Transport Research – An Editorial Note for the Selected Proceedings of WCTR 2019 Mumbai]. *Transportation Research Procedia*, *48*, 1635–1643. https://doi.org/https://doi.org/10.1016/j.trpro.2020.08.204

Hoory, L., & Bottorff, C. (2022). What is a stakeholder analysis? everything you need to know. https://www.forbes.com/advisor/business/what-is-stakeholder-analysis/#:~:text=What%5C%20is%5C%20the%5C%20main%5C%20purpose,the%5C%20project%5C%20from%5C%20the%5C%20start.

Hyun, M., Jee, W., Wegner, C., Jordan, J., Du, J., & Oh, T. (2022). Self-serving bias in performance goal achievement appraisals: Evidence from long-distance runners. *Frontiers in Psychology*, *13*. https://doi.org/10.3389/fpsyg.2022.762436

Jamei, E., chan melissa, m., Chau, H.-W., Gaisie, E., & Lättman, K. (2022). Perceived accessibility and key influencing factors in transportation. *Sustainability*, *14*. https://doi.org/10.3390/su141710806

Jang, S. (, Morrison, A. M., & O'leary, J. T. (2004). A procedure for target market selection in tourism. *Journal of Travel & Tourism Marketing*, *16*(1), 19–33. https://doi.org/10.1300/J073v16n01_03

Joshi, A., Kale, S., Chandel, S., & Pal, D. (2015). Likert scale: Explored and explained. *British Journal of Applied Science Technology*, *7*, 396–403. https://doi.org/10.9734/BJAST/2015/14975

Kadaster. (2023). Ruimtelijke plannen versie 3.1.0.25.

Kitchin, P., Paramio-Salcines, J., Darcy, S., & Walters, G. (2022). Exploring the accessibility of sport stadia for people with disability: Towards the development of a stadium accessibility scale (sas). *Sport, Business and Management: An international Journal*. https://doi.org/10.1108/SBM-05-2021-0064

KNMI. (2023). Daily data of the weather in the netherlands. https://daggegevens.knmi.nl/klimatologie/dag?date=2022-09-18&station=249

KNVB. (2022). *Concept competitieprogramma betaald voetbal 2022/'23*. Retrieved March 3, 2023, from https://www.knvb.nl/downloads/bestand/27108/conceptprogramma-betaald-voetbal-2022-23

KNVB Expertise. (2023). Knvb expertise.

Kumar, P., & Khani, A. (2020). Evaluating special event transit demand: A robust principal component analysis approach. *IEEE Transactions on Intelligent Transportation Systems*, *PP*, 1–13. https://doi.org/10.1109/TITS.2020.3001470

Kuppam, A., Copperman, R., Lemp, J., Rossi, T., Livshits, V., Vallabhaneni, L., Jeon, K., & Brown, E. (2013). Special events travel surveys and model development. *Transportation Letters*, *5*(2), 67–82. https://doi.org/10.1179/1942786713Z.0000000007

Kwoczek, S., Martino, S. D., & Nejdl, W. (2014). Predicting and visualizing traffic congestion in the presence of planned special events [Distributed Multimedia Systems DMS2014 Part I]. *Journal of Visual Languages Computing*, *25*(6), 973–980. https://doi.org/https://doi.org/10.1016/j.jvlc.2014.10.028

Lanzini, P., & Khan, S. A. (2017). Shedding light on the psychological and behavioral determinants of travel mode choice: A meta-analysis. *Transportation Research Part F: Traffic Psychology and Behaviour*, *48*, 13–27. https://doi.org/https://doi.org/10.1016/j.trf.2017.04.020

Lättman, K., Olsson, L. E., & Friman, M. (2016). Development and test of the perceived accessibility scale (pac) in public transport. *Journal of Transport Geography*, *54*, 257–263. https://doi.org/https://doi.org/10.1016/j.jtrangeo.2016.06.015

Lättman, K., Olsson, L. E., & Friman, M. (2018). A new approach to accessibility – examining perceived accessibility in contrast to objectively measured accessibility in daily travel [Competition and Ownership in Land Passenger Transport (selected papers from the Thredbo 15 conference)]. *Research in Transportation Economics*, *69*, 501–511. https://doi.org/https://doi.org/10.1016/j.retrec.2018.06.002

Li, X., Tang, J., Hu, X., & Wang, W. (2020). Assessing intercity multimodal choice behavior in a touristy city: A factor analysis [Cited by: 35]. *Journal of Transport Geography*, *86*. https://doi.org/10.1016/j.jtrangeo.2020.102776

Li, X., Wang, W., Yang, M., Wang, H., & Xu, C. (2016). Decision-making mechanism of integrated transportation multi-mode choice behavior for college students [Cited by: 3]. *Xi'an Jianzhu Keji Daxue Xuebao/Journal of Xi'an University of Architecture and Technology*, *48*(3), 357–361. https://doi.org/10.15986/j.1006-7930.2016.03.009

Lin, Y.-Z., & Chen, W.-H. A simulation-based multiclass, multimodal traffic assignment model with departure time for evaluating traffic control plans of planned special events [Cited by: 8; All Open Access, Gold Open Access]. In: *25*. Cited by: 8; All Open Access, Gold Open Access. 2017, 1352–1379. https://doi.org/10.1016/j.trpro.2017.05.161.

Louviere, J. J., Flynn, T. N., & Carson, R. T. (2010). Discrete choice experiments are not conjoint analysis. *Journal of choice modelling*, *3*(3), 57–72.

MacLeod, K. E., Thorhauge, M., Villalobos, V., van Meijgaard, J., Karriker-Jaffe, K. J., Kelley-Baker, T., & Ragland, D. R. (2020). To drive or not to drive? a study of travel behavior for a recent drinking occasion [Cited by: 4; All Open Access, Green Open Access]. *Travel Behaviour and Society*, *20*, 74–82. https://doi.org/10.1016/j.tbs.2020.02.008

Maeda, H. (2015). Response option configuration of online administered likert scales. *International Journal of Social Research Methodology*, *18*(1), 15–26. https://doi.org/10.1080/13645579.2014.885159

McFadden, D. (2000). Disaggregate behavioral travel demand's rum side. *Travel behaviour research*, 17–63.

Morris, J., Dumble, P., & Wigan, M. (1979). Accessibility indicators for transport planning. *Transportation Research Part A: General*, *13*(2), 91–109. https://doi.org/https://doi.org/10.1016/0191-2607(79)90012-8

Moutinho, L. (2000). *Strategic management in tourism*. CABI Pub. https://books.google.nl/books?id=wbEIbVjhRugC

Municipality of Alkmaar. (2005). Parkeerregulering tijdens voetbalwedstrijden en veiligheid van het kooimeerplaza en boekelermeer.

Municipality of Alkmaar. (2007). Parkeernormen 2007-2015. https://repository.officiele-overheidspublicaties.nl/externebijlagen/exb-2017-5741/currentItem

Murray-Webster, R., & Simon, P. (2007). Making sense of stakeholder mapping. *Project Management Practice*, *2007*.

Musgrave, J., Jamson, S., & Jopson, A. (2019). Travelling to a sport event: Profiling sport fans against the trans-theoretical model of change. *Journal of Hospitality and Tourism Research*, *45*. https://doi.org/10.1177/1096348020915255

NDW. (2023). Producttype snelheden en intensiteiten. https://docs.ndw.nu/producten/snelhedenenintensiteiten/#:~:text=Intensiteiten%20beschrijven%20het%20aantal%20voertuigen,op%20de%20weg%20wordt%20gemeten.

Newman, J., & Falcous, M. (2012). Moorings and movements: The paradox of sporting mobilities. *Sites: a journal of social anthropology and cultural studies*, *9*, 38–58. https://doi.org/10.11157/sites-vol9iss1id161

NOS. (2023a). 154 az-supporters in metro aangehouden vanwege antisemitische liederen. https://nos.nl/artikel/2474135-154-az-supporters-in-metro-aangehouden-vanwege-antisemitische-liederen

NOS. (2023b). Reconstructie: Me'ers 'als ratten in de val' bij bestorming az-stadion door legia-fans. https://nos.nl/artikel/2501929-reconstructie-me-ers-als-ratten-in-de-val-bij-bestorming-az-stadion-door-legia-fans

NOS. (2023c). Az-supporters bestormen hoofdtribune, waar veel familie west ham-spelers zit. https://nos.nl/collectie/13934/artikel/2475632-az-supporters-bestormen-hoofdtribune-waar-veel-familie-west-ham-spelers-zit

Pot, F. J., van Wee, B., & Tillema, T. (2021). Perceived accessibility: What it is and why it differs from calculated accessibility measures based on spatial data. *Journal of Transport Geography*, *94*, 103090. https://doi.org/https://doi.org/10.1016/j.jtrangeo.2021.103090

Preston, J., & Rajé, F. (2007). Accessibility, mobility and transport-related social exclusion. *Journal of Transport Geography*, *15*(3), 151–160. https://doi.org/https://doi.org/10.1016/j.jtrangeo.2006.05.002

Pulugurtha, S. S., Duddu, V. R., & Venigalla, M. (2020). Evaluating spatial and temporal effects of planned special events on travel time performance measures. *Transportation Research Interdisciplinary Perspectives*, *6*, 100168. https://doi.org/https://doi.org/10.1016/j.trip.2020.100168

Rao, V. R., et al. (2014). *Applied conjoint analysis*. Springer.

Rezaei, J. (2015). Best-worst multi-criteria decision-making method. *Omega*, *53*, 49–57. https://doi.org/https://doi.org/10.1016/j.omega.2014.11.009

Rijkswaterstaat. (2021). Spitsstroken. https://www.rijkswaterstaat.nl/wegen/wegbeheer/spitsstroken

Rijkswaterstaat. (2023). Snelweg a9. https://www.rijkswaterstaat.nl/wegen/wegenoverzicht/a9

Robinson, P., Heitmann, S., & Dieke, P. (2011). *Research themes for tourism*.

Ruan, J.-M., Liu, B., Wei, H., Qu, Y., Zhu, N., & Zhou, X. S. (2016). How many and where to locate parking lots? a space–time accessibility-maximization modeling framework for special event traffic management. *Urban Rail Transit*, *2*. https://doi.org/10.1007/s40864-016-0038-9

Rubin, O., Mulder, C. H., & Bertolini, L. (2014). The determinants of mode choice for family visits – evidence from dutch panel data. *Journal of Transport Geography*, *38*, 137–147. https://doi.org/https://doi.org/10.1016/j.jtrangeo.2014.06.004

Rudloff, C., & Straub, M. (2021). Mobility surveys beyond stated preference: Introducing mytrips, an sp-off-rp survey tool, and results of two case studies. *European Transport Research Review*, *13*. https://doi.org/10.1186/s12544-021-00510-5

Scheepers, C., Wendel-Vos, G., van Kempen, E., de Hollander, E., van Wijnen, H., Maas, J., den Hertog, F., Staatsen, B., Stipdonk, H., Int Panis, L., van Wesemael, P., & Schuit, A. (2016). Perceived accessibility is an important factor in transport choice — results from the avenue project. *Journal of Transport Health*, *3*(1), 96–106. https://doi.org/https://doi.org/10.1016/j.jth.2016.01.003

Schlereth, C., Eckert, C., Schaaf, R., & Skiera, B. (2014). Measurement of preferences with self-explicated approaches: A classification and merge of trade-off-and non-trade-off-based evaluation types. *European Journal of Operational Research*, *238*(1), 185–198.

Shahin, S., Hüseyin, T. O., & Kemal, Ö. S. (2014). Evaluating transportation preferences for special events: A case study for a megacity, istanbul [Transportation: Can we do more with less resources? – 16th Meeting of the Euro Working Group on Transportation – Porto 2013]. *Procedia - Social and Behavioral Sciences*, *111*, 98–106. https://doi.org/https://doi.org/10.1016/j.sbspro.2014.01.042

Sharmeen, F., & Timmermans, H. (2014). Walking down the habitual lane: Analyzing path dependence effects of mode choice for social trips. *Journal of Transport Geography*, *39*, 222–227. https://doi.org/https://doi.org/10.1016/j.jtrangeo.2014.07.012

Shobeirinejad, M., Veitch, T., Smart, J., Sipe, N., & Burke, M. Destination choice decisions of retail travellers: Results from discrete choice modelling in brisbane [Cited by: 3]. In: Cited by: 3. 2013. https://www.scopus.com/inward/record.uri?eid=2-s2.0-84916898696&partnerID=40&md5=7947db2d7583ad5b76ed1e60e49b1902

Skolnik, J., Chami, R., & Walker, M. D. (2008). *Planned special events economic role and congestion effects*. trid.trb.org/view.aspx?id=884222

Strömblad, E., Winslott Hiselius, L., Smidfelt Rosqvist, L., & Svensson, H. (2022). A qualitative case study examining individuals' perceptions of mode choice and the possibility to reduce car mileage for everyday leisure trips. *Case Studies on Transport Policy*, *10*(4), 2183–2194. https://doi.org/https://doi.org/10.1016/j.cstp.2022.09.013

Swait, J., & Andrews, R. L. (2003). Enriching scanner panel models with choice experiments. *Marketing Science*, *22*(4), 442–460.

Szeto, W., Wong, R., Yeung, J., & Wong, S. (2016). Mixed logit approach to modelling arrival time choice behaviour of cemetery and columbarium visitors during grave-sweeping festivals. *Transportmetrica A Transport Science*, *12*(4), 313–329. https://doi.org/https://doi.org/10.1080/23249935.2015.1135361

Talaat, N., & Rashwan, K. (2018). Success factors of hallmark events: The case of vietnam. *Journal of Association of Arab Universities for Tourism and Hospitality*, *15*, 79–84. https://doi.org/10.21608/jaauth.2018.54010

The Stadium Consultancy. (2021). *Projects: Afas stadium - az alkmaar*. Retrieved March 2, 2023, from https://www.stadiumconsultancy.com/project/afas-stadium-az-alkmaar/

TomTom Move. (2023). Tomtom move. https://support.move.tomtom.com/faq-data-source-quality/
Train, K. (2009). *Discrete choice methods with simulation* (Vol. 2009). https://doi.org/10.1017/CBO9780511805271
Transfermarkt. (2023). *Az alkmaar afas stadium*. Retrieved March 2, 2023, from https://www.transfermarkt.nl/az-alkmaar/stadion/verein/1090
TU Delft. (2022). Reader cie4831: Empirical analysis for transport and planning.
Turan, B., Ayataç, H., & Ince, E. C. (2022). Estimating the modal split ratios of square visitors in the case of istanbul's historical peninsula: Evidence from multinominal logistic regression model [Cited by: 0]. *Journal of Urban Planning and Development*, *148*(4). https://doi.org/10.1061/(ASCE)UP.1943-5444.0000880
UEFA. (2022). *2022/23 uefa europa conference league: Matches, draws, final*. Retrieved March 3, 2023, from https://www.uefa.com/uefaeuropaconferenceleague/news/0271-142f4c17015a-86d5502d5193-1000--2022-23-uefa-europa-conference-league-matches-draws-final/
United Nations. (2015). Un general assembly, transforming our world: The 2030 agenda for sustainable development. https://www.refworld.org/docid/57b6e3e44.html
United Nations. (2018). The netherlands is home to more bicycles than people! https://www.unep.org/news-and-stories/story/fridayfact-netherlands-home-more-bicycles-people
Van de Kaa, G., Taebi, B., Poel, I., & Kizhakenath, A. (2020). How to weigh values in value sensitive design: A best worst method approach for the case of smart metering. *Science and engineering ethics*, *26*, 475–494. https://doi.org/10.1007/s11948-019-00105-3
Van Wee, B., Hagoort, M., & Annema, J. A. (2001). Accessibility measures with competition. *Journal of Transport Geography*, *9*(3), 199–208. https://doi.org/10.1016/S0966-6923(01)00010-2
Verplanken, B., & Whitmarsh, L. (2021). Habit and climate change [Human Response to Climate Change: From Neurons to Collective Action]. *Current Opinion in Behavioral Sciences*, *42*, 42–46. https://doi.org/https://doi.org/10.1016/j.cobeha.2021.02.020
ViaStat. (2023). Wat bieden wij u? software, data, en educatie. https://www.via.nl/nl-NL/Products
Wang, Y., Chau, C., Ng, W., & Leung, T. (2016). A review on the effects of physical built environment attributes on enhancing walking and cycling activity levels within residential neighborhoods. *Cities*, *50*, 1–15. https://doi.org/https://doi.org/10.1016/j.cities.2015.08.004
Xianyu, J., & Juan, Z. (2012). Modeling commute length choice decisions in dual-income households [Cited by: 0]. *Wuhan Ligong Daxue Xuebao (Jiaotong Kexue Yu Gongcheng Ban)/Journal of Wuhan University of Technology (Transportation Science and Engineering)*, *36*(6), 1132–1135. https://doi.org/10.3963/j.issn.2095-3844.2012.06.008
Yang, Q., Gao, Z., Kong, X., Rahim, A., Wang, J., & Xia, F. (2015). Taxi operation optimization based on big traffic data, 127–134. https://doi.org/10.1109/UIC-ATC-ScalCom-CBDCom-IoP.2015.42
Zhao, J., Li, R., Liang, X., & Xu, K. (2016). Second ring is the most jammed road in beijing: A view from taxis and weibo, 1–6. https://doi.org/10.1109/ICSSSM.2016.7538630
Zheng, Y., Cao, J., Shen, Y., Liu, B., & Ji, Y. (2023). Parking planning with route assignment for planned special events. *Transportation Research Record*, *2677*(1), 266–280. https://doi.org/10.1177/03611981221098696
Zimmermann, M., Mai, T., & Frejinger, E. (2017). Bike route choice modeling using gps data without choice sets of paths [Cited by: 96; All Open Access, Green Open Access]. *Transportation Research Part C: Emerging Technologies*, *75*, 183–196. https://doi.org/10.1016/j.trc.2016.12.009
ZJA. (2021). *Stadion az, alkmaar*. Retrieved March 2, 2023, from https://www.zja.nl/nl/stadion-AZ-Alkmaar

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