A step in the right direction or losing your way?

A quantitative and qualitative master's thesis on the factors that influence pedestrian route choice

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Abstract

When people go for a walk, they must decide how they are going to walk from A to B. This can vary from person to person. Do you want the shortest route, or a scenic route? And how do you decide this if you are using a navigation system? Do you follow the navigation precisely? Or do you still let the environment guide you? Or what if you find out that the navigation does not meet your needs, because, for example, you want a route through nature, but are only guided through the city? Using mixed methods, this research examines the extent to which human, environmental and navigation factors influence the route choice of pedestrians in Wageningen. This is being investigated to find out whether navigation systems meet the wishes of pedestrians, and how walkability in a city can be increased. The results show that the pedestrian route choice is decided by the reason for the walk. When a pedestrian takes a practical walk, he or she will often take the shortest route. If the walk is recreational, it will be more likely to be guided by environmental factors, such as the aesthetics of the surroundings. A navigation system is only used if the pedestrian does not know the route and appears to be especially useful for walks where pedestrians want to walk the shortest route. However, there is no option for a recreational route that leads the pedestrian past attractive environmental places, partly because the maps are too incomplete for this.

Picture 1: Temporary pedestrian crossing (Glover Law Firm)
Logo’s frontpage: DTV (2024); Universiteit Utrecht (2024)

Preface

This is a master's thesis for the master’s degree in urban and Economic Geography. This topic was chosen in consultation with DTV. A consultancy company that carries out infrastructure assignments on behalf of all kinds of organizations, such as (local) governments. Together with them, I chose to investigate which factors influence the route choices of pedestrians. This is because I often use pedestrian navigation myself and I also experience problems using digital navigation systems when I want to discover new places as a pedestrian.

First, I would like to thank all respondents who completed the survey for me and therefore provided the primary data for my research. Secondly, I would like to thank all respondents with whom I had the opportunity to conduct a walk-along interview. Third, I would like to thank my thesis supervisor, F. Israel, for guiding my thesis throughout the entire process. Finally, I would like to thank my internship supervisor from DTV, C. Stolz, for supervising my thesis on behalf of DTV and granting me access to the survey on pedestrian behaviour in Wageningen. Without the above-mentioned people, this thesis would not have been possible.

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1. Introduction

Exploring the city on foot is a phenomenon that is becoming increasingly common. Walking is a way of moving that is important creating a sustainable and healthy city (Ferrer et al., 2015; Shamsuddin et al., 2012). In our ever-changing society, characterized by constant technological progress, digital navigation systems such as Google Maps and TomTom have become an indispensable role in the daily lives of people around the world (Fang et al., 2015). These technological aids have not only been limited to the world of drivers but have also found their way into traveling on foot (Fang et al., 2015). While these navigation systems are often praised for their accuracy, real-time updates and ease of use, there is an increasing need to investigate how pedestrians experience them and what problems they encounter while navigating (Fang et al., 2015).

Navigation is a spatial skill and behaviour and is helpful when people encounter unfamiliar environments. Spatial behaviour refers to the way individuals move in relation to their environment, which influences their fitness and interactions with other individuals and the environment (Stuber et al., 2022). Current research usually views pedestrian navigation as a process-oriented and goal-directed human behaviour. Because interactions and mutual influences between humans and the environment are so complicated, pedestrian navigation systems do not easily understand people's needs in a manner compatible their route choice preferences (Fang et al., 2015; Ferrer et al., 2015).

Because the needs of pedestrians sometimes cannot be fully met in digital systems, people deviate from the proposed route. Problems that cause people to deviate from the route are, for example, routes that are not passable, because pedestrians themselves know a shorter route or because of a personal preference. Delikostidis (2011) notes that accurate data entry of roads and footpaths into navigation system databases is crucial for proper functionality. However, limitations exist, such as inaccuracies or incompleteness in the database, leading to missing footpaths on digital maps (Barkham, 2020).

This incompleteness has to do with the underlying technology of navigation systems, namely Geographic information systems (GIS). GIS form the essential basis for the functioning of digital navigation systems (Longley & Cheshire, 2017). GIS integrates spatial data such as maps, location-specific information, and terrain features into a digital platform, making it possible to develop complex navigation algorithms and offer real-time route guidance (Longley & Cheshire, 2017). By using GIS, navigation systems such as Google Maps, can not only calculate the most efficient routes, but also consider factors such as traffic, roadworks, and alternative transport options. Furthermore, GIS offers the ability to provide users with additional information, such as points of interest, local businesses, and public transport schedules, further improving the user experience (Longley & Cheshire, 2017). In short, GIS is the backbone of digital navigation systems and plays a crucial role in providing accurate, reliable, and useful navigation aids for pedestrians and other road users (Longley & Cheshire, 2017). However, if this information is incorrect, it can cause travellers to have a negative experience or to deviate from the route (Ben-Elia & Avineri, 2015).

It is therefore interesting to conduct research on how digital navigation systems influence the route choices of pedestrians, because navigation systems can help in improving the walkability in a city and thus in stimulating walking on the first place (Pereira et al., 2020). However, other factors such as environmental ones should not be forgotten, as they can both influence pedestrians' route choice. Therefore, the following main question will be answered: *How do digital navigation tools and environmental factors influence the route choice behaviour of pedestrians?*

The aim of this thesis is to investigate the interconnection between the walking navigation tools and the users experience in combination with the environmental factors. For example, what problems pedestrians experience with digital navigation systems. This will allow us to gain a deeper understanding not only of how these technologies affect pedestrian route choice but also of what adjustments are needed to improve the experience of using navigation systems. Finally, this research will give insight in the influence of both environmental factors and technological factors for the route choice of pedestrians and how pedestrian experience the overall walkability in cities, based on both environmental and technological factors (Kapenekakis & Chorianopoulos, 2017; Pereira et al., 2020; Quercia et al., 2015).

First it is necessary to look at what pedestrians want from digital navigation systems to see why pedestrians may deviate from the specified route. The following sub-question will give an answer to this: *What are people's needs and desires in pedestrian navigation systems?* [Q1]

If pedestrians are using a navigation system, it influences their route choice behaviour (Garnter et al., 2011). That is why it is interesting to look at the following sub-question: *When does a GPS navigation system influence pedestrians' route choices?* [Q2]

Once the influence of navigational systems on pedestrians' route choice are known, it is useful to examine how pedestrians experience navigation systems, to further explore its influence on pedestrian route choices: *How do pedestrians perceive the quality of pedestrian routes proposed by a navigation system?* [Q3]

Not only pedestrians as an actor will be examined but also the navigation system that provides these routes: *How are pedestrian infrastructure and routes represented in geographical information systems (maps) and with what quality?* [Q4] This will show cases in which pedestrian deviate from the proposed routes by navigation systems and why they deviate from those routes.

Because not only navigation systems influence the route choice of pedestrians, but environmental factors as well (Ferrer et al., 2015), the following sub-question will provide more insight into this: *What environmental factors influence pedestrians' route choices?* [Q5]

1.2 Relevance

1.2.1 Scientific Relevance

The first research gap is about the combination of factors that influence the route choice behaviour of pedestrians. Research is mostly focused on personal factors, environmental factors, or digital factors, but does not combine those factors on route choice behaviour. For example, Basu et al. (2021) research factors that influence pedestrian route choice, examining social, physical, and individual factors.

In addition of combining the above-mentioned factors, it is also interesting to investigate to what extent socio-demographic factors influence pedestrian route choices. This will be explained by an example. A study by Fisu et al. (2024) shows how Generation Z has a different walking behaviour and thus route choice behaviour than other generations. This is because they are in a different phase of life than other generations. This study will include people from 18-year-old and onwards to research how different age categories have a different route choice and walking behaviour.

This study contributes to behavioural studies by trying to understand how individuals interact with and experience their surroundings using navigation systems and making spatial choices. This understanding is fundamental to design effective pedestrian navigation systems (Fang et al., 2015). This is because navigation systems are primarily designed to take users from point A to B, which is convenient for drivers but not necessarily for pedestrians who may have specific preferences about their walking routes (Kapenekakis and Chorianopoulos, 2017). Existing navigation systems do not fully gather which pedestrian preferences impact walkability.

In conclusion, this study aims to combine both environmental, navigational, and human factors and their combined influence on pedestrian route choice behaviour instead of only researching one or two factors, as literature by Basu et al. (2021) and Kapenekakis & Chorianopoulos (2017) for example did. Furthermore, it will also be investigated how and to what extent ages, a human factor, influence route choices. Because, although this has been done for generation Z by Fisu et al. (2024), it is interesting to research this for all generations and to combine this with all the three factors mentioned above.

By addressing these research gaps, this thesis aims to contribute valuable insights to the fields of urban planning, behavioural studies, and spatial cognition, enhancing the design of pedestrian navigation systems to better meet user needs and to understand more about which factors influences a pedestrian the most and when for its route choice behaviour.

1.2.2 Societal Relevance

This research aims to inform policymakers and urban and traffic designers about what problems pedestrians experience when walking their routes with a digital navigation system (Blečić et al., 2020).

Currently, there is a lack of real-time information through navigation systems and road signs for pedestrians (Prescott et al., 2021). For example, routes shown by navigation systems can be experienced as unpleasant by pedestrians, such as high vegetation, or because of a feeling of insecurity. Moreover, pedestrians can, for example, be send to unsafe locations when using a navigation system (Fang et al., 2015). This is reinforced because GIS systems have only limited knowledge of the footpaths, and more of street networks (Shields et al., 2021).

Pedestrian navigation systems are used for different purposes. This also depends on the actor. Most pedestrians tend to use a navigation system when they are unfamiliar with the area, for example, when they are on holiday (Fang et al., 2015; Philips et al., 2013; Siriaraya et al., 2020). Therefore, further research on pedestrian navigation with digital navigation systems is necessary to aid, for example, those tourists.

In this research, all the actors who use navigation systems for pedestrian navigation, including wheelchair users are included. It is also necessary to raise awareness of the problems that pedestrians with physical disabilities experience regarding navigating and walking. Research can help in creating inclusive navigation solutions that are accessible to all users (Basu et al., 2021; D’Orso and Migliore, 2018; Gamache et al., 2018; Siriaraya et al., 2020).

A good pedestrian network (physical and digital) is also necessary to create a higher walkability to enhance urban mobility. Good-function navigation systems will increase the promotion of walking as a sustainable and healthy mode of transportation (Fang et al., 2015; Shamsuddin et al., 2012; Shatu et al., 2019b). However, as will be explained in the next chapter, walking is not only a way as a practical form of transportation, but also for recreation (Ettema & Smajic, 2014).

Understanding the complex interactions between pedestrians, their environment, and digital navigation systems as an aid for pedestrian transportation is crucial for designers of such applications to reduce cognitive load, enhance decision-making, and provide a seamless navigation experience, especially in unfamiliar environments (Fang et al., 2015).

Continuous research can help improve the usability, accuracy, walkability, and effectiveness of digital navigation systems for pedestrians. By understanding user needs, preferences challenges and thus, their route choices, researchers can design more user-centric and intuitive navigation interfaces (Fang et al., 2015). This allows pedestrians to experience walking as more pleasant and allows government actors and urban planners to learn more about how they can make walking more accessible through navigation systems (Blečić et al., 2020; Shields et al., 2021).

2. Theoretical Framework

This chapter will first explain what motivations people have for walking and secondly the three factors: human, environmental and navigation that influences pedestrians' route choices. The human and environmental factors are more psychological in nature, based on perception, and the navigation system is a technological factor (Basu et al., 2021; Ettema & Smajic, 2014; Ferrer et al., 2015).

2.1 Walking & Route choice

First, why do people walk, and not, for example, take another means of transport? There are several reasons why people walk (Ettema & Smajic, 2014; Ferrer et al., 2015). This may be because they want to get from A to B, which is a practical walk. However, people can also walk because they enjoy it or for their health, which can be considered walking for recreational purposes. For example, people can go for a walk in nature or in the city (Ettema & Smajic, 2014). Furthermore, people can also start walking because this is good for their health, because walking is good for preventing cardiovascular diseases (Ettema & Smajic, 2014; Sevtsuk et al., 2021; Shatu et al., 2019b). Because the reasons for people to walk are different than those from other road users, the route choice behaviour for pedestrians is different in contrast to other road users (Garnter et al., 2011).

When people go for a walk, they make various choices before their walk based on different socio-temporal constraints. These include the destination, the road network, whether there are multiple destinations, the speed of walking and the extent to which you can become distracted by the environment. This is the travel behaviour (Basu et al., 2021).

It is also important to explain the previously mentioned term, route choice. Route choice means all routes a person can walk and will choose between the starting point and the destination. So as a pedestrian, or with other modes of transportation, you choose between a series of route options (Basu et al., 2021; Fang et al., 2015).

The route choice is also influenced by the wayfinding of pedestrians. "Pedestrian navigation focuses on the guidance process of pedestrian travel behaviour between identifiable origins and destinations." (Fang et al., 2015, p. 136). This is linked to the concept of the mental map, which will be explained in paragraph 2.2.1.2 (Hannes et al., 2010). Simple said, people need to know the road network to choose the route they want to walk.

According to Basu et al. (2021), there are three types of pedestrian behaviour that can influence a pedestrian's route choice: strategic, tactical, and operational walking. When people walk strategically, they have everything planned, such as the purpose of walking, the activities that will take place along the way, the destination, and the time they will leave. This is, for example, when someone walks from his or her home to work. In tactical walking, pedestrians make the decisions that will take place as they go. Finally, there is walking at the operational level. In this case walking will be interrupted by, for example, interaction with the pedestrians' environment. This interaction can take place both on and off the street (Basu et al., 2021). The reason people walk can therefore influence the route choices that people have (Basu et al., 2021; Ettema & Smajic, 2014).

2.2 Experience of walking

As Fang et al. (2015) explains: 'Wayfinding and navigation are two basic ways that describe the process behind human movement behaviour.' (p. 136). They are instinctive behaviours of people (Fang et al., 2015; Hannes et al., 2010):

> “Wayfinding involves four basic stages: orientation, route decision, route monitoring, and destination recognition. The complicated factors that are involved in these four stages include human and environmental factors. For example, human factors are spatial orientation, cognitive mapping abilities, route strategies, language, culture, gender and biological factors” (Fang et al., 2015, p. 136).

Cognitive mapping abilities means the power of the mind to be able to make a mental map, and thus to navigate through an area (Hannes et la., 2010). Environmental factors include the nodes, edges, paths, districts, landmarks, and signs (Fang et al., 2015). These all contribute to the experiences people have while walking (Ettema & Smajic, 2014; Fang et al., 2015).

Next, the personal factors, environmental factors and digital factors that may influence the experience of walking and route choices are discussed.

2.2.1 Personal factors

There are two types of personal factors that can influence pedestrians' route choices and preferences. These are socio-demographic factors at the macro level and mental maps at the micro level (Basu et al., 2021; Gim & Ko, 2016; Hannes et al., 2010; Shatu et al., 2019a). These will be discussed below.

2.2.1.1 Socio-demographic factors

Basu et al. (2021) indicates four socio-demographic factors that have positive or negative associations with the route choice decisions of pedestrians. These are age, gender, income, and the presence of companions.

Firstly, the age of pedestrians can influence their route choice behaviour. Fisu et al. (2024) did research on pedestrian navigation specifically on Generation Z and concluded that people of Generation Z have varied reasons they need to walk than other generations, because they are students or because their financial situation is different in relation to people of other generations. For example, students make more use of the public transportation than other generations. So, because the reasons for people of generation Z is different, their walking behaviour and route choices are also different. Generation Z is more likely to choose a route with both modern residential and commercial environment, while in general, pedestrians older than 65 years usually prefer a route with a higher walkability (Basu et al., 2021). This shows that a pedestrian's age can influence their route choice.

Secondly, the gender of pedestrians can influence a route choice. “Male pedestrians were likely to select a walking route with the quickest path, had fewer streets to cross, and was less crowded. On the other hand, the availability of shops was important for female pedestrians.” (Basu et al., 2021, p. 684). Research by Fisu et al. (2024) elaborates on this further and shows that the reasons why people walk are different. For example, men more often walk for pleasure and women more for practical reasons, such as to facilities. This also influences their pedestrian behaviour and route choice.

Even the income, a third factor of a pedestrian can influence the route choice. Shatu et al. (2019a) found that a route with commercial opportunities (for shopping or having food/drinks) is more likely to be chosen by higher-income students. Fisu et al. (2024) adds to this that people who need to use public transportation also make other route choices in relation to people who have access to private vehicles. So, the demographic factors age, gender and income influence the individual route choices that pedestrians make (Basu et al., 2021; Gim & Ko, 2016; Shatu et al., 2019a).

2.2.1.2 Mental Maps
A mental map means, in geographical terms, one's mental geographical knowledge. So, it is a map in a person's mind (Hannes et al., 2010). It is therefore a self-invented map of the spatial environment. It includes information about locations, routes, distances, landmarks, and spatial relationships stored in memory. Mental maps help individuals make sense of the world and guide their travel behaviour in various spatial tasks, such as wayfinding, navigation, and decision-making (Gartner et al., 2011; Hannes et al., 2010; Shatu et al., 2019a).

There are two ways in which a mental map contributes to an individual's route choice. The first is spatial cognition. When a person plans a trip or makes travel decisions, their mental map influences their choices of destinations, transport modes, and routes. Imperfect information in mental maps can affect decisions related to accessibility and trip planning (Hannes et al., 2010; Shatu et al., 2019a).

The second way in which a mental map contributes to route choice is through decision-making. When faced with travel decisions, individuals create mental models that include relevant choice factors and decision rules. These mental representations guide individuals in making choices related to travel destinations, modes of transportation, and scheduling activities. Understanding these decision-making processes can help in modelling and predicting individual travel behaviour (Hannes et al., 2010).

A mental map therefore shows that people only know a certain number of routes and will therefore choose a route between the routes they know. A mental map also ensures that people have preferences for certain routes. When people "execute" a route, they will be confronted with information that will update their mental map. Routes to primary nodes, such as home, work and the supermarket, will be better in the mental map than other locations. This, with other locations ensures that people get an "image of the city" (Basu et al., 2021; Hannes et al., 2010).

Thus, people use their mental maps to navigate (Basu et al., 2021). There is also a connection between mental maps and digital navigation. For example, 2D/3D maps show the nearby area where pedestrians walk, which includes the road network, buildings, points of interest to help them find themselves in their surrounding environment (Fang et al., 2015). This will add to their mental maps.

2.2.2 Environmental factors
In addition to personal factors, environmental factors can also influence pedestrians' route choice and navigation experience (Fang et al., 2015). Environmental factors are connected to walkability and accessibility of a route, such as the availability of benches along a path, and the physical factors in the environment of the area people walk. The presence of roads and a pedestrian network should not be missing. Safety is also an important environmental factor. This includes two types of safety, safety of crime and traffic safety (Ferrer et al., 2015; Hannes et al., 2010).

In addition to the safety factor that can influence a traveller's route choice and experience, physical environmental factors can also affect this. These physical factors can be divided into three categories, walking facilities, aesthetics and convenience and other preferences (Ferrer et al., 2015).

2.2.2.1 Safety

The first environmental factor that will be addressed is the degree of safety. This factor can be divided into two categories, the feeling of safety based on crime and road safety (Ferrer et al., 2015).

The perception of safety, based on crime, is a psychological factor, based on physical factors in the environment while walking. Factors that influence this include the presence of street lighting, the presence of other people and how clean the street is. The presence of street lighting contributes to a positive feeling of walking (Basu et al., 2021). The presence of other people and a clean street also contribute to a feeling of safety and to the choice of whether to walk at all and which route to take. Vice versa, the absence of streetlights, small alleys and the (lack of) presence of other people can have a negative effect on route choices (Basu et al., 2021; Ferrer et al., 2015; Shatu et al., 2019a). If pedestrians do not feel safe, they will choose a different route where they feel safer (Ralph et al., 2020).

An important note here is that the experience of safety is personal. This is because it is a psychological factor, based on the physical elements mentioned above. It is therefore possible that one user may experience a route as unsafe because there are few people walking there, while another person may prefer this route because they do not want to be in contact with other people. This is an example of how route choices are individual and can therefore differ per person (Ferrer et al. 2015).

In addition to the feeling of safety based on crime, there is also road safety. Traffic safety includes factors such as traffic volume, crossings, the behaviour of other road users and the width of the roads (Basu et al., 2021; Sevtsuk et al., 2021; Shatu et al., 2019a; Shatu et al., 2019b). Traffic density here concerns the number of cars that come close to pedestrians, such as driving on the same road or when crossing the road. Crossings themselves are also a factor that falls under road safety. For example, a zebra crossing, pedestrian lights, and a separate intersection add to road safety. However, people are willing to walk up to about seventy meters if they can avoid a busy crossing, because pedestrians prefer not to wait long at a crossing (Basu et al., 2021; Sevtsuk et al., 2021; Shatu et al., 2019a). The behaviour of other road users is also part of road safety. If other road users show unsafe behaviour on the road, this will lead to lower road safety (Basu et al., 2021; Ferrer et al. 2015). Overall, pedestrians prefer a route with a high degree of road safety (Basu et al., 2021; Sevtsuk et al., 2021; Shatu et al., 2019a).

The time-of-day influences both the feeling of safety and road safety. People do not want to walk in the dark because this gives them a feeling of insecurity based on crime, but also because it reduces road safety (Basu et al., 2021; Ferrer et al. 2015; Phillips et al., 2013).

The absence of pedestrian facilities can reduce road safety, such as the absence of a footpath/sidewalk. This means pedestrians must either take a different and longer route or walk on the road (Basu et al., 2021).

2.2.2.2 Walking facilities

The second environmental factor that contributes to pedestrians' route choice is the presence of walking facilities. There are four phenomena influencing this (Ferrer et al., 2015). The first one is the width of the sidewalk, pedestrians prefer a route with wide sidewalks (Ferrer et al., 2015; Shatu et al., 2019a). Secondly, the presence of obstacles ensures that pedestrians will avoid a certain route or road. Such obstacles include steep height differences, pedestrian crowding, or blockages due to trees, cracks, and barriers (Basu et al., 2021; Ferrer et al., 2015; Sevtsuk et al., 2021).

The third factor is the quality of the sidewalks (Ferrer et al., 2015; Shatu et al., 2019a; Shatu et al., 2019b). A sidewalk with a poor road surface is more likely to be avoided by pedestrians because of tripping hazards (Basu et al., 2021). This also includes the accessibility of sidewalks, through ramps. The more accessible a path, the more likely it will be walked (Basu et al., 2021). Finally, the availability of shade in the summer through trees also ensures that the route is experienced as pleasant (Basu et al., 2021; Shatu et al., 2019b). While people prefer a shorter route, they are willing to take a longer route if it has better walkability facilities (Basu et al., 2021; Ferrer et al., 2015; Sevtsuk et al., 2021; Shatu et al., 2019a; Shatu et al., 2019b).

2.2.2.3 Aesthetics

The third environmental factor is aesthetics. Pedestrians are more likely to take a route with a beautiful environment, such as parks, public greenery, the presence of shops and decoration, such as fountains (Basu et al., 2021; Ferrer et al., 2015; Sevtsuk et al., 2021).

The aesthetics factor is linked to the feeling of safety because abandoned buildings create a feeling of insecurity. This will cause pedestrians to avoid this route, even if it means taking a detour (Basu et al., 2021).

Not only our eyes, but also other senses influence the aesthetics. The noise level of the environment and odours influence the route choice and experience of pedestrians as well. Pedestrians will avoid a route with a high noise level and nasty odour (Basu et al., 2021; Ferrer et al., 2015; Sevtsuk et al., 2021).

Pedestrians prefer residential streets over the shortest path because residential roads are low in traffic. The chance of choosing a route, increases with the presence of commercial facilities, such as shops, along the route, because shops offer an opportunity to make an unplanned stop (Basu et al., 2021; Shatu et al., 2019b). Basu et al. (2021) also explains the following about the aesthetics of the walking environment:

> “Conversely, the presence of industry and traffic areas along the route is considered as an obstruction to route choice. In addition, vacant land along a route is perceived as unattractive to pedestrians and reduces the likelihood of that route being chosen.” (p. 682).

2.2.2.4 Convenience and other preferences

The factor convenience and other preferences factor includes aspects that can make walking more pleasant, who do not fall into the other environmental categories, such as the crowds on the street or the pedestrian path network. For example, pedestrians will avoid a route with a higher pedestrian density that increases the travel time to reach the destination (Ferrer et al., 2015; Koh and Wong, 2013). Travel time also influences people's route choice, and they often prefer a route with a shorter travel time. For example, pedestrians are more likely to take a route where they must wait less, such as for a traffic light. (Basu et al., 2021).

Furthermore, pedestrian networks with more angularity (turns) ensure that fewer people will walk there (Ralph et al., 2020). GIS can be used to calculate routes with the shortest time, or with the lowest angularity (Shatu et al., 2019b). This shows that both travel time and angularity are important for route calculation and that one method cannot exist without the other to present the best route to pedestrians. However, pedestrians tend to prefer fewer turns than a shorter travel time (Gartner et al., 2011; Shatu et al., 2019b). Pedestrians thus will choose a route which is more convenient to walk.

Moreover, the study by Garnter et al. (2011) looked at the relationship between the complexity of the route and the route with the shortest travel time. Users were encouraged to provide ratings for each decision point (DP) to show how complex they found the correct decision at this DP to be. In this way, two types of routes are offered: the least complex route (LCO route) and the route refined based on length and complexity. The LCO route is defined as the route with the lowest complexity rating between an origin and a destination. A route often consists of a series of DPs. The overall complexity rating of the entire route is simply calculated as the sum of the complexity ratings of each DP. The LCO route considers both the complexity assessments of DPs and the Euclidean distance of route sections. It tries to find the best compromise between the least complex route and the shortest route (Garnter et al., 2011). Sevtsuk et al. (2021) adds that crossings, both level and grade-separated, give pedestrians the idea that the route distance is technically longer. This is the concept of the “equivalent walking distance”. So, pedestrians will avoid complex crossings.

A last preference is that pedestrians with one to four companions when walking are likely to select routes other than the shortest route to enjoy walking, but pedestrians with five or more companions were likely to choose the shortest path (Gim & Ko, 2016; Basu et al., 2021). This indicates that the amount of people is a factor that also influences the route choice behaviour of pedestrians.

The above literature therefore shows that environmental factors, such as safety, aesthetics, walking facilities and convenience and other preferences, can have both a positive and negative influence on the pedestrian route choices made. A trade-off is also made between the length of the route/travel time and how difficult the route is (angularity).

Environmental factors and human factors also influence each other. For example, people do not always look at the shortest route, but can become distracted and have other preferences on certain environmental aspects based on their mental maps, such as the amount of other people during the walk (Basu et al., 2021; Ferrer et al., 2015; Sevtsuk et al., 2021).

2.2.3 Navigation systems & Digital factors

In addition to personal and environmental factors, there are also digital factors that may influence pedestrians' route choices. These are influenced by navigation systems. Navigation systems use Global Positions System (GPS) for continuous tracking of its users. That way it can provide its users with real-time route guidance (Garnter et al., 2011).

The main reason people use a navigation system is when they are unfamiliar with the area (Fang et al., 2015; Philips et al., 2013; Siriaraya et al., 2020). These people are on holiday, a day out or visiting friends in an area where they are not familiar. Sometimes signs are sufficient to reach the intended location. Digital maps, such as those from Google Maps, can also be used during the preparation of a route choice to avoid any confusion at the location itself. Such navigation systems are not only used for walking, but also in public transport and while driving (Phillips et al., 2013).

Navigation systems are known to calculate the shortest route in distance. However, the wishes of car users who use a navigation system are different from those of pedestrians. For example, pedestrians may not want to follow the most direct route, but rather follow a simple, safe, and more pleasant route. Environmental factors can also play a role in this. Nowadays, navigation systems are trying to introduce more attributes that respond to the environment and safety of the routes (Garnter et al., 2011; Siriaraya et al., 2020). Yang and Lam (2021) show that if environmental factors were considered more in the route calculation of a navigation system, routes would be calculated differently compared to car navigation.

Siriaraya et al. (2020) describes the development of navigation systems on practical aspects such as time and distance as a comprehensive approach. Initially, these systems were aimed at offering the best routes in terms of distance and time. Later, dynamic factors such as congestion and weather conditions were included in the route calculations.

Recent research has led to navigation systems that also consider aesthetic and safety aspects, as well as the well-being of users during their journey when calculating a route. This development is made possible by the enormous growth of available information from online social media and public datasets, allowing both objective and subjective aesthetics and safety aspects of routes to be analysed. Using this data, navigation systems can recommend routes that are not only efficient, but also maximise enjoyment, safety, and well-being during their journey for its users (Siriaraya et al., 2020). The factors that navigation systems (must) consider are explained below.

The first factor that navigation systems consider is safety (Siriaraya et al., 2020). This safety can again be divided into physical and psychological safety (Fang et al., 2015). Navigation systems should provide routes in such a way that users can safely follow the route with a low chance of encountering crime or traffic accidents. This is done based on the presence of environmental factors, such as street lighting. The data of unsafe situations can also be processed in the street system using static data and crowd-serve data from system reports (Siriaraya et al., 2020). Pedestrians have multiple senses, eyes, and ears, which perceive navigation instructions from navigation systems. These senses provide navigation instructions to the pedestrian's brain, and this perceived information can influence decisions about spatial behaviour in the surrounding environment. This auditory aspect is especially important because pedestrians can listen to navigation instructions while walking without having to look at the navigation screen to process instructions (Delikostidis et al., 2015; Fang et al., 2015).

Furthermore, there is also a safety factor when using a digital navigation system. For instance, pedestrians may be too focused on looking at the navigation app than on their surroundings and may fall or walk somewhere where it is not safe to walk. There is also the psychological aspect that the same instructions given by a navigation app can be interpreted differently by different people. Misinterpreting route instructions can cause people to walk the wrong way and then, again, walk in a place where it is unsafe (Delikostidis et al., 2015; Fang et al., 2015). If pedestrians are not sure whether the current route is correct, pedestrians should regularly confirm the direction they are walking with the planned route. This situation will cause frequent affirmative behaviour, which could result in a high cognitive load and would not be conducive to a relaxed physiological state. If pedestrians are familiar with parts of a current route and environment, they can walk to suitable routes themselves (Fang et al., 2015).

A second factor that navigation systems could consider is the health and physical condition of the users. This is done by not allowing users to walk in places with a lot of pollution (Siriaraya et al., 2020).

The third factor that navigation systems could consider discovering new areas. This is especially useful for tourists. “Contextual information such as the type of venue (museum, nightlife venue, etc.), the weather conditions and the time of the trip could be further incorporated to more accurately determine the attractiveness of the locations” (Siriaraya et al., 2020, p. 135574). The data for locations that tourists often want to visit comes from social media (Siriaraya et al., 2020). This involves looking at how often such a location is visited to give it a weighting. The geographical data for this comes from organisations such as OpenStreetMap (OSM) (Siriaraya et al., 2020).

Furthermore, it is the experience that influences a pedestrian's use of navigation experience. Navigation systems try to choose the best routes from an aesthetic point of view. This concerns routes that do not pass through smelly or boring areas, but, for example, through nature (Siriaraya et al., 2020).

GIS are often used to include the above factors in finding the best route. An example of this is that there is noise within a certain distance of a highway. A buffer can be used to calculate which surrounding roads are in the nuisance area of a highway. Navigation systems can then try to avoid these paths. For example, the data for the highways comes from OSM. For this it is important that the required data is correct and complete to be able to propose the correct routes to users. Otherwise, people will be led along roads that may be polluted or dangerous. The importance of the wishes is calculated based on weightings (Siriaraya et al., 2020).

Users prefer a navigation system that is complete. Pedestrians often must decide for themselves whether their route is walkable. For example, pedestrians who cannot climb stairs must check for themselves whether they can follow an alternative route without stairs. The experience of respect is also important here. If pedestrians consciously deviate from the route, they do not want to be confronted with endless instructions to turn around, but want an alternative route displayed (Fang et al., 2015).

2.2.3.1 Data

As Siriaraya et al. (2020) has already showed, it is important that navigation systems have the correct data to meet the needs of users. According to Siriaraya et al. (2020), there are three types of data types: Static Street features, dynamic street features and user experience features. This data can all be processed in GIS to optimise navigation systems.

Static street features are data aspects that are fixed, such as the physical properties of a road (its location, width, and road layer type). This also includes the facilities available on the route, including aesthetics. The data for this is usually collected by road networks, such as OSM (Siriaraya et al., 2020).

Dynamic street features are dynamic aspects of a path and route that differ based on time. This includes, for example, the traffic on the road, the weather, and the time of day. The data for this can be collected through social media and safety reports. Most navigation systems currently contain no or a limited amount of dynamic street features. This is because there is simply no way to quickly process this data when it changes (Metz, 2022; Siriaraya et al., 2020).

User experience features are related to the perceived opinions and experience of the users about the roads and routes. This is, for example, the feeling of safety or how aesthetic the environment is according to the users. This data is collected by asking users (Siriaraya et al., 2020).

The research by Siriaraya et al., (2020) shows that digital factors and environmental factors influence each other. For example, the 'costs' of travelling a route are not only determined by the travel time, but also by environmental factors. It is therefore especially important that navigation systems not only look at the shortest route, but also at the wishes of pedestrians (Fang et al., 2015).

2.3 Walkability

The above-mentioned factors (personal, environmental, and digital) all influence each other and together influence the walkability of a city. Walkability influences the route choice of pedestrians (Kapenekakis & Chorianopoulos, 2017). But what does the concept of walkability mean? Walkability refers to the extent to which an area, such as a neighbourhood or a city, is designed and arranged to encourage and support pedestrians to walk there (Kapenekakis & Chorianopoulos, 2017; Quercia et al., 2015). A walkable environment is one that can be explored easily and safely on foot, with attention to the needs and experiences of pedestrians. A high walkability score means that an area is well designed and equipped for pedestrians, which can improve the accessibility, health, and quality of life of residents (Kapenekakis & Chorianopoulos, 2017; Quercia et al., 2015). Eventually, the walkability of a route can be improved by showing the factors associated with PRC (Pedestrian Route Choice) (Basu et al., 2021).

First, the personal factors. These are influenced by mental maps, but also by demographic factors. The demographical factors include physical health, age, gender, and feeling of safety (Basu et al., 2021; Hannes et al., 2010; Quercia et al., 2015).

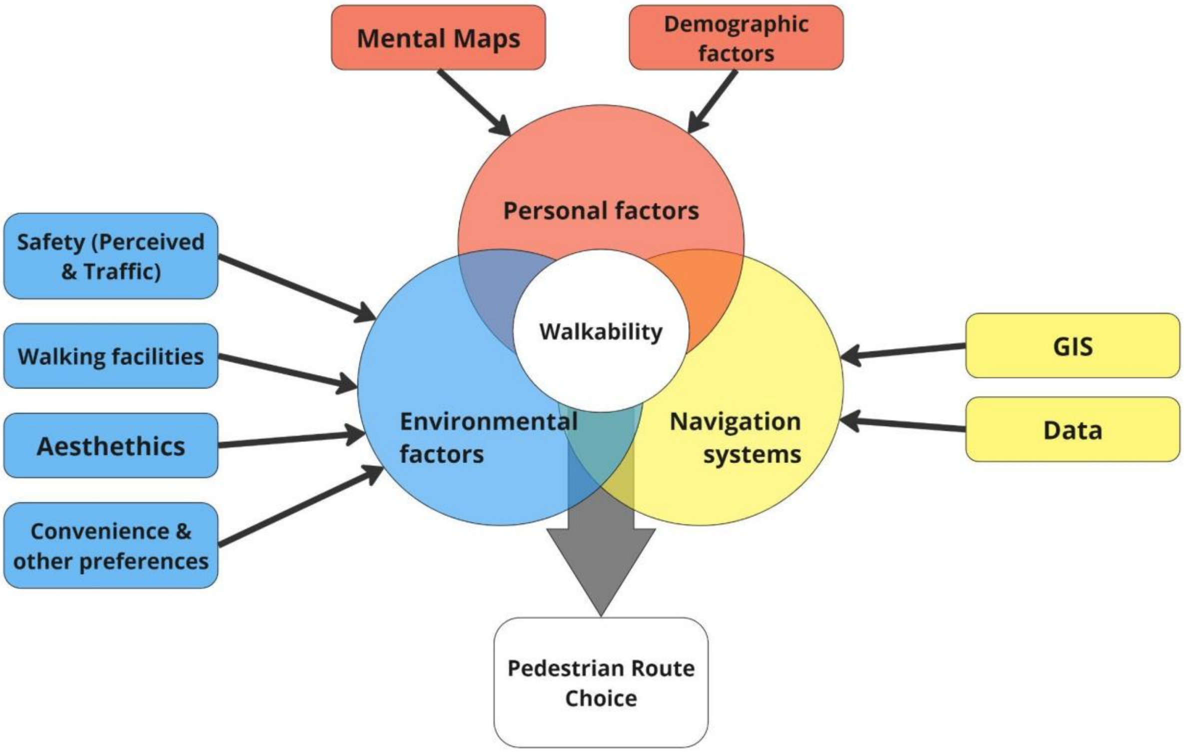
The walkability of a city/area influences the choices people make when choosing their route. When an area is considered highly walkable, with features such as safe crossings, well-maintained sidewalks, attractive surroundings, and nearby amenities, people will be more likely to travel on foot and choose routes that include these walkable features. These routes must be found by pedestrians, which is why, among other things like road signs, navigation systems are used. (Basu et al., 2021; Ferrer et al., 2015; Mulyadi et al., 2022; Shatu et al., 2019; Sevtsuk; 2021; Quercia et al., 2015).

Integrating walkability criteria into navigation apps and route planners can therefore contribute to promoting active mobility, creating walkable environments, and stimulating healthy and sustainable urban development. Improving navigation factors in relation to walkability can have a positive impact on the way people move and improve the quality of their urban experience (Kapenekakis & Chorianopoulos, 2017; Quercia et al., 2015).

2.4 Conclusion

Figure 1 shows that personal factors, environmental factors, and navigation systems together create an individual's walkability. This in turn influences people's pedestrian route choice. The personal factors consist of mental maps and demographic factors. Demographic factors concern personal preferences that are categorized by gender, age, etc. In addition to demographic factors, environmental factors also influence walkability and pedestrian route choice. These environmental factors consist of aesthetics, facilities, convenience and other preferences and safety. Safety can be divided into road safety and the feeling of safety, based on crime. The convenience of a route consists mostly of the presence of a pedestrian network. Finally, navigation systems or digital factors also influence walkability and pedestrian route choice. This is because pedestrians may not be shown the best route via these systems. The best route can be discovered via navigation systems, but it must meet the wishes of the users. This does not always have to be the fastest route but can be influenced by, for example, environmental factors. The three factors mentioned above also influence each other. For example, people may have different preferences on environmental factors due to personal factors, such as their familiarity with the area. One person may also experience a location as safe, but another person may not. Personal and environmental factors also influence navigation systems. The wishes of the users influence whether the navigation system is perceived as working properly.

Figure 1: Conceptual Model



3. Methodology

This chapter will explain which research methods were used, and why and how these methods were used. Any limitations and ethics will also be discussed in this chapter.

The formulation of the main question could be seen as causal as it examines the influence of navigation systems and environmental factors on the route choice of pedestrians. The theoretical framework describes how and which environmental, digital, and personal/human factors influence the route of pedestrians. It also explains how pedestrians react to the routes provided by navigation systems and how pedestrians experience them. Below is how the data will be collected and processed to answer the research question.

This research uses both qualitative and quantitative data, i.e. mixed methods. According to Basu et al. (2021) and Hay and Cope (2021), this method is useful to research the experience of the route by pedestrians and the associated environment.

The case study, in which both surveys and interviews are used as research tools, are held in Wageningen. The municipality has received many complaints from its residents regarding the walkability in the municipality. By focusing on Wageningen as a location, the interviews and case study can delve deeper into the specific context, challenges, and opportunities relevant to this area, which will provide valuable insights for the research and the municipality.

3.1 Survey

3.1.1 Data sampling survey

The quantitative data was collected using the survey program Mappinion. This is a survey program in which surveys can be created in the same way as other survey programs, such as Qualtrics, but there is a geographical component to this. It is DTV's geographical survey tool and provides insight into which roads/footpaths are used, in this case in Wageningen. The geographical component of this survey tool is that respondents can be asked to specify a specific route or location which they think, for example, is a dangerous place to walk (DTV, n.d.). Multiple methods were used to collect the necessary data to obtain a representative sample. The questionnaire was distributed online through the official channels of DTV. Consider the website and linked-in. The questionnaire was also distributed by the municipality of Wageningen among its residents. This approach offers a broad and accessible way to reach a diverse group of respondents. The quantitative methods will be used to answer Q4 and Q5. The questions of this survey can be found in the appendix.

3.1.1.1 Respondents survey

All respondents who participated in this survey have a minimum age of eighteen years, regardless the country of origin. This requirement is based on several ethical and practical considerations. The age of eighteen is the legal age of majority in the Netherlands. This means that people of this age are considered adults and are considered capable of making informed decisions about their participation in research. Ensuring the participation of adult respondents helps avoid ethical dilemmas regarding obtaining consent to participate. The respondents to the questionnaire all live in the municipality of Wageningen.

3.1.1.2 Time & location survey

The survey was conducted in the period from January 17 to February 13 and was distributed by DTV and the Municipality of Wageningen on digital platforms.

3.1.2 Data-analysis plan survey

For the quantitative method of this research, the data analysis is focused on using Mappinion data to identify the factors that influence the route choices of residents of Wageningen when walking, as well as the motives behind their walking behaviour. This will be achieved by applying descriptive statistics. The statistical software was SPSS version 29.

Inspired by Fisu et al.'s (2024) work on route choices of people specifically from the Generation Z. This survey will also analyse if different age groups have different environmental factors that influence their route choice when walking in Wageningen.

3.2 Walk-along interviews

3.2.1 Data sampling interviews

In addition to the survey, interviews were conducted. These interviews are walk-along interviews because respondents answer the questions during a walk using a digital navigation system, such as Google Maps. Questions will be asked when certain scenarios (see table 7 in the appendix). For instance, on a road without street lighting, they will be asked whether they would also walk here in the dark if a navigation system indicates this. The focus of these interviews is on finding out the triggers that users experience from a navigation system while walking. The purpose of the walk-along interviews is to see where navigation systems and the underlying GIS have shortcomings and most important, how users experience these shortcomings. This causes respondents to walk routes recommended by navigation systems (Siriaya et al., 2020). The routes are based on the data collected by the survey.

The interviews collect data to answer all sub-questions. For example, respondents are asked how they experience the available information and functions of navigation systems and how they experience the specified route. If there are respondents who have GIS experience, they will be asked additional questions about the underlying GIS procedures. The respondents for this study are collected through the snowball method, avoiding immediate family, friends, and acquaintances to make the study more reliable (Hay & Cope, 2021).

3.2.1.1 Participants interviews

The participants in the interviews are also all eighteen years or older, for the same reasons as those for the survey. However, the respondents for the walk-along interviews do not have to be familiar with Wageningen, because then they are in an unfamiliar area, which is when people use a navigation system the most (Fang et al., 2015; Philips et al., 2013; Siriaraya et al., 2020).

3.2.1.2 Time survey interviews

The interviews for this research are held between April 28 and May 4. The interviews also took place at various times throughout the day because the time of the day is an environmental factor (Basu et al., 2021; Ferrer et al., 2015; Shatu et al., 2019a).

3.2.1.3 Location interviews

Respondents can choose between a route on the recreational paths of the municipality of Wageningen, a route in the city or both. The survey data from Mappinion includes the roads people walk most on. These will be used as the beginning and destination of the proposed routes. The respondents were told that a walk needed to last at least twenty minutes and that they could choose to walk to or from the city-centre, point of public transportation or to a recreational area. The respondents were also told that they were allowed to deviate from the route.

3.2.2 Data-analysis plan interviews

For the qualitative data, the data analysis is focused on coding and analysing the data collected by the walk-along interviews, with a specific focus on individuals' experiences regarding the use of navigation systems in relation to environmental and personal factors. This will be achieved through thematic coding techniques to identify key themes and patterns in the data collected. Open coding is also used to identify codes that were not already made with thematic coding (Hay & Cope, 2021; Vaughn & Turner, 2016). After open coding, axial coding is used to process the open codes into broader codes that fit within the thematic codes (Hay & Cope, 2021; Vaughn & Turner, 2016). See the appendix for the complete code-tree. NVivo, a computer-aided qualitative data analysis software (CAQDAS), is used to code the interviews.

In addition, an in-depth analysis will be conducted to understand the complex interactions between different variables, such as user experience, environmental factors, and individual preferences (Hay & Cope, 2021). The research will also focus on understanding the motivations behind individuals' route choices and how these are influenced by several factors, which will contribute to a holistic understanding of walking behaviour in Wageningen.

3.3 Ethics

The participants' data will remain anonymous to guarantee their privacy. Any contact details of participants are to be deleted after the research (Boeije et al., 2016, pp. 59–61). Respondents can also always indicate during the survey or interview that their data may no longer be used. This will then be removed from the research.

A second overarching point of ethics to consider is the role of the researcher and its position of power relations. The researcher is a “Caucasian man”. However, research does not show that ethnicity or gender would influence walk-along interviews and its respondents. No research is conducted into different marginal groups in society, nor a distinction is made between certain socio-demographic characteristics.

3.3.1 Ethics survey

Using the survey data is ethically more difficult than for the interviews. The data for the survey was not collected by the researcher himself, so permission for the use of this data was requested and arranged by DTV, not the researcher himself. However, the researcher has signed a contract to use this data only for this research and not for his own purposes. People filling in the survey are beforehand told what would happen to their data. The data for the survey has been obtained anonymously and that there is no way to find out what the identity of the respondents is.

3.3.2 Ethics interviews

The researcher has acquired permission from all the respondents from the interviews before conducting the interviews. For this informed consent, each participant is informed in advance about what this research is about, the expectations of this research, what will happen to their data, if the gathered data may be used for this research and if the interviews were allowed to be recorded. The respondents are asked twice if it was allowed to record the interviews before the recording and during the recording. The respondents are told that only the researcher and possible his supervisor have access to the recordings.

3.4 Reliability & validity

The output of this research has been described as accurately as possible in this chapter to make the research as reproducible and therefore as reliable as possible (Hay & Cope, 2021). The sources used for the theoretical framework are all peer-reviewed scientific articles, to make that chapter more reliable (Hay & Cope, 2021). Scientific articles that use unreliable sources were not used in this study. The data for the data and results chapters respectively have been collected as accurately and objectively as possible. Partly for this reason, tables with descriptive statistics from the survey are listed in the results chapter to give the reader more knowledge on what data is used for the results of this research.

A factor that should not be forgotten in this research is the position of the researcher. Although every effort is made to keep this research as reliable and objective as possible, a researcher is never completely objective and there is always a degree of subjectivity involved. This is attempted to be minimized by coding multiple times and critically checking the written texts in the results chapter for traces of subjectivity by the researcher.

This research adds to validity in several ways. This research is construct valid because different measurement methods are used to research the extent to which varied factors influence the route choice of pedestrians, these are the survey and the interviews. The results of both methods of data collection will be compared (Basu et al., 2021; Hay & Cope, 2021).

This research also tries to keep the internal validity as high as possible (Hay & Cope, 2021). That is why the interviewer followed all route instructions from the respondents and did not interfere in any way with the routes that the respondents walked.

Unfortunately, this research has limited generalizability, because this is a case study in one municipality, due to the limited time of this research. For a higher external validity, a similar study should take place in several municipalities to compare these answers with each other (Hay & Cope, 2021). However, because this research is reproducible, further research could solve this problem (Hay & Cope, 2021).

3.5 Reporting plan

This research is a scientific study and will be carried out and drawn up on the basis of the Academic Skills manual, obtained from Utrecht University. Utrecht University has a publication obligation, so this thesis including its results will also be published with open access. The participants of the study will remain anonymous (Boeije et al., 2016, pp. 57-58).

The results of this research can be published by DTV, because this research was made in collaboration with this company and because their survey tool, mappinion and associated statistical data on pedestrian behaviour in Wageningen were used. The participants in the research will also remain anonymous (Boeije et al., 2016, pp. 57, 58).

The researcher himself did not have direct contact with the Municipality of Wageningen in any way and operates independently. DTV is an independent research company that conducts independent research on behalf of the Municipality of Wageningen. The interviewer himself does not benefit from certain results arising from this research. The results cannot therefore be influenced by desired outcomes from third parties. The position of the researcher is therefore independent.

3.6 Limitations

Unfortunately, there may also be limitations in conducting and generalizing the results of this study. The case study of this research has only been done in one municipality in the Netherlands. Because this research conducted a case study in one municipality, the results may not be generalizable because the results are too context dependent. As Basu et al. (2021) indicated, the PRC is context specific. The environment influences the route choice.

3.6.1 Limitations survey

Furthermore, the indicated routes in Mappinion were sometimes not fully completed by respondents. For example, small road segments are sometimes missing at intersections, but the start and end points of the routes with the roads in between are known. DTV has supplemented these missing links to try to make the routes as complete as possible.

In addition, the gender of the survey respondents was not asked. This makes it more difficult to determine to what extent the respondents' results are representative of the entire research population. This also means that it cannot be investigated to what extent the socio-demographic factor "gender" influences the route choices of pedestrians.

3.6.2 Limitations interviews

A final limitation is with conducting the interviews. It is always possible that respondents still feel influenced when walking their walking route in Wageningen, even though the interviewer said that they are completely free to do so. This could reduce the validity of the interviews. However, the interviewer clearly indicated in advance that the interviewer would only walk along, and it did not matter how they walked or what the destination was.

4. Data

As already mentioned in the methodology chapter, two types of data collection took place, surveys, and interviews. This chapter discusses the response groups from both the survey and the interviews.

4.1 Data Surveys

This paragraph looks at the response group of the surveys conducted in Wageningen. A sample of 465 respondents was collected.

4.1.1 Characteristics response group survey's

In this survey, only one control variable was collected, the age category of the respondents. This control variable was used to check whether the respondents correspond to the entire research population. The research population is all residents of Wageningen aged at least eighteen years or older. This is because people under the age of eighteen are excluded from this study. Table 1.1 shows the demographical statistics of the respondents of the survey and the real demographical statistics of the inhabitants of Wageningen. The expected N is based on figures from CBS (Centraal Bureau voor de Statistiek [CBS], 2023).

Table 1.1: Expected age distribution survey respondents (Source: CBS, 2023)

Age category	Observed (N)		Expected (N)		Residual
	N.	%	N	%	N
Younger than 20 years	1	0.22	16.7	3.59	-15.8
20-29 years	29	6.24	150.5	32.37	-121.6
30-39 years	68	14.62	65.6	14.11	2.5
40-49 years	90	19.35	52.2	11.23	37.8
50-59 years	119	25.60	57.5	12.37	61.5
60-69 years	104	22.37	55.2	11.87	48.7
70 years and older	54	11.61	67.0	14.41	-13.1
Total	465	100	465	100	

4.1.2 Representativity analysis & Weight factors

To test whether the sample population is an accurate reflection of the target population, a chi-square goodness-of-fit test is applied (see table 9.1 in the appendix). It was decided to weight by age to ensure that the response group coincides as closely as possible with the study population.

A Chi-square-goodness-of-fit test shows that the distribution of age classes in the sample does significantly not correspond to the age distribution of the population (X2(6, N=465) =251.6; p<0.001). There is an overrepresentation of respondents in the category 50 to 59 years and an underrepresentation of young people (20-29 years). This means that the answers of the survey will be weighted per age category. The weight factors can be found in table 1.2.

Because the age category 'Younger than 20 years' only contains one respondent and then would have a weight factor of 18, it will be merged with the group 20-29 years. This merge applies to the remainder of this study. A weight factor of 5.63 means that one answer of a person from the age category 18-29-years old will count as 5.63 answers to level the responses according to the real age distribution (Centraal Bureau voor de Statistiek [CBS], 2023).

Table 1.2: Weighting factors per age category

Age category	Population		Sample		Weighting factor
	Abs.	%	Abs.	%	
18-29 years	12646	36,0	30	6.4	5.63
30-39 years	4953	14,1	68	14,6	0.97
40-49 years	3946	11,2	90	19,4	0.58
50-59 years	4346	12,4	119	25,6	0.48
60-69 years	4178	11,9	104	22,4	0.53
70 years and older	5067	14,4	54	11,6	1.24
Total	35172	100	465	100	

4.2 Data Interviews

This research not only contains a survey, but also interviews. The researcher conducted the interviews himself. All respondents were asked in advance whether the interview could be recorded. This permission was asked again after starting while recording the interview, because then there can be no uncertainty about consent. All interviews lasted between 20 to 40 minutes. All interviews took place in Dutch, the native language of the respondents.

4.2.1 Characteristics response group

Table 2 shows the descriptives of the respondents of the interviews. A total of ten respondents were interviewed. Three of these identify as women and seven as men. The average age of respondents is 30 years old. The agricultural university is in Wageningen. This explains the high percentage of people aged 19 to 24 years old. Two respondents were familiar with Wageningen. Three are familiar with GIS. Eight respondents used Google Maps as their navigation system. This data is necessary to be able to compare different people with each other. For example, how someone with experience with GIS views the experience with a navigation system differently than someone who is not familiar with GIS.

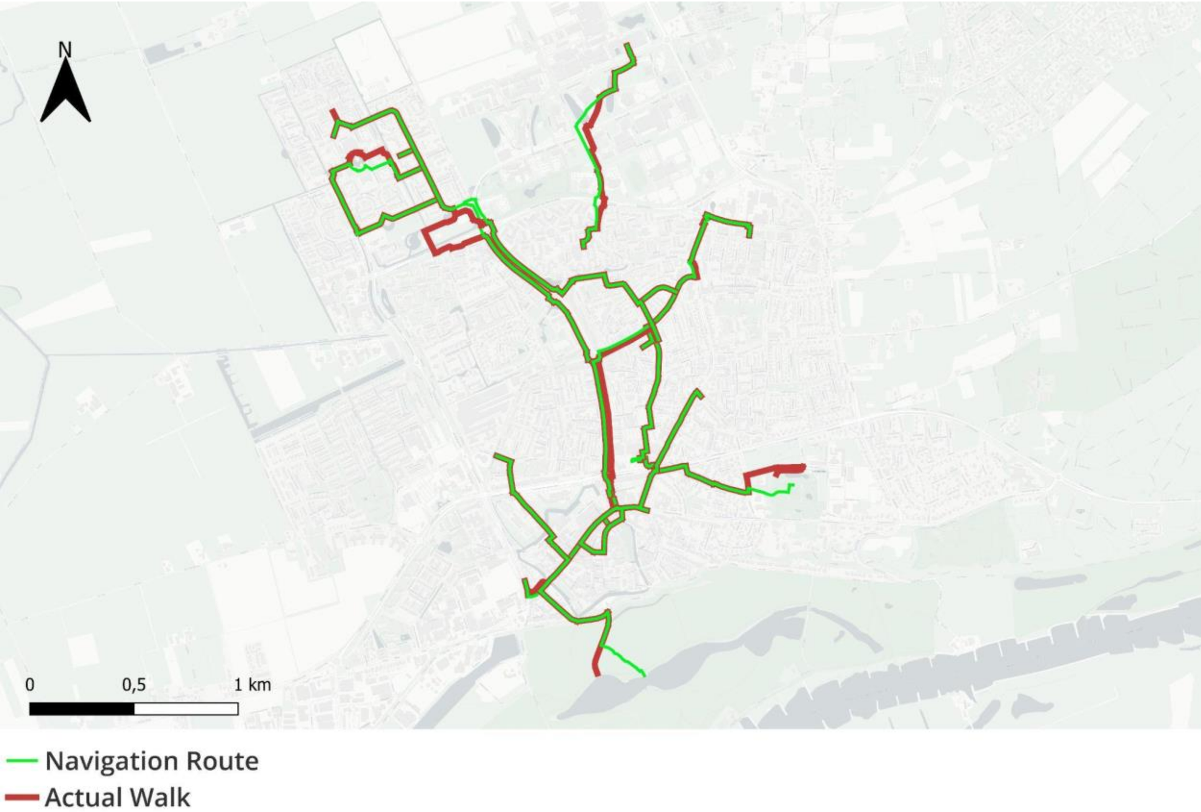
Table 2: Descriptive statistics interview respondents

Respondent	Gender	Age	Familiar with Wageningen?	Familiar with GIS?	Used Navigation system
1	Male	64	No	No	HereWeGo
2	Female	60	Yes	No	Google Maps
3	Female	22	No	No	Google Maps
4	Male	19	No	No	Google Maps
5	Male	21	No	No	Google Maps
6	Female	27	Yes	Yes	Google Maps
7	Male	24	No	No	Google Maps
8	Male	22	No	No	Google Maps
9	Male	22	No	Yes	Google Maps
10	Male	22	No	Yes	OSM

4.2.2 Location

Map 1 shows where the respondents walked in Wageningen, and which routes the navigation proposed. Respondents were given the choice to walk in the city or in the surrounding nature. The respondents were allowed to choose the starting point and destination themselves, but the walk had to last at least 20 minutes. The respondents were told that it was allowed to deviate from the suggested route by the navigation system. In the next chapter the most important routes will be shown again with the associated information gathered from the interviews.

Map 1: All Walk-Along Interviews with the proposed route by the navigation systems



Source: Carto, 2024; Google Maps, 2024; HereWeGo, 2024; OSM, 2024; Strava, 2024

5. Results

The results chapter will discuss the results of both the surveys and the interviews to find the answers to the research questions. These results were collected based on the above-mentioned methodology (chapter three) with the respondents mentioned in chapter 4.

5.1 Research Results Survey’s

In preparation for the walk-along interviews in Wageningen and to research the environmental factors that influence a pedestrian’s route choice, a survey was conducted among residents of the Municipality of Wageningen regarding their walking experience and route choices in the city. This survey investigates whether age influences the route choice and walking behaviour, as well as the improvement ideas of residents of Wageningen. It is also research what influences the walkability grade respondents have given about the walkability in Wageningen. All tables from this chapter are directly used from the data from the survey.

The first question asked the top three locations where people walk the most to in the city. Based on the descriptive statistics of the most walked destinations in Wageningen, there are several notable patterns across different age categories. The city-centre is the most popular destination, with a mean of 61% across all age groups, indicating a vital role in the walking habits of residents. The next most frequented destination is the walk to natural areas such as Binnenveld, Eng, or Rijn, with a mean of 49%, highlighting the appeal of natural landscapes for all age groups.

However, certain destinations showed statistically significant differences according to a chi-square test between the most walked locations and age groups. There are three destinations significantly influenced by the age categories of the respondents, recreational facilities, educational facilities, and work, as shown in table 3.

The group of 30–39-year-olds has a significantly higher chance of walking to recreational facilities, such as a playground. This is an age group that often has young children who need guidance at playgrounds. Likely, this is why this group goes to such places significantly more often, compared to the other age groups ($\chi^2(5)=45.606$, $p<0.001$, $V=0.140$).

In particular, the groups of 18–29-year-olds with 13% and the group of 30–39-year-olds with 25% have a significantly higher chance than the other age groups to walk to an educational facility ($\chi^2(5)=18.226$, $p=0.003$, $V=0.089$). This can be explained by the fact that 18–29-year-olds are often following education themselves, and the 30–39-year-olds have young children who need to be taken to daycare or primary school.

The group of 50–59-year-olds score significantly higher than the other age groups with 13% regarding their choice to walk to work ($\chi^2(5)=28.254$, $p<0.001$, $V=0.110$). The fact that elderly people aged 70 or older have 0% here can be explained by the fact that they are retired.

Table 3: Descriptive statistics most walked destinations in Wageningen (%)

Location	Age categories						Total	
	18-29 years (N=30)	30-39 years (N=68)	40-49 years (N=90)	50-59 years (N=119)	60-69 years (N=104)	70 years or older (N=54)	Mean	N
City-centre	63.33	67.65	61.11	58.82	57.69	61.11	60.86	283
No facility:	46.67	26.47	46.67	60.50	50.96	51.85	48.82	227

walk to Binnenveld / Eng / Rijn								
No facility; just taking a walk or walking the dog	40.00	36.76	45.56	38.66	34.62	27.78	38.28	178
Public transportation	40.00	30.88	22.22	21.85	22.12	29.63	25.38	118
Shops outside city-centre	16.67	23.64	15.56	15.13	21.15	20.37	17.85	83
No facility; walking to friends, family, or acquaintances	23.33	11.76	12.22	9.24	11.54	12.96	13.69	56
Cultural facility (e.g. Theatre, museum, or arboretum)	13.33	4.41	11.11	8.40	15.38	11.11	10.54	49
Hotel, restaurant & café	10.00	7.35	13.33	11.76	6.73	11.11	10.11	47
Recreational facilities (e.g. playground, park)	0.00	25.00	6.67	5.04	6.73	4.81	8.82***	41
School/ university/ education or daycare	13.33	25.00	14.44	2.52	1.92	0.00	8.39***	39
Work	3.33	2.94	7.78	13.45	2.88	0.00	6.24***	29
Sport	16.67	5.88	3.33	4.20	6.73	5.56	5.81	27
Social facilities (e.g. library, community centre, town hall)	0.00	5.88	1.11	4.20	8.65	5.56	4.73	22
Care (e.g. GP, dentist, physio)	3.33	5.88	3.33	1.68	6.73	3.70	4.09	19

Garden centre, hardware store	0.00	1.47	2.22	0.00	0.96	1.85	1.08	5
Total multi-response							264.69	1223

*p < 0.1; **p < 0.05; ***p < 0.01.

5.1.1 Route preferences

Secondly, it was investigated whether the age categories of the respondents significantly influence the route preferences of respondents. Respondents could choose three locations they walk most to out of fifteen locations, listed in table 3, such as the “city-centre”, “work”, “public transport”, etc. If a respondent had indicated a certain location, such as the city-centre, they were asked the following question: *“Why do you take this route to the city-centre?”* For each chosen location, respondents could choose which factor most influenced their route, such as “shortest route”, “greenery” or “variety”. This means that respondents indicate up to three times which factor influences their route choice the most. To find out which factor influences the route choice of respondents the most, the three chosen route preferences of the respondents were added together to give a total score of which factors they consider most important for their route choices. So, the number of times a route factor is chosen per age category, in table 4, are the average of the selected route factors. This creates an interval variable between 0 and 3. Respondents could indicate that they would take the shortest route at all three chosen locations. Then that respondent has a score of 3 for shortest route, but 0 for all other factors. This has created a multi-response.

To research whether the age of a respondent influences the factors that influence a respondents' route choice, a Kruskal-Wallis H test was carried out. A one-way ANOVA was preferred to explore differences between the age categories and environmental factors, but the homogeneity presupposition was partially not met (see table 9.7 in appendix).

The analysis of environmental factors influencing route choices among different age groups in Wageningen reveals some interesting insights. The factors “greenery”, “accessibility”, “other route is unsafe” and “variety” are significantly influenced by the age categories of the respondents.

For “greenery”, this suggests that while all age groups value greenery, its importance varies slightly but meaningfully depending on the respondent's age ($H(5)=11.37$, $p= 0.045$, $\eta^2=0.02$). Especially younger people (18-29 years old) choose greenery as the reason to walk a certain route (Mean = 0.93). Furthermore, it is interesting that the younger people and older people (70 years or older) give the accessibility of the footpaths the highest rank as reason to walk a certain route ($H(5)=12.86$, $p=0.025$, $\eta^2=0.02$). For the elderly, this concerns walking with a walker. This is sometimes complicated by high edges on the sidewalks. They cannot enter these sidewalks. Safety, including both traffic and perceived safety is most chosen by the 30-39 years old ($H(5) = 22.22$, $p<0.001$, $\eta^2=0.05$). Lastly, apart from the elderly, with an average of 0.54, it can be concluded from table 4 that the older someone is, the more important the variety of a route becomes when choosing a route ($H(5)=4.66$, $p=0.012$, $\eta^2=0.03$).

Although the factor 'shortest route' is not significantly influenced by the age of the respondent, with an average of 1.35 it is the most frequently chosen reason people walk a certain route. This indicates that people in Wageningen walk for practical reasons. Then the factors 'beautiful route' and 'greenery' emerge highest with averages of 1.06 and 0.66

respectively as important reasons why people walk a certain route. These are environmental factors when people walk recreationally. The presence of rest points, with an average of 0.02, is the lowest reason pedestrians choose a certain route. From this it can be concluded that this factor does not influence the route choice of people in Wageningen.

Overall, these findings highlight that while all these factors are important to some extent, their influence on route choice is nuanced and varies across different age groups in Wageningen.

Table 4: Mean score of environmental factors per age category

Route choice	Mean per age category						Total	
	18-29 years (N=30)	30-39 years (N=68)	40-49 years (N=90)	50-59 years (N=119)	60-69 years (N=104)	70 years or older (N=54)	Mean	N
Shortest route	1.67	1.47	1.42	1.29	1.25	1.24	1.35	628
Beautiful route	1.07	0.78	1.17	1.05	1.18	1.04	1.06	494
Prescence of rest points	0.00	0.01	0.01	0.03	0.01	0.02	0.02	7
Greenery	0.93	0.44	0.81	0.65	0.69	0.52	0.66	308
Accessibility	0.63	0.38	0.34	0.30	0.29	0.67	0.38**	178
Other route is unsafe	0.03	0.19	0.02	0.00	0.06	0.00	0.05**	22
Variety	0.20	0.25	0.38	0.50	0.64	0.54	0.46**	213
Facilities on the route	0.13	0.13	0.06	0.11	0.13	0.22	0.12	56
Total multi-response								1896

*p < 0.1; **p < 0.05; ***p < 0.01.

5.1.2 Improvement for the walkability of Wageningen

The respondents were able to choose measures that could improve the walkability of Wageningen. These are listed in the rows in table 5.1 Across the entire response group, 43% most opted for better maintenance of footpaths as an idea to increase the walkability of Wageningen. 36% of the respondents also opted to build more sidewalks. Respondents were also able to answer an open question about improvements for the walkability in Wageningen, this is discussed in more detail in section 5.1.2.1.

Table 5.1: Improvement ideas for walking in Wageningen (%)

Improvement ideas	Age categories						Total	
	18-29 years (N=30)	30-39 years (N=68)	40-49 years (N=90)	50-59 years (N=119)	60-69 years (N=104)	70 years or older (N=54)	Mean	N
Better maintain footpaths	26.67	35.29	50.00	36.97	44.23	61.11	43.01***	200
Build more footpaths	26.67	45.58	33.33	38.66	34.62	37.04	36.77	171
Promote walking as a mode of transport	26.67	22.06	14.44	23.53	27.88	20.37	22.37	104
Widening the footpaths	10.00	35.29	24.44	19.33	16.35	20.37	21.50**	100
Adding signs for pedestrians	10.00	5.88	8.89	7.56	5.77	7.41	7.31	34
No idea / no improvements needed	23.33	7.35	16.67	11.76	11.54	11.11	12.69	59
Total multi-response							143.65	568

*p < 0.1; **p < 0.05; ***p < 0.01.

Just as with route preferences, it was also researched whether the age categories of respondents can significantly influence the choices for improvement ideas. A Kruskal-Wallis test analysis (table 5.1) reveals that age categories significantly influence certain preferences for improvements in footpaths. Specifically, older respondents (70 years or older) with 61% are significantly more likely to prioritize better maintenance of footpaths compared to younger respondents (18-29 years), with only 27% ($H(5)=15.73$, $p=0.008$, $\eta^2=0.03$). This preference indicates a higher concern among older individuals for the condition of walking infrastructure, due to increased mobility challenges with age.

A second improvement idea that is significant influenced by the age categories of the respondents is widening of the footpaths. People between 30-39 years tend to prioritize this improvement with 35% more than the other categories ($H(5)=12.46$, $p=0.029$, $\eta^2=0.03$). Many people aged 30-39 are of age to have young children. With young children and strollers, the need for wider sidewalks may increase to provide enough space for safe and comfortable walking with the whole family.

The residents of Wageningen were able to answer an open question with points for improvement to increase the walkability in the city. First, at 43%, the most frequently mentioned improvement point is better maintenance of the footpaths (table 5.1). The sidewalks in Wageningen contain many wobbly stones, which makes walking difficult and makes the sidewalk impassable for wheelchairs and strollers. This encourages pedestrians to walk on the street, but then cyclists and cars speed close past pedestrians. Better maintenance of the sidewalks therefore contributes to road safety and thus the walkability of Wageningen.

There are also obstacles that pedestrians must deal with, one respondent experienced unsafe roads due to high vegetation:

> "Here, two rows of paving stones are overgrown by lampreys / plants. You cannot walk next to each other here. Pricks bushes all have protrusions near the eyes of children. My daughter has already had one in her eye because they are almost impossible to see in the dark."."[1]
>
> Respondent x

Moreover, about the accessibility of roads. Some sidewalks around nursing homes, especially at Westerhofseweg, are considered inaccessible to the elderly because the sidewalk has a raised edge and lacks an entrance/exit.

Not only the feeling of safety, but also improving road safety for pedestrians is mentioned by respondents as a point of improvement for walkability in Wageningen. For example, installing lighting over the Grebbedijk is seen as necessary, because otherwise you could cycle down the dike and end up in a ditch.

5.1.2.1 Pedestrian network

A particularly important idea for improving the walkability in Wageningen is the construction of more footpaths. Table 5.2 shows, with 55%, that the residents of Wageningen do not miss any important connections in the pedestrian network of Wageningen. However, this means that 45% of respondents do think so. Respondents answered an open question about where they think important connections in the pedestrian network in Wageningen were missing.

Especially the campus, a place where a lot of students walk, is mentioned several times as a location where footpaths are missing:

> "It is a cycle path and is also used to walk to the Campus or otherwise, which creates dangerous situations for pedestrians (I once hit someone because they did not pull over despite a lot of ringing with my bicycle)"[2]
>
> Respondent y

Interview 6 showed that navigation systems also direct you along these cycle paths.

Furthermore, a connection between Dijkgraaf and Bornsesteeg could provide an attractive detour but is currently not possible because there is no footpath. Another example is that footpaths to the Grebbedijk, a place people like to walk recreational, are sometimes missing. There is also no longer a passage via the Dreijenlaan, so you must walk around the arboretum. This makes the arboretum, a place where people like to walk as well, less

[1] "Hier worden twee rijen stoeptegels overwoekerd door prikstruiken/ planten. Je kan hier niet met z'n tweeën naast elkaar lopen. Prikstruiken heeft allemaal uitsteeksels ter hoogte van de ogen van kinderen. Mijn dochter heeft er al eens een in het oog gehad want ze zijn in het donker bijna niet te zien."

[2] "Het is een fietspad en wordt ook gebruikt om naar de Campus te lopen of overig, daarmee ontstaan gevaarlijke situaties voor voetgangers (heb zelf een keer iemand aangereden omdat men niet aan de kant ging ondanks veel bellen met mijn fiets)"

accessible. Constructing more footpaths therefore not only contributes to a safer, but also a more enjoyable walking network.

Furthermore, it is calculated if the age categories of the respondents influence their opinion about weather Wageningen is missing important connections in its pedestrian network. The chi-square test results ($X^2(5)=10.81$; $p=0.055$; $V=0.154$) of table 5.2 indicate that there is a significant influence of age on whether respondents perceive important connections missing in the pedestrian network ($p < 0.1$). While this result is not highly significant, it does suggest a trend worth noting. The age group 30-39 years has the highest percentage (58%) of respondents who believe there are important connections missing in the pedestrian network. This could be due to higher mobility needs or specific concerns related to daily commuting and family activities.

Furthermore, the age groups 18-29 years and 70 years or older have lower percentages of respondents who perceive missing connections (33% and 39%, respectively), suggesting that younger and older individuals may have different priorities or may not encounter the same mobility challenges.

Table 5.2: Are there important connections missing in the pedestrian network? (%)

Connections missing?	Age categories						Total	
	18-29 years (N=30)	30-39 years (N=68)	40-49 years (N=90)	50-59 years (N=119)	60-69 years (N=104)	70 years or older (N=54)	Mean	Abs.
Yes	33.33	58.21	43.33	50	37.25	39.22	44.74*	204
No	66.67	41.79	56.67	50	62.75	60.78	55.26	252
Total	100	100	100	100	100	100	100	456

*p < 0.1; **p < 0.05; ***p < 0.01.

The literature shows that pedestrians consider it important that there is a complete walking network (Garnter et al., 2011). On average, the respondents from Wageningen give the municipality's walkability a 7.2 (table 5.3). The chi-square analysis of table 5.3 indicates that the opinion if connections are missing in the pedestrian network in Wageningen do significantly influence the walkability grade. This difference is significant at the 0.01 level, indicating that perceptions of network completeness are linked to overall walkability assessments. Thus, creating a better and more inclusive pedestrian network in Wageningen could enhance the overall pedestrian experience and satisfaction and thus increase the walkability grade.

Table 5.3: Chi-square test of missing connections and walkability grade

Connections missing?	N		Walkability Mean
	Mean	Abs.	
Yes	44.74	204	6.7
No	55.26	252	7.6
Total	100	456	7.2***

*p < 0.1; **p < 0.05; ***p < 0.01.

5.1.3 Walkability Wageningen

Finally, it was researched to what extent the demographic factor age categories influence the experience of walkability in Wageningen. The respondents between 18 and 29 years old give the highest mean grade with a 7.6. The respondents between 30-39 years give the lowest grade with a 6.7. To indicate if the age of the respondents influences the experienced walkability of Wageningen, a Kruskal-Wallis H test is calculated. An ANOVA test had the preference, but the homogeneity requirement of an ANOVA was not met. This table is in the appendices (table 9.11).

The Kruskal-Wallis H test, depicted in table 6, reveals that age significantly influences the experienced walkability of Wageningen ($H(464)=16.84$, $p=0.005$, $\eta^2=0.04$). While younger adults (18-29 years) and those aged 40-49 years report higher satisfaction with walkability (Mean = 7.6 and 7.5 respectively), the 30-39 age group reports the lowest satisfaction with only a 7.0. Addressing the specific needs of different age groups through targeted improvements can enhance the overall walkability experience in Wageningen. The p-value of 0.005 confirms that these differences are unlikely to be due to random chance. The lower satisfaction among the 30-39 age group indicates a need for targeted improvements to address the specific concerns of this demographic. It is also the group that has the highest percentage of respondents who think that important connections are missing in the pedestrian network in Wageningen, with 58% (table 5.2). Likely, the walkability grade among this age group will improve if more connections are created in the walking network in Wageningen. At 46%, this was also the most chosen solution to improve the walkability (table 5.1).

Table 6: Descriptive statistics walkability grade Wageningen per age group

	Mean	N
18-29 years	7.6	30
30-39 years	6.7	68
40-49 years	7.5	90
50-59 years	7.0	119
60-69 years	7.4	104
70 years or older	7.2	54
Total	7.2***	465

*p < 0.1; **p < 0.05; ***p < 0.01.

5.2 Research Results Interviews

In addition to the conducted surveys, walk-along interviews were also conducted to research not only the environmental and human factors, but also the navigation factors and their influence on route choices in Wageningen. The results of the interviews will be discussed in this paragraph.

Two parts are discussed: the deviations from the navigation proposed routes that walk-along respondents walked and the content of the walk-along interviews itself. Because the interviews are held in Dutch, all quotes are translated to English. The corresponding Dutch quotes are in the footnotes. The coding of the interviews is listed in the appendix (figure 2).

5.2.1 Deviations from the route

There are several reasons why respondents deviated from the routes suggested by the navigation systems. These are explained below. It is interesting to mention that respondent 2 did not deviate from the route in any way. This means that 9 out of 10 respondents did not walk the route exactly as shown on the navigation system. During the interviews, respondents deviated from their planned route while walking for various reasons. These deviations can be divided into unconscious and conscious deviations.

Also important to explain is that every map below can be interpreted the same way. The green line shows which route the navigation system suggested. The red line shows how the respondent walked. These were then laid over each other to visualize where in Wageningen people deviated from the proposed route during the walk-along interviews. For each deviation, it is explained below why the respondent deviated from the proposed route.

5.2.1.1 Unconscious deviations

Unconscious deviations occur when pedestrians were not paying close attention to their navigation. This can happen through various forms of distraction, such as conversations with other people (respondent 9), the environment (respondent 4)., the GPS-signal (respondent 1) or simply by daydreaming while walking (respondent 4).

Respondent 9 unconsciously walked straight ahead at the T-junction Louis Davidsstraat with the Weteringsteeg, as shown on map 2.1. However, the respondent did not find this a problem because he found the route attractive to walk. He walked straight for too long unconsciously because he was distracted by the interviewer's questions. These unconscious deviations are unintentional and the result of mistakes by the respondents.

Map 2.1: The proposed route and actual walked route of respondent 9

Source: Carto, 2024; Google Maps, 2024; Strava, 2024

While walking the route during interview 1, respondent 1 deviated twice from the proposed route, as shown on map 2.2. The first deviation was accidental. The respondent walked into the wrong street. This is because the GPS signal was not correct. The respondent realized that he was going the wrong way and turned around to follow the proposed route. He noticed that he was walking a longer route because he saw on the navigation app that the route had become longer, and the navigation system suggested to turn around.

Map 2.2: The proposed route and actual walked route of respondent 1

Source: Carto, 2024; HereWeGo, 2024; Strava, 2024

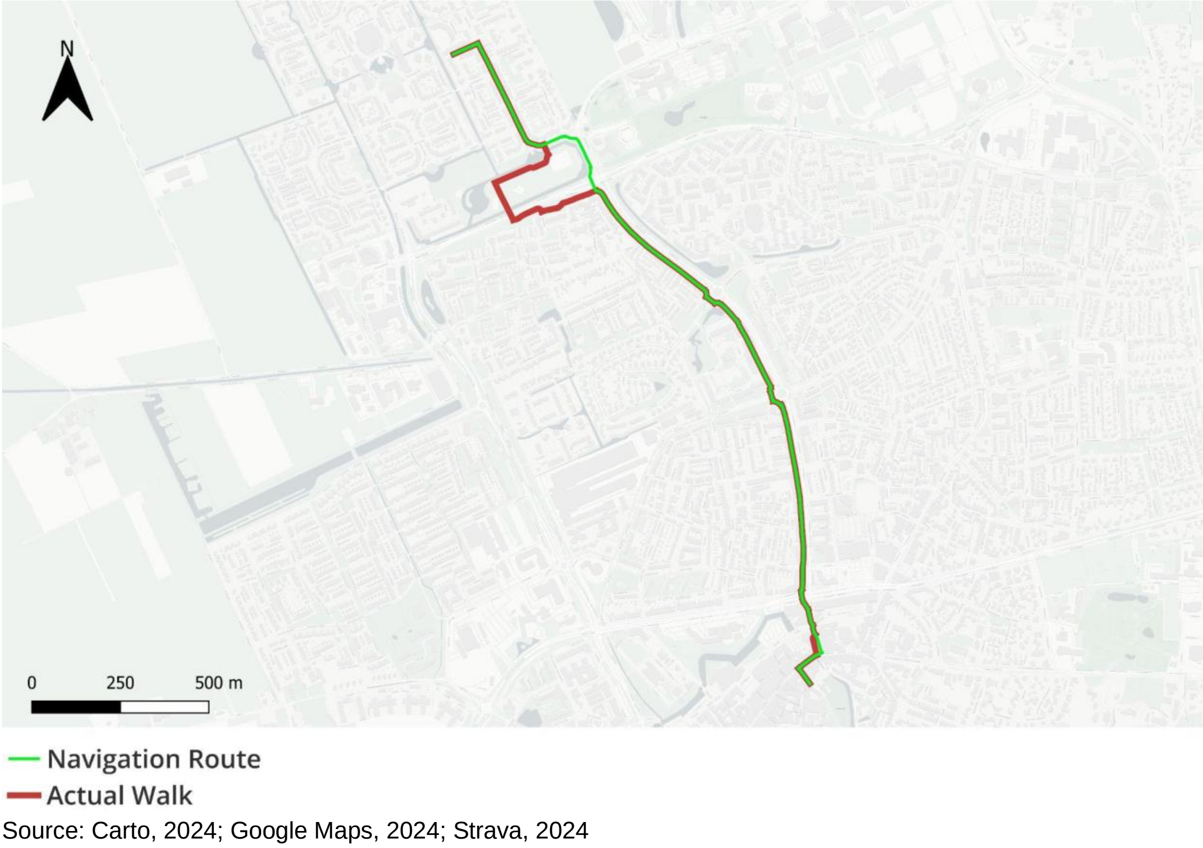
Respondent 4 preferred to walk in the park, a conscious deviation. However, once in the park, respondent 4 was not paying attention to his phone, but became distracted by the nature and tranquillity of Park Noordwest, and thus said the following:

> "We really should have gone there. But this is the tourist route."[3]
>
> Respondent 4 (male, 19 years)

Once in the park he walked straight for too long, which meant we walked in the park even longer than necessary, as shown in map 2.3. However, the respondent did not see that as a problem, because he liked walking in the park. His explanation for walking the wrong way was that he did not want to look at his phone all the time and had the navigation on silent mode. This deviation was mostly because of an environmental factor and a mistake from the pedestrian itself.

[3] "We hadden eigenlijk, daar naartoe moeten gaan. Maar dit is de toeristische route."

Map 2.3: The proposed route and actual walked route of respondent 4



Source: Carto, 2024; Google Maps, 2024; Strava, 2024

5.2.1.2 Conscious deviations

Conscious deviations, on the other hand, are the result of intentional choices that pedestrians make during their journey. For example, people may decide to adjust their route because they find a different environment more attractive to walk, as respondents 1 and 4 did. Both respondents preferred to walk through a park rather than along a main road (see map 2.2 & 2.3 respectively). Other deliberate deviations may arise because people choose to cross a road earlier or later, to avoid crowds, because of personal preferences or because the respondents planned their route further in advance. Respondents 3, 6, 7 & 8 did this. The deviation from the route was caused by the pedestrian. Environmental factors therefore had more influence on pedestrians' route choice than the navigation system.

The second deviation of respondent 1 was a conscious choice. The respondent preferred to walk through the park rather than along the road (map 2.2). This is because there is more nature, and it is quieter. But the navigation suggested walking via the road and did not adapt to the preference of respondent 1 because the bridge to the park was not in the database, according to respondent 1.

Respondent 3, for example, crossed the Van Uvenweg earlier than Google Maps suggested, as shown on map 2.4. This was because she wanted to walk in the shade because of the heat. The respondent was aware that she would eventually have to turn left and that it did not matter when she needed to cross the street.

Map 2.4: The proposed route and actual walked route of respondent 3

Source: Carto, 2024; Google Maps, 2024; Strava, 2024

Furthermore, respondent 6 was familiar with Wageningen. As a result, shortcut routes have sometimes been taken in the park that Google Maps did not suggest, as can be seen in map 2.5. The Campus Plaza square was also not on the map. As a result, the navigation guided the respondent around the square, while it was shorter to cross the square diagonally. This was also visually confusing for her, because Google Maps showed the square as a green area. As a result, respondent 6 also walked on the other side of the road as Google Maps had suggested. This deviation was thus influenced by the mental map of the respondent.

Map 2.5: The proposed route and actual walked route of respondent 6

Source: Carto, 2024; Google Maps, 2024; Strava, 2024

Respondent 8 also tried to follow the route suggested by the navigation as accurately as possible. The biggest deviation is that the respondent was already walking on the right side of the Rooseveltweg because he had already planned ahead, as shown in map 2.6. The Wageningen bus station is also not accurately listed in Google Maps. There are several paths between the parking lot and the Wageningen bus station. Because Google Maps is not familiar with these paths, it will lead the pedestrian around them. Respondent 8 was aware of this and decided to take a shortcut to shorten his actual route. This is again an example of a conscious deviation, initiated by the respondent because of navigational skills.

Map 2.6: The proposed route and actual walked route of respondent 8

Source: Carto, 2024; Google Maps, 2024; Strava, 2024

In addition, practical obstacles such as muddy paths, broken roads, or traffic signs prohibiting access can force people to choose an alternative route. In these cases, the deviation is a conscious decision resulting from a direct response to circumstances or personal preferences. This happened to respondents 5 and 10. The deviation was the result because of the incompleteness of the navigation system. Environmental factors therefore had more influence on pedestrians' route choice than the navigation system.

Respondent 5 consciously, but not voluntarily, deviated from the route once, as can be seen on map 2.7. The proposed route turned out to be impassable to walk due to too much mud:

> "But then we must go through that puddle. So, then I choose to follow this path. And then we will see where we are approximately."[4]
>
> Respondent 5 (male, 21 years)

The alternative route also turned out to be impassable due to high vegetation. The alternative route was a path that was not in the database of Google Maps:

> "Now he also gives... Oh. He now says we must go back. Do you see it? We went wrong, I think. The path is not there. Okay, I do not think we need to continue here."[5]
>
> Respondent 5 (male, 21 years)

[4] "Maar dan moeten we door die plas. Dus dan kies ik er wel voor dat we dit pad volgen. En dan kijken we waar we ongeveer zijn."

[5] "Nu geeft hij ook... O. Hij zegt nu dat we terug moeten. Zie je het? We zijn verkeerd gelopen, denk ik. Het pad staat er niet op. Oké, hier hoeven we niet verder, vind ik."

Google Maps also did not show any other alternatives. Respondent 5 therefore decided that it was not possible to reach the specified final location.

Map 2.7: The proposed route and actual walked route of respondent 5

— Navigation Route
— Actual Walk

Source: Carto, 2024; Google Maps, 2024; Strava, 2024

Respondent 10 used OSM instead of Google Maps. Just like respondent 8 had with Google Maps, OSM was unfamiliar with the sidewalks at the bus station of Wageningen. Respondent 10 walked the rest of the route according to the navigation system, until the Aroboretumlaam, as visualised on map 2.8. There the respondent was directed onto a road with a sign saying "verboden toegang voor onbevoegden" (forbidden for unauthorized persons). His opinion was that it did not seem sensible to follow the route and so the respondent chose to take a detour. However, once at the edge of the park, there appeared to be a fence and the respondent found it impossible to reach the desired end point and therefore chose to end the walk early:

> "The location is approximately here. It is actually behind that fence over there."[6]
>
> Respondent 10 (male, 22 years)

Both times that respondent 10 deviated from the route was due to obligations imposed by the physical environment because the navigation lacked the data that those paths were not accessible.

[6] "De locatie is ongeveer hier. Het ligt eigenlijk achter dat hek daar."

Map 2.8: The proposed route and actual walked route of respondent 10

Source: Carto, 2024; OSM, 2024; Strava, 2024

Both types of deviations, both unconscious and conscious, influence the route choice and can lead to unexpected turns while walking. Understanding these anomalies can help improve pedestrian navigation systems to better account for the realities of human behaviour and the unpredictability of the walking path. A further explanation of how pedestrians experience the use of a navigation system and what pedestrians would like to see improved when using a navigation system follows in the next paragraph.

5.2.2 Results Interviews

The textual results of the interviews will be discussed below. These will be discussed per concept, environmental factors, human factors, and navigational factors, which are based on the Theoretical Framework.

5.2.2.1 Environmental factors

Below are the results of the respondents processed for each factor: aesthetics, walking facilities, convenience & other preferences, and safety. The interviews show that respondents consider safety especially important, but other factors are also relevant to the route choices of the respondents.

Aesthetics

At first, respondents have been asked where they prefer to walk and why they have a preference, based on environmental factors. All respondents said at first that it does not matter where they walk that much if they need to get from A to B quickly. However, the respondents said that they preferred to walk in the nature, especially the forest or sometimes along a river. Like respondent 7 said:

"It really depends on whether it is just recreational. Then I would say I take the route along beautiful nature and the beautiful buildings. Yes. But if it is purely just need to get from A to B. Yeah, then I would not do that. Then I would take the fastest route." [7]

Respondent 7 (male, 24 years)

Only respondents 8 and 9 preferred to walk in a residential area instead of nature. Both these respondents also said during the beginning of the interviews that they only walk if they need to. For example, to go to public transportation. The respondents also indicated that they would deviate from the route if they were familiar with the area, to walk a more beautiful route:

"If I am walking to a destination where I do not know where to go and I just must go there and I do not know the route, I always take the route that Maps shows. But if I do know the way a bit, I sometimes choose a nice route and then maybe go through a park or something, instead of always following the road."[8]

Respondent 5 (male, 21 years)

After respondents indicated where they liked to walk, they were asked how they could find beautiful aesthetic routes on navigation systems. This turned out to be difficult, and respondents indicated that they wanted a function that ensured that they had to walk a little longer for a more beautiful route. However, they wanted to know the number of detours this entailed:

"Then you should have had the option of a more beautiful route. It must be clear how much."[9]

Respondent 1 (male, 64 years)

Currently, pedestrians find it difficult to choose a more beautiful route through nature, because not all paths are shown on navigation systems, as became clear in interview 5, as shown in paragraph 5.2.3.1. However, on more practical walks, aesthetics is less important, as noted by respondent 9. Respondents 8 and 9 indicated that they only walk out of necessity and were both also the only respondents who did not consider aesthetics important in their route choice.

The centre of Wageningen was specifically mentioned as a pleasant route because of its aesthetic appeal, which was confirmed by respondents 2 and 5. These respondents consciously chose to walk through the centre of Wageningen because of the aesthetic buildings in the centre.

Respondent 10 indicated that OSM is a navigation system where you could more easily find an aesthetically more beautiful route than on Google Maps. This makes it easier to find nice points on a walk, such as viewpoints.

[7] "Ja, dat ligt er dus erg aan als het gewoon recreatief is. Dan zou ik zeggen ik pak de mooie natuur, de mooie gebouwen. Ja. Maar als het puur inderdaad gewoon gaat om van A naar B komen. Ja, dan zou ik dat niet doen. Dan zou ik toch de snelste weg pakken."

[8] "Als ik naar een bestemming loop waar ik niet weet waar ik heen moet en ik moet daar gewoon per se heen en ik weet de route niet, dan neem ik eigenlijk altijd de route die Maps aangeeft. Maar als ik de weg wel een beetje weet, dan kies ik soms ook nog wel eens een mooie route en dan ga ik misschien door een park ofzo, in plaats van dat ik steeds de weg volg."

[9] "Dan had je dus de optie moeten kunnen hebben van een mooiere route. Dit moet wel inzichtelijk zijn hoeveel."

Convenience & other preferences

When choosing walking routes based on environmental factors, various practical considerations play a significant role in addition to aesthetic preferences and safety concerns. Many respondents preferred a route that required as few turns as possible:

> “Yes, so it is nice that you actually have a route where you do not have to go left and right very much so that you can put your phone away as soon as possible."[10]
>
> Respondent 3 (female, 22 years)

This not only makes navigation easier, but also reduces concerns about walking. As a result, the respondents perceived the route as faster in terms of time. In addition, strong preference is given to routes with little traffic and obstacles. Pedestrians also like safe crossings such as zebra crossings, because this makes the walking experience calmer and safer:

> “You have zebra crossings everywhere, so you do not have to think where you are walking.”[11]
>
> Respondent 4 (male, 19 years)

Accessibility for the elderly is also a crucial factor. Elderly people often have less mobility and therefore benefit from smooth, well-maintained paths without obstacles.

Another important preference is avoiding muddy trails. The respondents indicated they are willing to walk a longer route to avoid muddy areas or trails with tall vegetation. The respondents therefore indicated that it would be nice if a navigation system would provide a notification if a path were unsuitable for walking, as respondent 5 experienced. However, Respondent 9 acknowledges that it is difficult to indicate all muddy areas in a navigation app but emphasizes that a warning about this would be appreciated.

Another aspect that influences the choice of routes is the presence of busy events. Busy events can slow a pedestrian down due to the substantial number of people:

> “Oh god, no. We do not go to events. You should not put me in the International Four Days Marches Nijmegen, hahaha. That does not make me happy. Then I get way too distracted and overstimulated, and I can become very claustrophobic when I am with a large group of people. When I go for a walk, I see it more as something to relax. So, then I do not want to walk into the crowds. Because then I have no peace.”[12]
>
> Respondent 6 (female, 27 years)

Pedestrians like to have the option to avoid or pass through such events, depending on their personal preferences and needs. However, other respondents indicate that they want to be surprised by an event. The desirability of events on a walking route therefore varies per respondent.

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[10] “Ja dus dit is wel fijn dat je eigenlijk een route hebt waarbij je niet heel veel naar links naar rechts hoeft zodat je zodra je telefoon even weg kan leggen.”

[11] “Je hebt overal zebrapaden, waardoor je niet hoeft nadenken waar je loopt.”

[12] “Oh god, nee. We gaan niet bij evenementen lopen. Je moet mij niet in de Nijmeegse Vierdaagse zetten, hahaha. Daar word ik niet gelukkig van. Dan raak ik veel te veel afgeleid en overprikkeld en het kan heel claustrofobisch worden als ik een grote groep mensen ben. Als ik ga wandelen, dan zie ik dat meer als iets om rust te hebben. Dus dan wil ik niet in de mensenmassa gaan lopen. Want dan heb ik geen rust.”

Safety

One of the most important environmental factors is safety. This can be divided into road safety and experience of crime.

First, the feeling of safety, based on crime. Most respondents avoid walking in the dark at night, if possible. This gives them a feeling of insecurity. Respondents responded positively to the idea that navigation systems should have a function that would not lead them along unlit paths in the dark. This could be made possible if data were entered for streets as to which paths have lighting and which do not. Moreover, respondent 8 indicated that he only walks on illuminated roads when traveling on unfamiliar roads for fear of walking wrong or falling, for example.

Not only does the presence of lighting influence pedestrians' sense of safety, but the presence of people also does this too. Respondents indicated that they prefer not to walk in places that are too remote from other people and appreciate the presence of people in the evening:

> "In any case, if I walk alone, also safety and especially at night, then yes, then it is indeed in the output of okay, which roads can I walk along and where if I shout, they will hear me.[13]
>
> Respondent 6 (female, 27 years)

In addition to this, respondent 2 also indicated she experiences a large group of people as frightening if she needs to walk alone in the dark.

In addition to a feeling of safety in terms of crime, there is also road safety. Although this can also be experienced differently by people, these answers were unanimous, in contrast to the feeling of safety based on crime. Respondents particularly note the presence of a sidewalk as a facility that increases road safety for a pedestrian:

> "A sidewalk in a city primarily offers safety."[14]
>
> Respondent 2 (female, 60 years)

However, there is no function in the navigation systems the respondents used that has an option to only walk on the sidewalks or pedestrian designated areas.

In addition to footpaths, zebra crossings are also regarded as facilities that increase the traffic safety of pedestrians. These could be placed at the bus station in Wageningen. Respondent 8 indicated that this bus station is confusing, also on the digital navigation app. He did not understand where he was allowed to walk and where he was not allowed to walk because buses will drive there.

5.2.2.2 Personal factors

The socio-demographic characteristics of the respondents have already been discussed in the data chapter. No differences in walking behaviour and preferences were found based on gender or age. Both men and women and both people in their 20s or 60s prefer not to walk in the dark. It also does not appear from the interviews that young people know how to use navigation better than older people.

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[13] "In ieder geval als ik alleen loop ook veiligheid en vooral s'avonds dan ja, dan is het wel inderdaad het uitvoer van oké, wat welke wegen kan ik wel langslopen waar als ik schreeuw dat ze me horen."

[14] "Een stoep in een stad biedt vooral veiligheid."

The main reasons given by respondents for walking can be divided into practical walks and recreational walks. The practical walks are to go from A to B, such as to the train station. The destination is fixed here, and respondents indicated that they would follow a route as quickly as possible, for example to catch a train. The respondents who indicated that they regularly walk recreationally do so mainly for exercise or for pleasure:

> "Because I have a dog that needs to be walked. And in addition to that, I am involved in scouting, which means I also do a lot of walking during the weekend."[15]
>
> Respondent 10 (male, 22 years)

The respondents who like to walk recreationally are also the respondents who indicated that they found aesthetics to be an important factor in their route choice and sometimes adjust their route accordingly, even when they must deviate from the navigation, as respondents 1, 4 and 6 did during their interviews.

In addition to personal factors based on socio-demographic factors, mental maps also influence the route choice of respondents (Basu et al., 2021; Hannes et al., 2010). Respondents who are familiar with Wageningen tend to navigate more based on their own knowledge than a navigation system. Respondents indicated that they only use a navigation system if they are unfamiliar with the area and otherwise will rely on their mental maps:

> "I prefer without if I know the way. If I do not know the way, then that is the end of course."[16]
>
> Respondent 5 (male, 21 years)

This was also evident from the fact that some respondents put their phones away while navigating.

5.2.2.3 Navigational factors

Navigation systems provide a positive experience for pedestrians, but there are several factors that can affect its usability. One of the biggest problems the respondents noticed is the reliability of GPS signals:

> "In fact, I often find myself going in one direction and then having to walk the other way."[17]
>
> Respondent 5 (male, 21 years)

In dense urban areas, the GPS signal can become disrupted, leading to an inaccurate location, and confusing the user about the correct route. These glitches can be frustrating and negatively impact the walking experience.

Respondents emphasize the importance of critical thinking when using a navigation system. While these technologies are useful, users should always use common sense and not blindly follow the route. This is especially important in situations where the system is not completely reliable or when local knowledge is required to choose the best route. However, in

[15] "Omdat ik een hond heb die uitgelaten moet worden. En naast dat zit ik op scouting, waardoor er in het weekend ook veel wordt gewandeld."
[16] "Ik heb het liever zonder als ik de weg weet. Als ik de weg niet weet dan houdt het op natuurlijk."
[17] "Eigenlijk heb ik het wel vaker dat ik dan een beetje de ene kant op ga en dan toch de andere kant moet oplopen."

general, respondents have a lot of confidence in their navigation systems and allow their route choice to be influenced by this technology, especially when they are in an unfamiliar area:

> "For the very simple reason that if I have the knowledge to deviate from a route, then I do not need that navigation system."[18]
>
> Respondent 8 (male, 22 years)

When planning a route with a navigation system, respondents have no intention of deviating from the planned route, as described in paragraph 5.2. They trust the system to provide the best route and usually follow it closely. This shows how important a reliable navigation system is for users who seek security and convenience during their walks and how much influence this has on their route choice.

At last, many users use Google Maps, both on Apple and Android phones. Google Maps offers extensive map data and route options, making it a popular choice among pedestrians. The ease of use and the well-known interface contribute to the wide acceptance of this application.

Data

One of the components of the navigation systems is the knowledge navigation systems have. GIS calculates the calculations of the shortest route, but this requires data. For example, a navigation system must know where the roads are, plus associated information, such as the maximum speed on a road (Siriaraya et al., 2020).

Information that respondents found particularly useful was street name signs to help them orient themselves. It helps users better to understand their location and get visual confirmation of the route:

> "Yes, that is good, because the house numbers are also on it, so you can orient yourself very well."[19]
>
> Respondent 1 (male, 64 years)

However, there are also several limitations regarding the data found in navigation systems by respondents. The first limitation of this was the incompleteness of the data, and therefore of the map and its specified routes. Examples of this were small unpaved paths between apartment buildings and the Rooseveltweg who were not known by Google Maps and the paths in the nature in the Uiterwaarden. The lack of data is precisely why respondent 10 consciously uses OSM instead of Google Maps:

> "Google Maps only knows about twenty percent of all hiking trails. This works well in cities, but not in forests. Google Maps does not know anything in forests. And the OSM map knows all the paths."[20]
>
> Respondent 10 (male, 22 years)

[18] "Om de heel simpele reden dat als ik de kennis heb om af te wijken van een route, dan heb ik dat navigatiesysteem niet nodig."

[19] "Ja, dat is goed, want de huisnummers staan er ook op, dus je kan je wel heel goed oriënteren."

[20] "Google Maps kent maar ongeveer twintig procent van alle wandelpaden. In steden gaat dat goed, maar in bossen niet. In bossen weet Google Maps helemaal niks. En de OpenStreetMap-kaart weet wel alle paden."

Not only does OSM's database contain more pedestrian roads, also the rest points, such as benches, but also viewpoints are processed in OSM. This indicates that there is a need for more detailed and inclusive map data, at least for pedestrians, because these are environmental factors which influences the route choice of pedestrians. If these data are more available navigation system can calculate better routes for its users, according to their needs.

Moreover, squares are calculated in an unpredictable manner by navigation systems. In this way, pedestrians are guided around squares instead of over them, as respondent 6 noticed. This could indicate a lack of detailed data or routing algorithms that are not optimal for pedestrians. This deficiency also applies to pedestrian crossings:

> "Sometimes you are walking towards something and then the sidewalk suddenly stops or something. Yes, then you must cross. Then it would be useful if they would indicate that."[21]
>
> Respondent 7 (male, 24 years)

Furthermore, footpaths separated from the road are also not always included, which can confuse the orientation of users, according to respondent 9. This is an explanation why the navigation does not indicate when you should cross the road as a pedestrian.

Besides the static data mentioned above, there is also real-time data (Siriaraya et al., 2020). Although respondents indicated that they would like real-time data implemented in navigation systems, such as notification when roads are impassable due to mud or events, most respondents are also sceptical about how this can be processed in navigation systems. For example, respondent 4 thinks that the app may be overloaded or that it may become confusing to use a navigation system. Respondent 8 suggested a function that would allow users to provide this information themselves but feared misuse by other users.

Not only roads are missing from the data from navigation systems, but also restrictions. For example, respondent 10 was sent onto a road that was forbidden to unauthorized persons. As a result, he had to find another route himself, but in that case the navigation did not adapt to the user and the situation. Many of the navigation problems can be solved by improving or supplementing the data a navigation system needs to provide accurate information to pedestrians.

Functions

The literature showed that not only data, but also certain functionalities may be missing or not function properly in a navigation system (Siriaraya et al., 2020; Yang and Lam, 2021). The lack of options for a preferred route was particularly noted by the respondents. These preferred routes would then mean that pedestrians can choose a more scenic route:

> "It does not always have to be the quickest route, it can also be the most beautiful route."[22]
>
> Respondent 6 (female, 27 years)

[21] "Soms dan loop je ergens op af en dan stopt het voetpad opeens ofzo. Ja, dan moet je oversteken. Dan zou het toch handig zijn als ze dat misschien aan zouden geven."

[22] "Het hoeft niet altijd de snelste route te zijn het mag ook de mooiste route zijn."

Now respondents needed to search for the "most beautiful" route themselves. Due to this shortcoming, respondents 1, 4 and 6 decided to deviate from the route during the interviews themselves:

> "You only have a few options of preferred routes. As with some systems, you can choose a beautiful route, but with this system there are only unpaved roads and ferries that you can set off."[23]
>
> Respondent 1 (male, 64 years)

Although this option is not available, respondent 1 also indicated that it should be clear how much longer you must walk if you had the option to choose between certain scenic routes. An option could be added for how long a pedestrian is willing to take a detour.

In addition to the option to choose a more scenic route, respondents often commented negatively on the audio option of navigation systems, because they affect the peace and quiet of walking and can be seen as distracting:

> "Yes, I find that very annoying, just that it is said about so many meters to the left. [...] That is a bit of a distraction, so that is why I turned that function off."[24]
>
> Respondent 3 (female, 22 years)

However, respondent 5 had deliberately turned on the vibration mode. This way he could put his phone away while walking straight ahead and only needed to look at his navigation system when his phone vibrated. This way he could enjoy more of his surroundings.

Respondent 8 indicated a way of navigation that was different from that indicated by the other respondents:

> "It would be very nice for me if, for example, certain landmarks were indicated. And that is of course very difficult to do, because everyone uses different things as a point of reference. For example, if the route says... Instead of a street or something, because those street signs cannot be found everywhere: For example, up to the corner house or [...] left between the Lucardie and the Hema. And that is of course also very difficult to maintain, because street names do not change as often as shops and so on. But... Yes, that is how I navigate my way through something." [25]
>
> Respondent 8 (male, 22 years)

This is a feature that is currently not available in Google Maps, the navigation system chosen by the respondent in question.

Furthermore, respondent 7 was negative about the feature that a navigation system has an expected arrival time function:

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[23] "Je hebt weinig opties van voorkeurs routes. Zoals bij sommige systemen kun je mooie route kiezen, bij dit systeem zit alleen maar onverhard en veerponten hier die je uit kan zetten."

[24] "Ja, ik vind dat heel irritant, gewoon dat er wordt gezegd over zoveel meter naar links. [...] Dat lijdt een beetje af, dus vandaar dat ik die functie uit heb staan."

[25] "Voor mezelf zou het heel fijn zijn als er bijvoorbeeld bepaalde herkenningspunten staan aangegeven. En dat is natuurlijk heel moeilijk om te doen, want iedereen gebruikt andere dingen als een herkenningspunt. Als er bijvoorbeeld op de route staat... In plaats van een straat ofzo, want die straatnaambordjes zijn ook niet overal te vinden: Bijvoorbeeld staat tot aan het hoekhuis of [...] links tussen de Lucardie en de Hema. En dat is natuurlijk ook heel moeilijk te doen te houden, want straatnamen veranderen nu bijna niet zo vaak als winkels enzo. Maar... Ja, zo navigeer ik dan mijn weg ergens doorheen."

> “I do not always know whether it is reliable. Because every now and then I think, well, that was also made at a pace that I cannot maintain. I like to have a gentle pace[26]
>
> Respondent 7 (male, 24 years)

Respondent 7 suggested that this could be set more dynamically based on how fast you walk. He would find that a bit more realistic. He felt rushed and that made the experience of walking less relaxing which was the purpose for him to walk.

GIS

Navigation systems that use GIS technology can efficiently calculate new routes, especially when the original route is abandoned for any reason. However, these systems tend to automatically choose the shortest route. This was evident, for example, from the experience of respondents 1, 4 and 6, who chose to voluntarily walk through a park instead near the road. The system adapted to its new path and recalculated the route without any problems. Respondent 3 also thought this was a necessary function in combination with real-time data:

> “Yes, if that is done. For example, if I see, hey, I cannot go straight, I just go to the right based on intuition, and that it will indeed say, oh, she is going to the right and then it will deviate you around the street that is blocked.”[27]
>
> Respondent 3 (female, 22 years)

Yet there are exceptions to this adaptivity. Respondent 10 experienced a problem when the navigation system guided him on a road that was prohibited to unauthorized persons. This incident shows that although GIS systems are adaptive, they are sometimes unable to recognize and avoid all road network limitations.

Because the function of most beautiful routes is not a functionality that can be calculated by GIS, respondent 10 takes matters into his own hands:

> “I personally find it easier to take matters into my own hands. Because then you can make a more beautiful route. Instead of taking the fastest route between points A to Z.”[28]
>
> Respondent 10 (male, 22 years)

Respondent 10 explained that he creates routes on the computer in advance to create more beautiful routes, where more environmental factors have an influence. He does this when he walks through nature with his scouting association, a recreational walk.

On one hand, a major disadvantage of current GIS-based navigation systems is that they do not navigate using landmarks. This can make it more difficult for users to find their way, especially in unfamiliar areas. Respondent 8 highlighted this problem by stating that the

[26] “Ik weet niet altijd of het even betrouwbaar is. Want af en toe denk ik wel eens van, nou, dat is ook gemaakt op een tempo wat ik niet volhoud. Ik ben van de rustige pas.”

[27] “Ja zolang dat maar gewoon gedaan wordt. Als ik bijvoorbeeld zie van hé, ik kan niet rechtdoor, dus ik ga maar op intuïtie naar rechts dat die dan inderdaad heeft van oh, ze gaat naar rechts en dan lijdt het je om de straat die geblokkeerd is.”

[28] “Zelf vind ik het makkelijker om het in de hand te nemen. Want dan kan je een mooiere route maken. In plaats van dat die de snelste route pakt tussen punten A tot en met Z.”

system did not use visual landmarks when navigating based on the physical environment. This is a limitation as pedestrians often rely on landmarks while walking to confirm their route and orient themselves. The lack of this feature can reduce the user-friendliness of the navigation experience and make navigating more difficult.

On the other hand, a positive feature of GIS navigation systems is their ability to distinguish between paved and unpaved roads. This can be particularly helpful for hikers who have preferences for the type of trail they want to hike. Respondents 1 and 5 noted that the system knows the difference between those road types and that there is a function to avoid unpaved roads on a route.

Visuals

A final factor of the experience of using navigation systems is the visuals. This is what a map of the navigation system looks like. Respondents liked the visual aspects of a navigation system for orientation in relation to the physical environment. For example, they indicated that the colours between built-up areas and nature were a useful tool for this. Street signs and house numbers that could be seen on the map were also mentioned as useful tools for orientation. Respondent 8 even navigates via the map:

> "I plan, I saw that we had to go through the entire shopping street and that we only had to turn at a larger road, because that was also indicated in terms of width. Those roads are thicker if we are more important for the bigger road. When we arrived at a larger road, we had to turn left. So, it also vibrates when there is a turn."[29]

Respondent 8 (male, 22 years)

The visual map is therefore practical for orientation and for planning a route in advance, so that the phone can be put away for a while or respondents can find a more efficient route, as respondents 4 and 8 did.

The colours on the map are not only used for planning ahead while navigating, but also to determine a desired destination in advance:

> "We use the maps to easily see where areas are located. Remember the map just has different colours for sand areas, hill areas, forest areas. And with that you can quickly determine where what is. And then you can walk there in one go." [30]

Respondent 10 (male, 22 years)

Not only the colours, but also the number of roads visible on the map contribute to the positive experience of navigation systems. However, there are still some limitations to this that may cause some confusion. For example, separate footpaths next to the road are sometimes not on the map. This caused confusion for respondent 9 when orientating:

[29] "Ik plan vooruit, ik zag dat we de hele winkelstraat door moesten en dat we pas bij een grotere weg om moeten, want dat zaten we ook qua breedte aangegeven. Die wegen zijn dan wel dikker als we belangrijker zijn voor de grotere weg. Toen we bij een grotere weg aankwamen, dat we dan linksaf moesten. Dus hij trilt ook als er een afslag komt."

[30] "Wij gebruiken de kaarten om makkelijk te kunnen zien waar gebieden zitten. Denk aan dat de kaart gewoon verschillende kleuren heeft voor zandgebieden, heuvelgebieden, bosgebieden. En daarmee kan je heel snel bepalen waar wat zit. En dan kan je er in één keer heen lopen."

> "Yes, that might depend more on if you somehow had to represent the road for cars and for a cycle path. And, for pedestrians."[31]
>
> Respondent 9 (male, 22 years)

When these paths are not shown separately, it can be difficult to make accurate decisions about which route to take, especially in areas with a complex network of roads and paths. A clear distinction between pedestrian and cycle paths on the navigation would significantly improve the user-friendliness and accuracy of route planning, making it easier and safer for users to find their way.

5.2.2.4 Wageningen

Because Wageningen is the location where the interviews were conducted, and the location may influence the walking experience due to, for example, environmental factors, mental maps or because navigation systems miss certain data, respondents were also asked questions about Wageningen itself.

The respondents indicated that it was pleasant to walk in Wageningen, both respondents who are familiar and unfamiliar with Wageningen. The car-free centre and the Uiterwaarden were particularly mentioned.

Furthermore, the presence of many sidewalks was appreciated, although sometimes perceived as crooked:

> "It is not too bad for walking, but if you had a wheelchair here, you would shake out. Also look here, the tiles are uneven, they are crooked."[32]
>
> Respondent 1 (male, 64 years)

Respondent 3 had an explanation for this:

> "In general, the sidewalks are fairly straight. Of course, you have a subsidence every now and then. But that makes sense, since there are many trees planted along the edges. But I do not mind walking."[33]
>
> Respondent 3 (female, 22 years)

In addition to the large presence of sidewalks, which ensures a better walking network, several respondents mention the presence of street name signs (Ferrer et al., 2015; Koh and Wong, 2013; Ralph et al., 2020). For example, respondent 2 used the street signs to reorient herself when she no longer knew where she was in Wageningen while using Google Maps. The respondents could read the street names on the navigation systems.

It was more difficult for respondent 5 to orientate himself when he left the city-centre and walked in places where there are no street signs. Although the Uiterwaarden are experienced as a pleasant place to walk, respondent 5 was bothered by the tall grass. He also had a solution for this:

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[31] "Ja, dat ligt dan misschien meer aan als je op een of andere manier de weg zou moeten weergeven voor auto's en voor fietspad. En ook voor voetgangers."

[32] "Om te wandelen valt het mee, maar als je hier een rolstoel zou hebben, dan schud je eruit. Kijk hier ook, tegels liggen wel ongelijk, dat loopt van scheef."

[33] "Over het algemeen zijn de stoepen wel redelijk recht. Je hebt natuurlijk af en toe een verzakking. Maar dat is ook wel logisch, aangezien er veel bomen langs de randen geplant staan. Maar ik vind het niet vervelend lopen."

"Maybe you can mow the lawn a little more or something. That it is clearly a path."[34]

Respondent 5 (male, 21 years)

Although street signs were widely available, respondents did miss signage signs for pedestrians in the city. This is especially true if paths are difficult to see due to tall vegetation. The respondents considered a navigation system necessary in Wageningen because they often had no signs towards the centre or other sights such as the Grote or Johannes de Baptistkerk.

In conclusion, Wageningen was experienced as an accessible and pleasant place to walk, except for the bus station, according to respondent 8. Respondent 10 added that he likes the fact that cars are only allowed to drive at a speed of 30 km/h on many roads, making the streets in the residential areas more pleasant to walk.

[34] Misschien kan je het gras een beetje meer maaien ofzo. Dat het duidelijk een pad is.

6. Conclusion

6.1 Human factors

Although there was no specific research question about the influence of human factors on the route choices of respondents, it does appear to influence their route choices. For the demographic factors, the survey results showed that the age of the respondents does have an influence on the environmental factors “accessibility”, “other route is unsafe” and “variety”. The interviews also show that the mental maps determine whether people use a navigation system or not, which is explained in paragraph 6.2.

6.2 Navigational factors

To answer the first sub-question: *What are people's needs and desires in pedestrian navigation systems?* it is important to distinguish the purpose of the walk between a practical or recreational walk. For practical walks, where the primary objective is to navigate from point A to point B, the primary need is efficient and safe navigation to the intended destination. This fundamental requirement is well-addressed by current navigation systems, as confirmed by interviews. However, walking is not solely a utilitarian activity, but also for recreational purposes. In such cases, additional factors, such as the presence of natural scenery, significantly influence route selection. Recreational walkers express a desire for navigation systems that incorporate these scenic elements, including information on the length of these routes. Additionally, pedestrians often prefer to deviate from proposed routes when it is dark to avoid poorly lit paths. Consequently, there is a demand for navigation systems to offer options for illuminated routes.

The absence of features such as 'only illuminated routes' and 'recreational routes' indicates gaps in current pedestrian navigation systems. Despite this, the sub-question: *How do pedestrians perceive the quality of pedestrian routes proposed by a navigation system?* is answered positively by the respondents. This positive perception is due to the efficient route planning facilitated by these systems. The option to omit unpaved roads from proposed routes is also considered useful, especially for the elderly and people with wheelchairs. Nevertheless, navigation systems lack real-time data. When you are walking and take a detour the navigation automatically adjusts the route. However, this feature is not always reliable if roads are not accurately represented. Nevertheless, because the pedestrian network, especially in built-up areas, is perceived as complete, pedestrians are satisfied with the quality of the routes suggested by navigation systems.

The third question is: *When does a GPS navigation system influence pedestrians’ route choices?* This depends on the pedestrians familiarity with the area. Pedestrians mostly use a navigation system if they are unknown to the area and thus lack a mental map of the area. Conversely, those familiar with the area and possessing a mental map are less likely to depend on navigation systems and are not influenced by them. When a pedestrian does utilise a navigation system, it will follow the route proposed by the navigation system and only deviate from the proposed route unless they consciously decide to deviate, either by consulting the map themselves or by relying on their local knowledge.

Deviations from the proposed route can arise in various ways. There are conscious and unconscious deviations. Unconscious deviations were made by the respondents themselves, for example by not paying attention. Deliberate deviations from the navigation system can be due to people navigating themselves and looking at the map, or due to obstacles on the road, such as restrictions or mud. This leads to the question: *How are pedestrian infrastructure and* *routes represented in geographical information systems (maps) and with what quality?* Respondents are satisfied with the routes, because in most cases they take you from A to B and the roads in built-up areas are correct in the navigation systems. However, this is not always the case for nature recreational areas, for example in the Uiterwaarden. A few other flaws that navigation systems have regarding the route networks for pedestrians is that alleys are not on the map but do shorten the route in reality.

In general, while pedestrians systems are useful for practical navigation, there are areas for improvement to give better routes for recreational walking. Enhanced route options, real-time updates, and more accurate road networks of pedestrian paths are essential to fulfil the needs of pedestrians.

6.3 Environmental factors

The data for the environmental factors was collected through both surveys and walk-along interviews and are linked to one research question: *What environmental factors influence pedestrians' route choices?* Most pedestrians take the shortest route and do not care about environmental factors that much, as stated in both the survey’s and the interviews. When pedestrians do not take the shortest route, because for example they walk recreational, aesthetical factors, such as 'beautiful routes' and the presence of greenery influences the route choice of pedestrians the most.

The most useful improvement that would enhance the walkability of Wageningen, according to the survey, is better maintaining the footpaths and building footpaths where the respondents think important connections in the pedestrian network are missing. This is because better maintenance of the footpaths is the most chosen improvement for the walkability of Wageningen. Additionally, creating a better pedestrian network is significantly proven to improve the walkability grade. This was also shown in the survey, where respondents who think that connections in the pedestrian network are missing have given a significantly lower walkability grade than those who believe the pedestrian network in Wageningen is complete.

6.4 Main conclusion

How do digital navigation tools and environmental factors influence the route choice behaviour of pedestrians? The level of influence of environmental factors and navigational factors are both depended on the reason of the walk and the mental map of the pedestrian. Environmental factors will be more influential than navigation tools when respondents are taking a walk for pleasure and will become less important if a pedestrian walks for practicalities, partly because navigation systems are insufficient in navigation recreational routes. Likewise, a navigation system will only have more influence on the pedestrian route choice if the pedestrian is unfamiliar with the environment and network.

It can be concluded that environmental factors, digital navigation tools and personal factors all influence the walkability and the route choice of pedestrians. The factors also influence each other on various degrees. This depends on the reason for the walk, the environment and the associated personal preferences and knowledge of pedestrians, and the quality of the navigation system, including its maps.

7. Discussion

The aim of this thesis was to research the interconnection between navigation systems and the users experience in combination with the environmental factors. This allows for a deeper understanding of how these technologies affect pedestrian route choice and which adjustments are needed to improve the experience of using navigation systems. Three words are important to argue why this aim has or has not been met. These are 'interconnection', 'users experience' and 'adjustments', which will be explained in this chapter.

The sub questions *How do pedestrians perceive the quality of pedestrian routes proposed by a navigation system?* and *How are pedestrian infrastructure and routes represented in geographical information systems (maps) and with what quality?* tried to give information on the 'user experience' of digital navigation tools. The walk-along proved a useful data-sampling tool to answer those sub questions. For example, a lack of real-time data, as discussed by Fang et al. (2015) and Longley & Cheshire (2017), appeared to make navigating with a navigation system more difficult. This also turned out to be the case for respondent 5, whose route had been flooded with mud and had therefore did not know how to reach his destination. This shows that the sub-questions in this paragraph contribute to answering the 'user experience' of digital navigation tools.

The sub-question *What are people's needs and desires in pedestrian navigation systems?* tried to determine the possible 'adjustments' of navigation systems. The solution about an option for recreational routes, proposed by the respondents of the interviews, is not mentioned in the discussed literature of the theoretical framework. Conversely, what is mentioned is that navigation systems guide pedestrians over paths with obstacles (Mulyadi et al., 2022; Prescott et al., 2021). Something that does not emerge in the interviews but does emerge from the surveys. Respondents indicate that vegetation can cause footpaths to become too narrow to walk on safely.

The last concept is 'interconnection'. To answer this concept, the influence of the various factors must be examined separately. The sub-questions *When does a GPS navigation system influence pedestrians' route choices?* and *What environmental factors influence pedestrians' route choices?* each answer a part of the interconnection, combining the main research question *How do digital navigation tools and environmental factors influence the route choice behaviour of pedestrians?* The results from the interviews show that pedestrians will mainly use a navigation system when people are unfamiliar with the road network, which is consistent with literature from Fang et al. (2015); Philips et al. (2013) and Siriaraya et al. (2020) who indicate that navigation systems are mainly used when people are unfamiliar with the environment, road network and destination.

The reliability for researching the environmental factors was increased by using both quantitative and qualitative data collection. The research shows that respondents of both the survey and the interviews often take the shortest route, which is consistent with the research of Shatu et al. (2019b). Multiple aesthetic factors, such as greenery and buildings are also frequently mentioned as an influential factor according to both respondents to this study and scientific literature (Basu et al., 2021; Ferrer et al., 2015). However, the amount of influence of those factors depends on the reason for the walk (Garnter et al., 2011).

A second component of environmental factors is the walking facilities. Some of the answers from the survey do not correspond with the literature of the theoretical framework. This concerns the presence of rest points. These are perceived as unimportant by the respondents, while this has emerged several times in the literature as an environmental factor that can influence the route choice of pedestrians (Ferrer et al., 2015; Shatu et al., 2019a).

Other facilities, such as road quality, emerge both the survey and scientific literature as an important environmental factor that can influence route choices of pedestrians (Ferrer et al., 2015; Shatu et al., 2019a).

Lastly, the results of the survey show that walkability and thus route choice in a city are influenced by the availability of the pedestrian network. This is consistent with the literature by Ralph et al. (2020) and Shatu et al. (2019b), who state that pedestrians prefer a coherent network with fewer turns.

7.1 Limitations

There are several limitations of this study that should be addressed in future research to enhance generalizability of the findings.

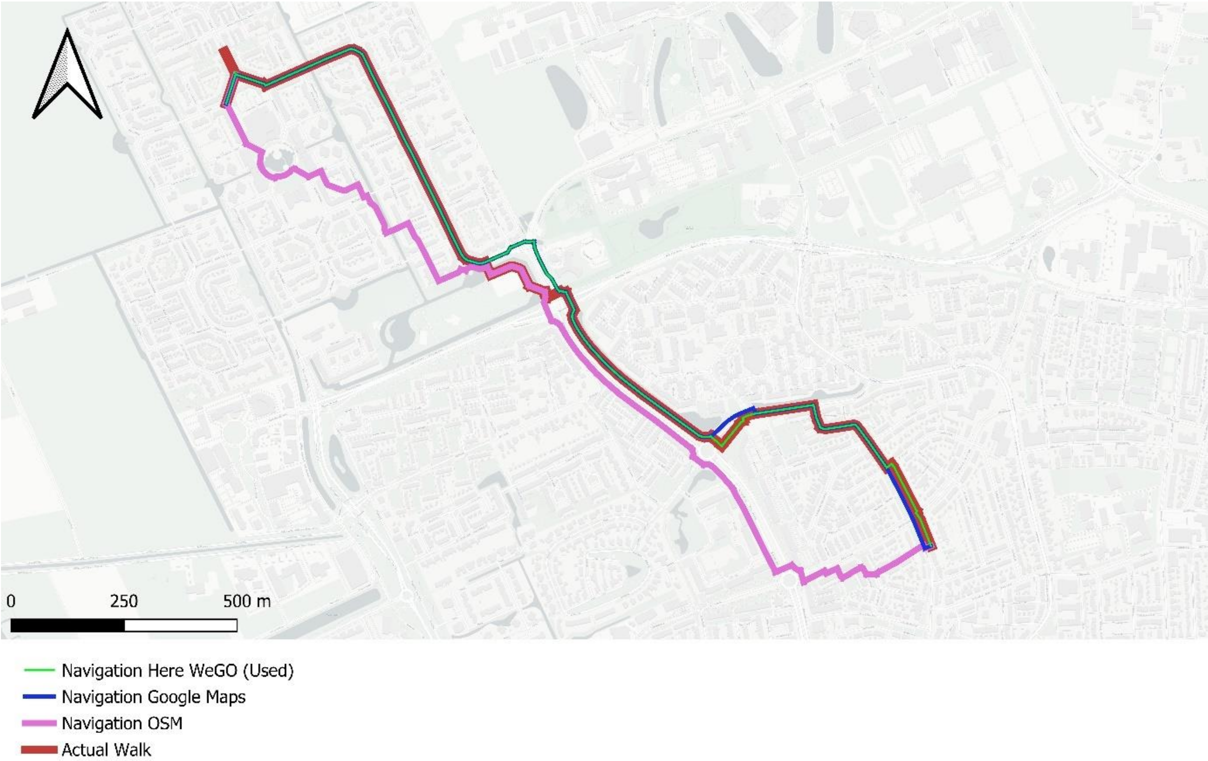
First, according to Basu et al. (2021) and Shatu et al. (2019a), people's demographic factors influence pedestrians' route choices. While the current survey identified how age and environmental factors influence route choices, it did not account for variables such as gender and income. This reduces the reliability of the survey data. However, because the survey contains 465 respondents, there is high internal validity and there are expected to be at least 30 female respondents (Hay & Cope, 2021). Including questions about gender and income would provide a more comprehensive understanding of how representative the respondent group is and how the factor safety relates to route choices (Boeije et al., 2016). Additionally, incorporating questions about mental maps, such as the duration of respondents' residency in Wageningen would give a deeper insight in human factors and its influence on route choices.

Second, the research was conducted in only one city, Wageningen. To increase the generalizability of the results. Future studies should be conducted in diverse urban areas to compare results and to be able to generalise the results to a more meta-level.

Third, young people have been heavily weighted, with a weighting factor higher than 5. Although the other age categories did not have to be extremely weighted and there was an N of ≥ 30, a respondent from the 18–29-year-old group has a lot of influence in this research (Boeije et al., 2016).

Finally, comparing different navigation systems on the same starting points and destinations could be useful to research. It is possible that people make different route choices depending on the proposed route (Delikostidis et al., 2015). It could therefore have been an addition to research how different navigation systems influence the route choices of pedestrians. For example, map 3 shows that navigation systems indicate different routes. The respondent only walked with Here WeGo. If the respondent had walked with OSM, he might not have deviated from the route in the park, as it would have already guided the user through the park. This can also be explained by the fact that OSM is the navigation system with the most extensive data for pedestrians, out of the three included in map 3. OSM contains better data for paths in recreational areas and even information where interesting destinations for pedestrians, such as viewpoints, are located (respondent 10).

Map 3: Walk of respondent 1 with multiple navigation systems



Source: Carto, 2024; Google Maps, 2024; Here WeGo, 2024; OSM, 2024; Strava, 2024

7.2 Recommendations for further research

Apart from the above limitations, which can also be implied in subsequent research, questions have also emerged where further research could provide clarification for.

This research has focused on the needs and desires of users of navigation systems, but not on the solutions that can be offered by the people who make such navigation systems possible. An addition to this research could be in-depth interviews with GIS experts. According to Longley and Cheshire (2017), there is opportunity for innovations in geographic information systems (GIS) that can increase the accuracy and usability of navigation systems. This can lead to a better understanding of how GIS techniques can be applied to make navigation systems more user-friendly and reliable for pedestrians.

Second, an interesting finding in this study is that the presence of rest points is less important to respondents than what the literature by Ferrer et al. (2015) suggests. This raises the question of why benches are considered less relevant in this specific context compared to research by Ferrer et al. (2015). A more extensive survey or new walk-along interviews, may be able to provide more information on why rest points are not important for route choices.

7.3 Policy recommendations

To improve the walkability of Wageningen, several policy recommendations for the municipality of Wageningen are proposed. The first one is repairing and better maintaining existing roads to ensure safe and smooth travel. Well-maintained roads reduce the risk of accidents and enhance the walking experience (Basu et al., 2021). Second, expand the pedestrian network to provide more and safer route options. Third, increase street lighting to enhance safety. At last, implement clear and consistent signage in areas like the Uiterwaarden to guide pedestrians effectively.

Appendix

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Topic List

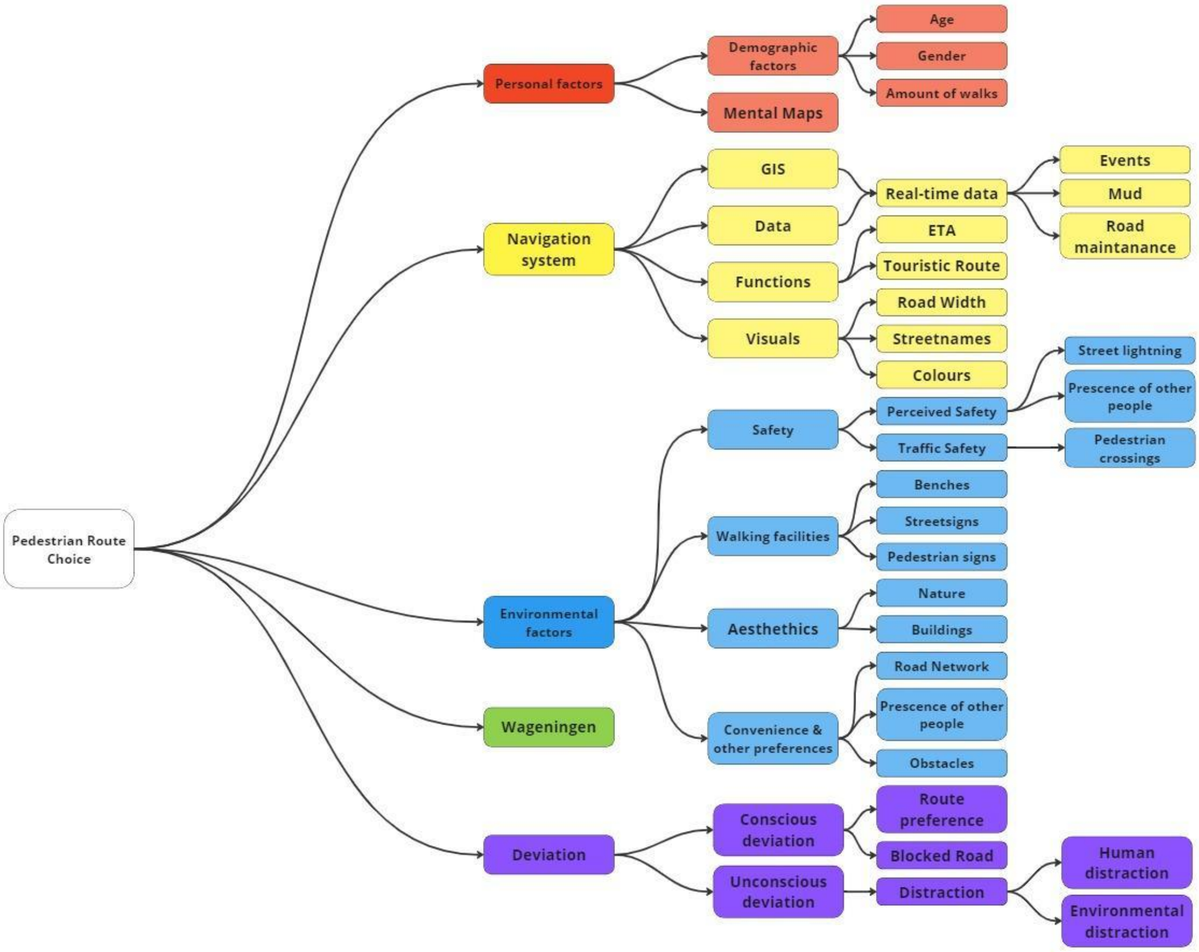
Table 7: Topic-list Walk-along interview

Theme	**Questions/text**
Introduction	● The research is about your route choices ● This interview will last approximately 20 to 60 minutes. ● Everything you share is confidential and will be anonymized. ● Can it be recorded? The recording is only used to accurately process the information. The recording can be stopped at any time and will be deleted after the examination. ● Does the respondent have any questions about the research or the subject prior to the research? This is also allowed during and after the interview.
Personal factors	● Age ● Gender 1. How often do you walk? 2. Why do you walk? 3. How often do you use digital navigation systems when walking? a. When? b. Why? 4. Are you familiar with Wageningen?
Environmental factors	5. Could you describe what kind of environmental factors you notice while walking through Wageningen that influence your route choices? Explain: a. Safety b. Aesthetics c. Facilities d. Convenience and other perceptions 6. Have you noticed that certain parts of Wageningen are more attractive to walk through than others? If so, what makes these areas more attractive? 7. Are there specific moments or situations when you are willing to take a longer route because of certain environmental factors? E.g. a. Unilluminated streets when it is dark b. Street without other pedestrians (when it is dark) c. Tunnels & bridges when it is dark 8. How important are factors such as the presence of aesthetics (greenery, buildings), road quality, safety, and sidewalks in determining your route? 9. How do social factors such as the presence of other people, social activities, and events influence your route choices? a. What do you think about the app not showing things like the market or a festival? 10. Have you noticed that your route choices change depending on the time of day or the weather? If yes, how?

Digital factors	11. To what extent do digital navigational factors, such as Google Maps, influence your route choice? 12. Are there specific moments or situations when you are willing to take a different route because of certain navigational factors? 13. Are there functions you miss when you use a digital navigation system when walking?
Wageningen	14. Are there parts of Wageningen that you avoid walking through due to certain environmental or navigational factors? If yes, what factors are involved? 15. How would you describe the overall walking experience in Wageningen in terms of the influence of environmental and navigational factors on your route choices?
End	● Do you have any questions? ● Thank you for participating in the research

Code scheme

Figure 2: Code scheme Walk-along interview



Survey

Table 8: Survey questions and answers

Question	Answers
1. What is your age?	• <20 years • 20-29 years • 30-39 years • 40-49 years • 50-59 years • 60-69 years • >70 years
2. Which facilities do you walk to the most?	• City-centre • Shops outside city-centre • Hotel, restaurant & café • Cultural facility (e.g. Theatre, museum, or arboretum) • Garden centre, hardware store • School/university/education or daycare • Public transportation • Work • Sport • Care (e.g. GP, dentist, physio) • Social facilities (e.g. library, community centre, town hall) • Recreational facilities (e.g. playground, park, vegetable garden/picking garden) • No facility; walking to friends, family, or acquaintances • No facility: walk to Binnenveld / Eng / Rijn • No facility; just taking a walk or walking the dog • Other
3. You have indicated that you often walk to the city-centre. Which route do you usually walk to the city-centre?	• Draw a route on the map.
4. Why do you take this route to the city-centre?	• Shortest route • Beautiful route • Lot of rest points (e.g. benches) • Greenery • Accessibility / lot of space for pedestrians • Other route is unsafe • Variety • Facilities/destinations along the way (shops, schools, friends/acquaintances) • Other
5. You have indicated that you often walk to shops outside the city-centre. Which route	• Draw a route on the map.

do you take to shops outside the city-centre?	
6. Why do you take this route to shops outside the city-centre?	• Shortest route • Beautiful route • Lot of rest points (e.g. benches) • Greenery • Accessibility / lot of space for pedestrians • Other route is unsafe • Variety • Facilities/destinations along the way (shops, schools, friends/acquaintances) • Other
7. You have indicated that you often walk to hotels, restaurants, and/or café's. Which route do you take to the hotels, restaurants, and/or café's?	• Draw a route on the map.
8. Why are you taking this route to hotels, restaurants, and/or café's?	• Shortest route • Beautiful route • Lot of rest points (e.g. benches) • Greenery • Accessibility / lot of space for pedestrians • Other route is unsafe • Variety • Facilities/destinations along the way (shops, schools, friends/acquaintances) • Other
9. You have indicated that you often walk to a cultural facility. Which route do you take to a cultural facility such as theatre or museum?	• Draw a route on the map.
10. Why do you take this route to a cultural facility such as a theatre or museum?	• Shortest route • Beautiful route • Lot of rest points (e.g. benches) • Greenery • Accessibility / lot of space for pedestrians • Other route is unsafe • Variety • Facilities/destinations along the way (shops, schools, friends/acquaintances) • Other
11. You have indicated that you often walk to a garden centre or hardware store. Which route do you take to a garden centre or hardware store?	• Draw a route on the map.

12. Why do you take this route to a garden centre or hardware store?	• Shortest route • Beautiful route • Lot of rest points (e.g. benches) • Greenery • Accessibility / lot of space for pedestrians • Other route is unsafe • Variety • Facilities/destinations along the way (shops, schools, friends/acquaintances) • Other
13. You have indicated that you often walk to school/ university/education or daycare. Which route do you walk to school/university/ education or daycare?	• Draw a route on the map.
14. Why do you take this route to school/university/education or daycare?	• Shortest route • Beautiful route • Lot of rest points (e.g. benches) • Greenery • Accessibility / lot of space for pedestrians • Other route is unsafe • Variety • Facilities/destinations along the way (shops, schools, friends/acquaintances) • Other
15. You have indicated that you often walk to a bus stop/bus station. Which route takes you to a bus stop?	• Draw a route on the map.
16. Why are you taking this route to a bus stop/bus station?	• Shortest route • Beautiful route • Lot of rest points (e.g. benches) • Greenery • Accessibility / lot of space for pedestrians • Other route is unsafe • Variety • Facilities/destinations along the way (shops, schools, friends/acquaintances) • Other
17. You have indicated that you often walk to work. What route do you walk to work?	• Draw a route on the map.
18. Why do you take this route to work?	• Shortest route • Beautiful route • Lot of rest points (e.g. benches) • Greenery • Accessibility / lot of space for pedestrians

	• Other route is unsafe • Variety • Facilities/destinations along the way (shops, schools, friends/acquaintances) • Other
19. You have indicated that you often walk to a sports facility. Which route do you take to a sports facility?	• Draw a route on the map.
20. Why do you take this route to a sports facility?	• Shortest route • Beautiful route • Lot of rest points (e.g. benches) • Greenery • Accessibility / lot of space for pedestrians • Other route is unsafe • Variety • Facilities/destinations along the way (shops, schools, friends/acquaintances) • Other
21. You have indicated that you often walk to a healthcare facility. Which route do you take to a healthcare facility (e.g. GP, dentist, physio)?	• Draw a route on the map.
22. Why do you take this route to a healthcare facility (e.g. GP, dentist, physio)?	• Shortest route • Beautiful route • Lot of rest points (e.g. benches) • Greenery • Accessibility / lot of space for pedestrians • Other route is unsafe • Variety • Facilities/destinations along the way (shops, schools, friends/acquaintances) • Other
23. You have indicated that you often walk to a social facility. Which route do you usually walk to a social facility (e.g. library, town hall)?	• Draw a route on the map.
24. Why do you take this route to a social facility (e.g. library, town hall)?	• Shortest route • Beautiful route • Lot of rest points (e.g. benches) • Greenery • Accessibility / lot of space for pedestrians • Other route is unsafe • Variety • Facilities/destinations along the way (shops, schools, friends/acquaintances)

	• Other
25. You have indicated that you often walk to a recreational facility. Which route do you usually walk to a recreational facility (e.g. playground, park, vegetable garden/picking garden)?	• Draw a route on the map.
26. Why do you take this route to a recreational facility (e.g. playground, park, vegetable garden/picking garden)?	• Shortest route • Beautiful route • Lot of rest points (e.g. benches) • Greenery • Accessibility / lot of space for pedestrians • Other route is unsafe • Variety • Facilities/destinations along the way (shops, schools, friends/acquaintances) • Other
27. You have indicated that you often take a walk or walk the dog. Which detour do you take, or which route do you walk with the dog?	• Draw a route on the map.
28. Why do you take this route?	• Shortest route • Beautiful route • Lot of rest points (e.g. benches) • Greenery • Accessibility / lot of space for pedestrians • Other route is unsafe • Variety • Facilities/destinations along the way (shops, schools, friends/acquaintances) • Other
29. You have indicated that you often walk to family, friends, or acquaintances. Which route do you take to family, friends, or acquaintances?	• Draw a route on the map.
30. Why do you take this route to friends, family, or acquaintances?	• Shortest route • Beautiful route • Lot of rest points (e.g. benches) • Greenery • Accessibility / lot of space for pedestrians • Other route is unsafe • Variety • Facilities/destinations along the way (shops, schools, friends/acquaintances) • Other

31. You have indicated that you often walk to Binnenveld / Eng / Rijn. Which route do you usually walk to Binnenveld / Eng / Rijn?	● Draw a route on the map.
32. Why do you take this route to Binnenveld / Eng / Rijn?	● Shortest route ● Beautiful route ● Lot of rest points (e.g. benches) ● Greenery ● Accessibility / lot of space for pedestrians ● Other route is unsafe ● Variety ● Facilities/destinations along the way (shops, schools, friends/acquaintances) ● Other
33. You have specified another facility or reason. Which route do you take to another facility or for another reason?	● Draw a route on the map.
34. Why are you taking this route to another facility or for another reason?	● Shortest route ● Beautiful route ● Lot of rest points (e.g. benches) ● Greenery ● Accessibility / lot of space for pedestrians ● Other route is unsafe ● Variety ● Facilities/destinations along the way (shops, schools, friends/acquaintances) ● Other
35. Are there important connections missing for pedestrians in Wageningen?	● Yes ● No
36. Where are important footpaths currently missing? Or where is it not easy for you to walk at the moment?	● Put a point on the map.
36.1. Can you explain why it is not easy to walk here?	● Open answer
37. Where do you like to run or walk?	● Put a point on the map.
37.1. You have designated a place where you like to walk or walk. Why did you choose this place?	● Space for pedestrians ● Low level of car nuisance ● Low level of bicycle nuisance ● Greenery ● Near the water ● Much to see ● Presence of facilities such as shops,

	restaurants, hotels, and café's. ● Nice place to be ● Accessible for people with a disability ● Traffic is safe ● Social safe place ● I can walk my dog here ● Quiet ● Other
38. Where is it not pleasant to walk?	● Put a point on the map.
38.1 You have designated a place where you do not like to walk or walk. Why did you choose this place?	● Little space for pedestrians ● There is no sidewalk, or the sidewalk is poorly maintained ● Nuisance from car traffic ● Nuisance from cyclists or bicycles ● No greenery ● Bad air quality ● Little to see ● Few facilities such as restaurants and shops ● Not accessible for people with mobility problems or poor vision ● You cannot cross the road properly here ● Noisy ● Traffic unsafe place ● Not a pleasant place to be ● Socially unsafe place ● I cannot walk my dog here ● Other
39. Do you (ever) use aids while walking? (e.g. a walking stick or a rollator)	● Yes ● No
40. Why do you walk?	● Shortest travel time ● I do not have another mode of transportation ● Health ● Fun ● Other
41. Why do you like walking here?	● Accessible ● Lot of greenery ● Quiet ● Busy ● Lot of traffic ● Low amount of traffic ● Direct routes ● Lot of rest points ● Near the water ● Presence facilities ● Much to see

	• Presence lighting (social safety) • I can walk my dog here • Nice place to be • Other
42. What can the municipality of Wageningen do to improve walking in Wageningen?	• Widening the footpaths • Build more footpaths • Better maintain footpaths • Promote walking as a mode of transport • Adding signs for pedestrians • No idea / no improvements needed • Other
43. Do you have a nice story about walking in Wageningen that you would like to share with us? We would like to hear it!	• Open answer
44. How do you rate walking in Wageningen?	• 1 • 2 • 3 • 4 • 5 • 6 • 7 • 8 • 9 • 10

Tables

Table 9.1: Chi-square-goodness-of-fit test representativity analysis on age categories

Chi-square	251,582[a]
df	6
Significance	<0.001

a. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 16.8.

Table 9.2: Chi square test of age categories and recreational facilities

Chi-square	45.606[a]
df	5
Significance	<0.001

a. 2 cells (16.7%) have expected frequencies less than 5. The minimum expected cell frequency is 2.52.

Table 9.3: Chi square test of age categories and educational facilities

Chi-square	18.226[a]
df	5
Significance	0.003

a. 3 cells (25.0%) have expected frequencies less than 5. The minimum expected cell frequency is 1.87.

Table 9.4: Chi square test of age categories and work

Chi-square	28.254[a]
df	5
Significance	<0.001

a. 2 cells (16.7%) have expected frequencies less than 5. The minimum expected cell frequency is 2.65.

Table 9.5: Chi square test of route choices and age

Chi-square	28.257[a]
df	15
Significance	0.020

Table 9.6: Descriptive statistics route preferences of respondents in Wageningen

Route factor	N	Abs.	%	Std. Deviation	Minimum	Maximum
Shortest route	465	628	32.95	0.938	0	3
Beautiful route	465	494	25.92	0.925	0	3
Prescence of rest points	465	7	0.37	0.122	0	1

Greenery	465	308	16.16	0.846	0	3
Accessibility	465	178	9.34	0.740	0	3
Other route is unsafe	465	22	1.15	0.290	0	3
Variety	465	213	11.18	0.748	0	3
Facilities on the route	465	56	2.94	0.397	0	3
Multi-response	465	1906	100			

Table 9.7: Test statistics of a Kruskal-Wallis H test on route choices and age categories

Route factor	Kruskal-Wallis H	df	Asymp. Sig.
Shortest route	8.079	5	0.152
Beautiful route	9.481	5	0.091*
Prescence of rest points	1.629	5	0.898
Greenery	11.365	5	0.045**
Accessibility	12.860	5	0.025**
Other route is unsafe	22.228	5	<0.001***
Variety	14.662	5	0.012**
Facilities on the route	6.176	5	0.289

*p < 0.1; **p < 0.05; ***p < 0.01.

Table 9.8: Test statistics improvement ideas walking in Wageningen

Improvement idea	Kruskal-Wallis H	df	Asymp. Sig.
Better maintain footpaths	15.731***	5	0.008
Build more footpaths	4.430	5	0.489
Promote walking as a mode of transport	5.605	5	0.347
Widening the footpaths	12.461**	5	0.029
No idea / no improvements needed	6.425	5	0.267
Adding signs for pedestrians	1.230	5	0.942

*p < 0.1; **p < 0.05; ***p < 0.01.

Table 9.9: Are there important connections missing for pedestrians in Wageningen?

Age category	Yes	No	N

	Abs.	%	Abs.	%	
18-29 years	10	33.33	20	66.67	30
30-39 years	39	58.21	28	41.79	67
40-49 years	39	43.33	51	56.67	90
50-59 years	58	50	58	50	116
60-69 years	38	37.25	64	62.75	102
70 years or older	20	39.22	31	60.78	51
Total	204	44.74	252	55.26	456

Table 9.10: Test of homogeneity of variances Route choice with Age categories

Based on mean	Levene Statistic	df1	df2	Sig.
Shortest route	0.843	5	459	0.520
Beautifull route	1.972	5	459	0.082
Lot of rest points	1.312	5	459	0.258
Greenery	2.069	5	459	0.068
Accessibility	6.648	5	459	<0.001
Other route is unsafe	19.227		459	<0.001
Variety	10.655	5	459	<0.001
Facilities on the route	4.662	5	459	<0.001

Table 9.11: Tests of Homogeneity of Variances Walkability grade with Age categories

Based on mean	Levene Statistic	df1	df2	Sig.
Walkability grade	2.370	5	459	0.039

Table 9.12: Descriptive statistics walkability grade Wageningen per age group

	Mean	Std. Deviation	Minimum	Maximum	Range	N
18-29 years	7.6	1.351	2	9	7	30
30-39 years	6.7	1.723	1	10	9	68
40-49 years	7.5	1.202	3	10	7	90
50-59 years	7.0	1.546	1	10	9	119
60-69 years	7.4	1.062	3	10	7	104
70 years or older	7.2	1.538	1	10	9	54
Total	7.2	1.425	1	10	9	465

Table 9.13: Kruskal-Wallis H Test Statistics Walkability grade per age group

	Walkability grade
Kruskal-Wallis H	16.839
df	5
Asymp. Sig.	0.005