The influence of the mix of modalities on the walking safety of older adults in Zwolle, Groningen, and Utrecht.

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Abstract

This study examines the perception of pedestrian safety of older adults in Utrecht, Groningen, and Zwolle. Walking and cycling are the most sustainable modes of transportation, hence spatial planners are enthusiastic about the re-implementation of these active transportation modes in the Dutch built environment. Due to over-crowdedness, some cities already face the first drawbacks of their success. The research question of this study is the following: “What is the perception of older adults regarding the current mix of modalities on pedestrian safety in Dutch inner cities?”. The data is collected among individuals aged ≥65 (N=105) via a Likert survey. An analysis is conducted separately for the three different cities, mobility levels, and age groups. The results show that the variables age; physical mobility; and behavior of other road users influence the walking behavior. The latter is considered an issue, as many citizens violate traffic laws, thereby increasing the perception of risk. Besides these aspects, results show that older adults perceive the city as ‘too crowded’ and visit the inner city at different time slots. Overall, we can say that some do avoid or limit the number of visits to the inner city due to the amount of traffic, but this is not the case for every older adult. Most are in favor of increasing the number of pedestrian zones with ‘bicycle as a guest’, to increase safety. However, the group is too diverse for the generalization of perceptions and solutions. A suggestion for future research would be to investigate how to implement safe pedestrian zones in which cycling is allowed, without needing time regimes.

Table of Contents

1. Introduction

1.1: Background

Walking and cycling are considered the sustainable methods of transportation for short journeys, due to their consumption of space, environmental impact, and contribution to physical activity. But most importantly, it is accessible to everyone (Emanuel et al., 2020). In the past century, the built environment transformed to become car-friendly, this was the desire at that time. Nowadays, we are aware of the negative consequences. Mass use of cars imposes substantial costs on the economic, social, and environmental front (Rli & EEAC, 2012). This all decreases the liveability of our living environment. Spatial planners express enthusiasm for the re-introduction of active transportation modes in the Dutch built environment, as this is beneficial for society (Brunlett and Bruntlett, 2018; Pooley et al., 2013). Active transportation in this study is human-powered mobility.

The Dutch story has spread and is now commonly considered an example (Brunlett and Bruntlett, 2018). However, some cities begin to experience the first drawbacks of their success. The inner cities become overcrowded with pedestrians and cyclists who often share the same spaces. The current mix of modalities could deter less-mobile citizens from visiting the inner city (Schepers et al., 2017; Bonem et al., 2015; Aceves-González et al., 2020).

Dutch cities continue to grow in size and traffic participants. Simultaneously, their population is aging, a phenomenon experienced in many countries. The Dutch share of older adults ≥65 increased by 7% in 30 years (CBS, 2022). The current literature on the perception of safety and its relationship to walking behavior for older adults is limited, especially in the context of Dutch cities. This gap presents challenges for the planning field. The implemented policies are directed at improving active mobility but overlook the associated subjective risks for society. For older adults, walking is essential for the prevention of chronic diseases and their favorite physical activity (Szanton et al., 2015). Therefore, a road toward truly sustainable transport should thus require acknowledging that well-intended interventions could also negatively impact vulnerable groups (Rod et al., 2023). By taking a different perspective, we could make the inner city a place for everyone.

1.2: Research aim & questions

The aim of this research is to document the gap in the literature for the cities of Utrecht, Zwolle, and Groningen. The main research question is the following: “What is the perception of older adults regarding the current mix of modalities on pedestrian safety in Dutch inner cities?”. The main question will be addressed through two secondary questions: (1) *“Do older adults avoid the inner city due to the amount of traffic?*” and (2) *“What policy recommendations would older adults propose to improve the perception of pedestrian safety?”.*

1.3: Hypothesis

It is hypothesized that, a negative perception regarding pedestrian safety due to the current mix of modalities negatively influences the walking behavior of older adults.

1.4: Structure of the thesis

In chapter two, an introduction to the case cities is made. Their history, current policies, issues, and visions are highlighted. In the third chapter, the theoretical framework regarding pedestrian safety is discussed. The framework delves into the relationship between the built environment, the objective, and subjective safety. This is followed by the methodology of the research which goes into the research design, study population, data collection, and data analysis. In the fifth chapter, the results from the survey and literature research are explained and compared to the theory. The research questions are answered in the conclusion and a suggestion for future research is made.

2. Context

The Netherlands is unique in mobility. There are more bicycles than humans which are used annually for 4.5 billion trips (Brunlett & Bruntlett, 2018). Therefore, the Netherlands is the cherry on top for some two-wheeled inspiration. Other countries will find a number of critical takeaways, but it is never as simple as copying-and-pasting successful methods. In the remainder of this chapter, the cities of Zwolle, Utrecht, and Groningen will be described. These are also the cities that are used for the cases in this study. The three cities are located across the Netherlands (see Figure 1).

Figure 1: The cities of Groningen (top), Zwolle (middle), and Utrecht (bottom).

2.1 Zwolle

Zwolle is the city with the highest cycling rate in the world, the second national rail hub, and has excellent car accessibility (Gemeente Zwolle, 2019). The city is located between the north and the Randstad, making it a popular location. Consequently, the city plans to build 3,000 new homes in the inner city, resulting in 15,000 additional traffic movements each day (Gemeente Zwolle, 2019). The city stimulates and facilitates active transportation modes for short journeys as they value the vitality of their citizens. Hence, the prediction is a vast increase in the number of cyclists, mainly during rush hour. Inevitably this will lead to negative consequences for less-mobile citizens. At the same time, the city strives to be an inclusive city where thinking about accessibility for the less mobile is nothing out of the ordinary. The city designs its new infrastructure with an aging population in mind. The creation of *comfort routes* near important facilities allows disabled persons and residents with poor mobility to remain autonomous. In both (re)design of public spaces and new construction projects, the city uses the 'STOP' principle, a sequence where pedestrians and cyclists get priority over public and private transport (Gemeente Zwolle, 2019). Their pedestrian zone is divided into multiple sections, making their historic inner city almost one big pedestrian zone (see Figure 2). There are three sections: (1) you can always cycle; (2) only cycle between 22h-12h; (3) cycling is strictly prohibited. Unfortunately, many cyclists ignore the signage, creating conflicts between the different modes of slow traffic. The city acknowledges the problems. With taking a communicative approach, the city tries to improve the situation.

Figure 2: The historic inner city of Zwolle with the different pedestrian zones (source: Gemeente Zwolle, 2023)

2.2: Utrecht

The busiest cycling paths can be found in the inner city of Utrecht (Es, 2019). The current situation is not ideal for the pedestrian. According to the municipality, it is due to a combination of factors. The pavements are narrow, full of obstacles, and bumpy. The cycling routes are too busy, bus lanes are considerable barriers, and long waiting times at cycling-priority traffic lights (Gemeente Utrecht, 2021). In the pedestrian zone of the city (see Figure 3), there are issues with the pedestrian spaces. A few examples are: much traffic, containers from companies, parked bicycles & cars, delivery vehicles, terraces, and shop displays (Gemeente Utrecht, 2021). All these issues in combination with the many narrow streets make the pedestrian zone in Utrecht not as friendly as the municipality desires it to be.

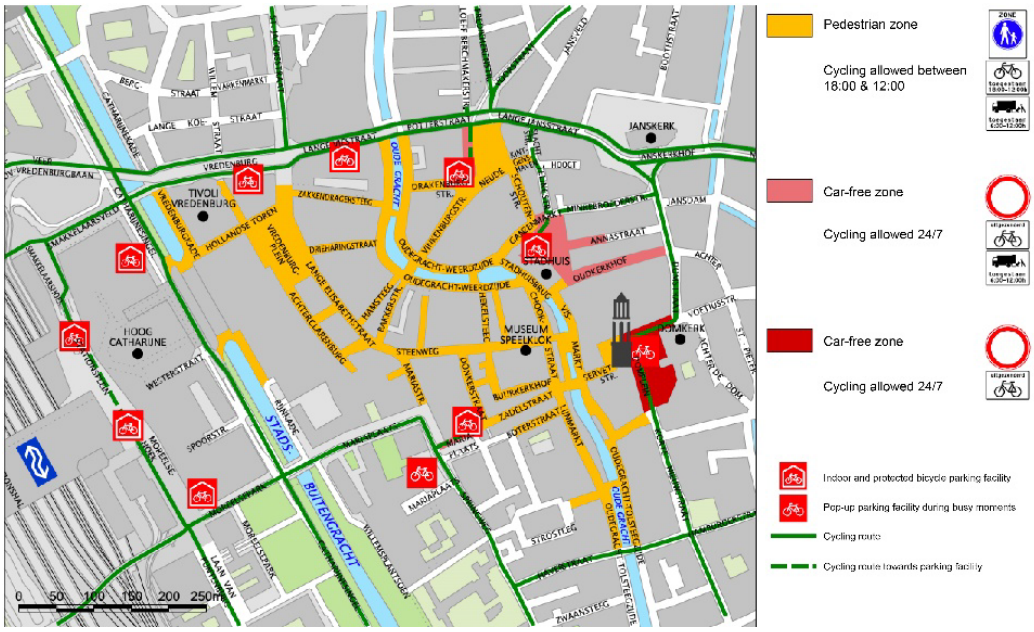

Figure 3: The current pedestrian & car-free zones in Utrecht. Source: www.utrecht.nl. (n.d.).

Utrecht has the ambition to improve accessibility for each citizen. Several adjustments to the built environment are essential to achieve this. The municipality proposed multiple solutions to improve the situation. These are the following: (1) construction of mixed-use in each neighborhood; (2) essential facilities should be accessible by safe and efficient routes, similar to comfort routes in Zwolle ; (3) crossings need modification. Besides these aspects, the city is researching how to implement the bicycle 'as a guest' in the pedestrian zone, whilst taking into account the crowdedness, pedestrian, and social safety (Gemeente Utrecht, 2021). Envisioned for 2040, is that the pedestrian has priority in the inner city and around important facilities. This will be accomplished by enlarging the pedestrian zones.

2.3: Groningen

The success of the cycling policies is becoming a challenge for the city. The overwhelming number of cyclists cause trouble for pedestrians. The bicycles get parked everywhere in the city, taking away much space from pedestrians (Brunlett and Bruntlett, 2018). The municipality acknowledges that the situation is urgent, especially with the awareness that the number of residents is increasing in the coming decades. This makes it inevitable that the crowdedness in the inner city will increase, but the available space will remain the same. Without adjustments, the number of conflicts between cyclists and pedestrians will increase (Gemeente Groningen, 2016). To decrease the number of unsafe situations, the municipality wants to adjust the design of the shopping area, taking into account the primary needs of the pedestrian. The unifying of the multiple pedestrian zones should decrease the number of dangerous crossings (see Figure 4a) (Gemeente Groningen, 2016). The bicycle remains welcome in the shopping streets, but faster attractive routes are created (Main bike route (Figure 4b) for cyclists that do not have a destination in the inner city. The cyclists that do need to be in the inner city are there 'as a guest' in the pedestrian zones. As indicated in Figure 5b, bicycling routes remain straight through the pedestrian zones. This is understandable as there are many activities (e.g. university buildings) in the inner city. Although this is beneficial for the bicycle user, it can be dangerous for pedestrians. The combination of bicycles and pedestrians in the same area creates situations where it is hard to cross the street, decreasing the effectiveness of the pedestrian zone.

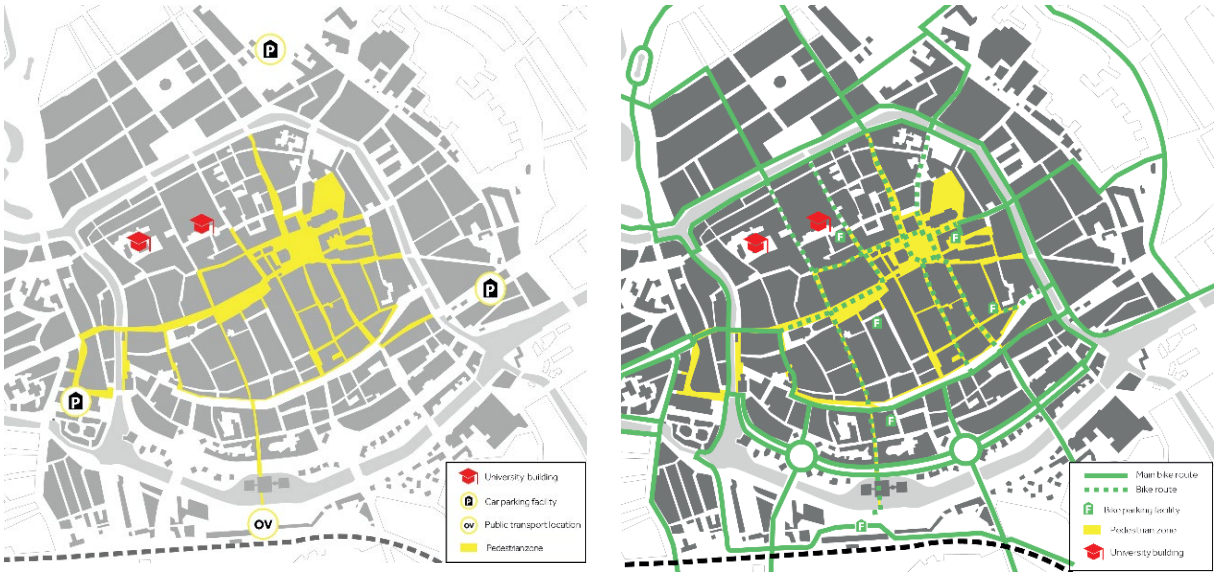

Figure 4a & 4b: Pedestrian zones & cycling routes in the inner city of Groningen. Source: Gemeente Groningen (2016)

2.4: Pedestrian zone policy

The cities all have a pedestrian zone within their inner city. However, there are differences in whether bicycles are allowed or not. Zwolle and Groningen have pedestrian-only streets. However, the largest share of the pedestrian zones has a time regime for the bicycle, this allows cycling in the quiet periods. Utrecht observes that there are drawbacks to this system, because of the diversity of functions at different time stamps. Multiple-time regimes are undesirable as this requires many signs, resulting in large, complicated, and unreadable signs (utrecht.bestuurlijkeinformatie.nl., n.d.). Zwolle has multiple time regimes in their inner city. The city of Groningen tries to influence the behavior of its citizens via the usage of yellow stones, which should contribute to a calm and recognizable streetscape (Gemeente Groningen, n.d.). Although the stones are in pedestrian zones, it does not indicate that you are only allowed to walk.

The cities all have their issues that have a negative effect on the pedestrian. Mainly, the number of cyclists creates dangerous situations. To improve pedestrian friendliness, the cities have different ideas such as pedestrian-only zones, comfort routes, time regimes, and attractive alternative routes for cyclists. The next chapter delves into the theory written about pedestrian safety.

3. Theoretical framework

3.1: The advantages and disadvantages of walkable cities

Recently, the concept of walkability gained popularity in urban and transport planning. Cities with high walkability promote physical activity, reduce per capita emissions and contribute to social interaction between citizens (Liao et al., 2020). For the older adult it is important for their outdoor mobility and their independence, two aspects of healthy aging (Rod et al., 2021). For cities to become sustainable, adjustments in transport are inevitable. This will likely lead to the introduction of policies such as car-lite areas, thereby also stimulating the usage of active modes of transport (Rod et al., 2023). The increased share of bicycles and pedestrians will benefit vulnerable road users as they have a lower crash risk in car-lite areas (Elvik & Goel, 2019). However, pedestrian-friendly policies can have negative consequences. High pedestrian densities disproportionally increase older people's objective and perceived risk (Schepers et al., 2017). As a result, people adjust their walking behavior and deliberately avoid these hotspots.

3.2: Objective and subjective measurements of walkability

Walkability is often measured via objective methods. The existing methods have their limitations regarding the measured indices (Liao et al., 2020). The selection and weight of the variables are based purely on theoretical considerations. Commonly, the measurements take into account several built environmental characteristics to define the walkability. The used variables are density (household & job density), diversity (land-use mix), design (intersection & street density), destination (job accessibility), and distance (to transit) (Liao et al., 2020). Lately, subjective approaches to measuring walkability have received attention. The approaches use the individuals' perception of risk, measured via surveys (Liao et al., 2020). The conventional approach to safety planning emphasizes police crash reports. Recently, transportation professionals recognize the importance of proactively identifying risks (Cho et al., 2009).

In the proactive approach, the individuals' perception of risk provides the valuable information that is desired (Cho et al., 2009). The study of Stahl et al. (2008) identified aspects of the built environment that are perceived as barriers. These are high curbs, narrow sidewalks, uneven surfaces, and a lack of sitting places. The insufficient number of benches prevents older adults from visiting, as they have the desire to be able to sit down and rest, otherwise feeling less safe (Stahl et al., 2008). Given the wide variety of the built environment, measuring the relationship between the aspects and perceived safety is a challenging task. Besides the subjective aspects, the objective characteristics of density and diversity are found to be related to perceived safety (Cho et al., 2009).

3.3: Perceived safety and actual risk

The individual's perception is a crucial determining factor for their walking behavior (Rod et al., 2023). The concept of perceived safety is important in this study. In the paper of Mouratidis (2019, p. 2), the definition is the following: "*an individual's level of comfort and perception of risk within the environment*". In transport planning, safety involves being protected from traffic-related danger, risk, or injury (Basu et al., 2022). Consequently, in this study, the concept of perceived safety is defined as the pedestrian's perceived risk of pedestrian injury within the urban environment. In the remainder of this study, the abbreviation by Rod *et al.* (2023) will be used for the Perceived Risk of Pedestrian Injury (PRPI). It reflects the perception of the actual situation in terms of practices, policies, procedures, routines, and sanctions (Gehlert et al., 2014). This implies that the results are not valid for the road user population at large. The perceptions are influenced by cognitive, affective, and behavioral components. The pedestrians' different experiences may shape their cognitions, emotions, or behaviors toward the traffic in the inner city (Xu et al., 2018).

The perception of risk does not reflect the actual risk of the environment. The research of Cho et al. (2009) investigated the role of the built environment in the relationship between actual and perceived safety. They found that there is an asymmetry between perceived and actual risk of injury. The higher neighborhood density and diversity are positively related to actual risk, while the density was positively associated with perceived risk, and mixed land uses were negatively related to perceived risk (Cho et al., 2009). More interestingly, residents from neighborhoods with mixed land uses were more likely to perceive their environment as safer than residents of neighborhoods dominated by single land uses (residential), but the actual injury risk was higher (Cho et al., 2009). Similarly, more crossings in the built environment may reduce the perceived risk of injury, but they have been associated with an increased police-reported crash rate (actual risk) (Cho et al., 2009).

3.4: The variables influencing perceived safety

Different studies conclude that age is an explanatory variable for risk perception (Bonem et al., 2015). A plausible reason would be that young traffic users (18-29) do not understand traffic risks (Basu et al., 2022). A study by Wang et al. (2023), found that older adults are less functionally fit, they are less likely to walk far from home. This makes them more restricted to their immediate environment in which they perceive more danger, ultimately influencing their walking behavior. Additionally, the road behavior of others in the environment also plays a significant role in risk perception (Aceves-González et al., 2020). The traffic behavior that has an effect is lack of respect, speeding, poor road culture, and violation of traffic rules.

As stressed by Rod et al. (2023), when policymakers do not manage risk perceptions, individuals can decide to avoid walking in 'risky' areas. It is possible also that some individuals continue to use the areas more carefully. (Cho et al., 2009). A second concern mentioned by Rod et al. (2023) is that some groups of pedestrians are more vulnerable to risks than others, leading to an inequitable effect on walking behavior in urban areas.

The relationship between subjective and actual risk of injury delivers an important message with regard to which approach a city should take. A conventional approach such as education or engineering is emphasized when the level of actual risk was higher than the perceived risk, as this indicates individuals' low awareness of crash risk (Cho et al., 2009). Inversely, with a high perceived risk to actual risk, the proactive approach would be suitable. This as individuals tend to avoid, limit, and are more cautious when they perceive the inner city as dangerous. Using only crash data may underestimate the risk of the situation (Cho et al., 2009). In the following chapter, it will be discussed how the perceived safety in the case cities will be investigated.

4. Methodology

In this chapter, the design of the research which is conducted in the three different studies is discussed. The chapter will start by explaining the conceptual framework, the foundation of this study. In the remainder, the measuring of the built environment is explained, along with the data analysis.

4.1: The conceptual framework

In order to address the research questions, a conceptual framework (Figure 5) is used to gain an understanding of the different variables influencing walking behavior. The framework consists of two aspects: (1) the objective walkability and (2) the perceived risk of pedestrian injury (PRPI). To capture the PRPI, three different measurable variables are used. These are the individual's level of mobility (self-assessed), age, and perception of other people's behavior. The built environment aspects are not measured via the survey.

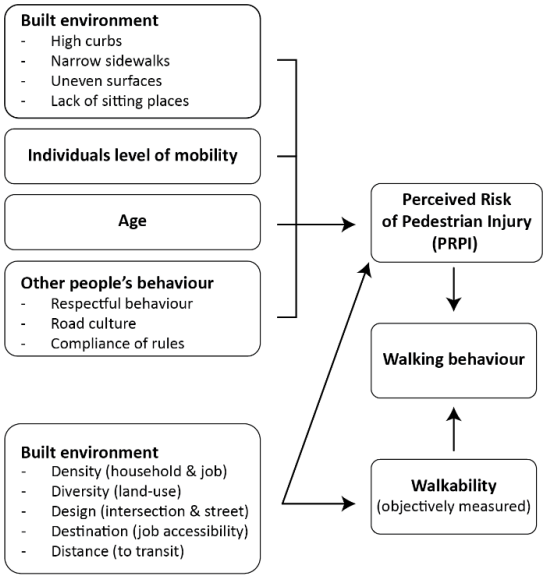

Figure 5: The conceptual framework

4.2: Research method & study population

The study population is diverse in mobility, age, and perceptions of safety. To capture the perceptions of individuals, a qualitative method is a possibility, but due to the diversity, a larger sample would be preferable. For a comparison between the cities, a quantitative method is more suitable. Consequently, the variables will be measured via quantitative data collection, in the form of a Likert survey. This allows the respondents to rate the statements on a five-point scale between 'completely disagree' and 'completely agree'. A survey (see Appendix A) consisting of 2 open questions and 17 statements was created to capture the perception of the population. The variables of age and number of visits are the open questions for analysis purposes. To get sufficient amounts of data in each city, a minimum of 30 respondents is required. The data is collected among individuals aged ≥65. To acquire representative results, individuals of different ages and mobility levels are requested to participate in the study.

4.3: The process of the city selection

This research is conducted in three different Dutch cities with similar built environment and demographic structures, which allows to compare and generalize. The selected cities are Zwolle, Groningen, and Utrecht. The compact built environment of the cities is ideal for the usage of active transportation modes. The importance of active modes is also stressed in the mobility plans of the different cities.

4.4: Quality of data & ethical considerations

The participants are contacted in neighborhoods near the inner city. In Utrecht, some respondents came together in a group for entertainment purposes. To ensure that the data is not biased, the maximum number of one group is 10. The group did consist of individuals of mixed age and mobility levels. Most of the paper surveys are filled in together with the older adult so that the survey is correctly understood and completed according to their perception. Most older adults preferred to have the statements read out for them, for their convenience, or lack of reading spectacles. The participants are not pushed into answering the statements in a certain way. All of the respondents are anonymized and their name is unknown. All of the surveys are given a unique ID and put into an Excel sheet for data analysis.

4.5: Built environment variables

The relationship between the built environment and perceived safety is challenging to measure in ways that are meaningful (Cho et al., 2009). For the purpose of this study, the aspects that influence the PRPI are researched via municipal documents. The variables that mainly impact the objective walkability, the scores of Liao et al. (2020) are used (Appendix C). In their research, the variables are divided into four parts: density variables, facilities variables, green space variables, and land use mix variables.

Due to the complexity of the relationship between the built environment and perceived risk, it is decided not to ask many specific questions to the participants about their perceptions of built environment characteristics.

4.6: Data analysis

Descriptive statistics (i.e. mean) are used to summarize the purely quantitative variables such as age and number of visits to the inner city. The results received via the Likert scale are summarized in percentages via Microsoft Excel. The age distribution is analyzed via SPSS and compared to the normal curve.

5. Results

In this chapter, the results from the survey will be discussed and compared to the theory. The objective of this research is to document the gap in the perception of pedestrian safety among older adults in three different Dutch cities. The aim is to find an answer to the main research question: "What is the perception of older adults regarding the current mix of modalities on pedestrian safety in Dutch inner cities?". Besides this, the two secondary questions will be addressed. The secondary questions are: (1) *"Do older adults avoid the inner city due to the amount of traffic?*" and (2) *"What policy recommendations would older adults propose to improve the perception of pedestrian safety?".*

5.1: Sample composition

The analytical sample comprised 105 respondents (N=105). Of these, 29% lived in Groningen, 30% in Zwolle, and 41% in Utrecht. There are two clusters in the sample around the ages of 70 and 80 years old (see Figure 6, top left). The mean age of the sample is 74.7 years old. The different cities show differences in age composition, with Utrecht having the largest and oldest sample. In Utrecht, 32% of the sample is between 80-85 years old, whereas this is 20%, and 13% for the other cities (see Appendix B). The sample of Zwolle is the opposite, as the sample consists of 42% of individuals between 65-70.

The distribution of the sample in Utrecht and Zwolle can have implications for the results. The theory described that age has an influence on the perceptions of traffic safety and on walking behavior (Wang et al., 2023; Bonem et al., 2015). This makes it likely that a younger sample will give more positive results. Simultaneously, there is a low number of participants between the ages 75-80, at around 13% on average per city. As this will have an impact on the results, we should be careful with the interpretation of it. When the results are divided per city, an average is given to limit the bias of the sample distribution of specific cities.

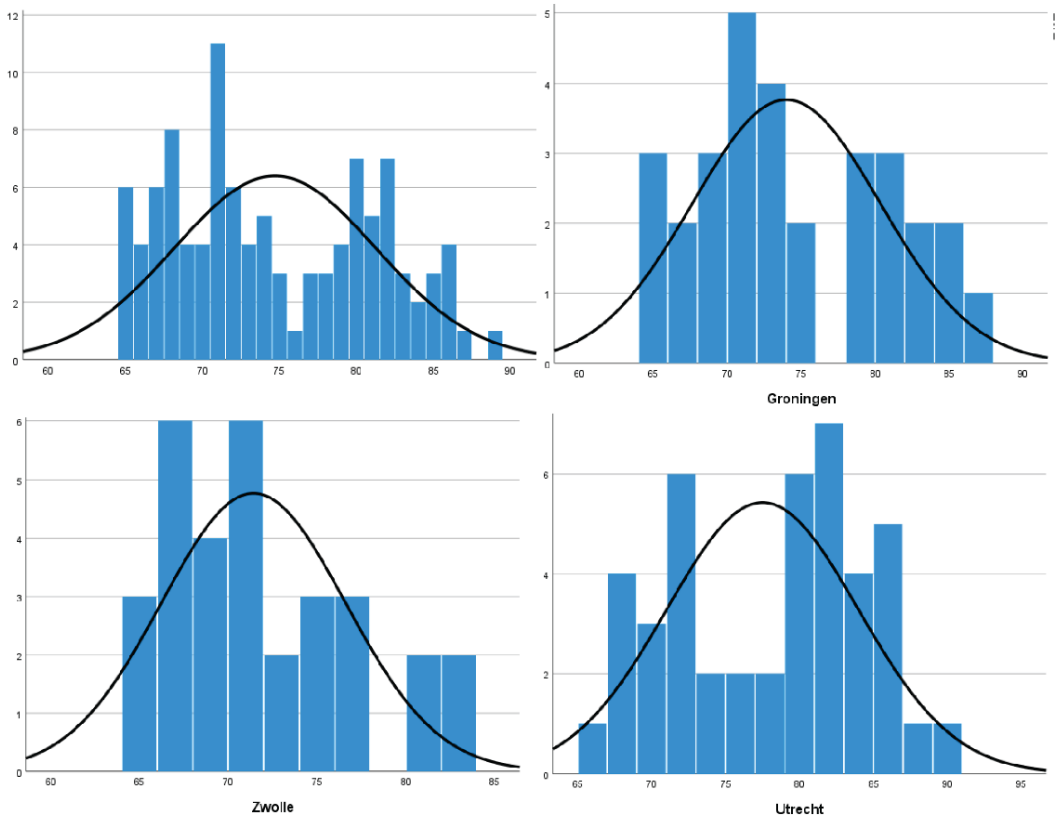

Figure 6: The age distribution of the sample

5.2: age

The study by Wang et al. (2023) found that with age, individuals become less functionally fit, resulting in fewer visits to the inner city. The sample shows that there are differences in the number of visits between age groups (Figure 7). The youngest category visits the inner city on average 2.85 times a week, gradually decreasing to 0.5 times. Therefore, age is an explanatory variable for the number of visits and likely also walking behavior. This relationship confirms the findings from the literature. A study conducted by Bonem et al. (2015) concluded that age is a significant explanatory variable for the perception of risk. In Groningen and Utrecht, the findings correspond with the literature (see Figure 8). Zwolle is an exception to the theory, although there is an increase in the number of 'neutral' answers, but nobody disagreed with the statement. The sample size of 80-85 in Zwolle is small with 4 respondents and the category 85-90 is missing. Due to this limited amount of data, it is difficult to argue that Zwolle is perceived as safer for adults >80. For the category <80, the sample is more positive with the statement, when compared to Utrecht and Groningen.

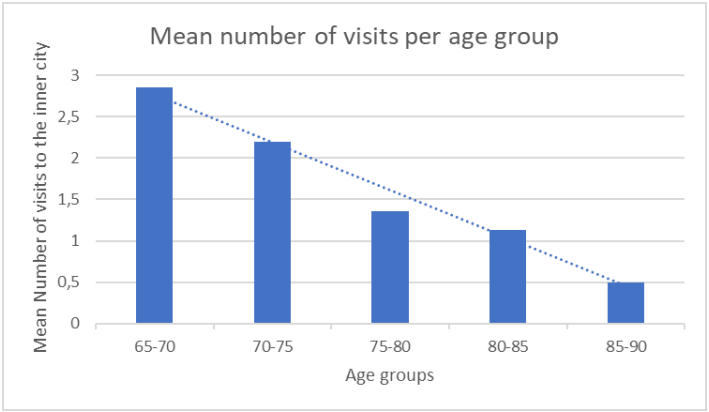

Figure 7: The age and number of visits

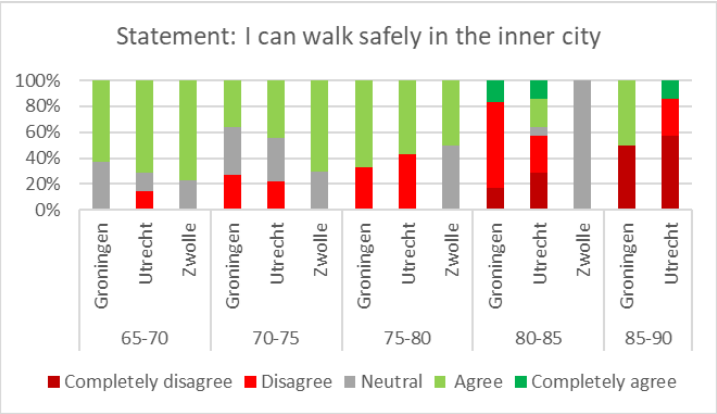

Figure 8: Age and perceived walking safety

5.3: Self-assessed mobility

The first statement that was scalable is *"I can move myself smoothly as a pedestrian"*, thereby self-assessing their mobility level. The results are as follows: 9.5% responded *completely disagree*, 20% *disagreed*, 14% *neutral*, 37% *agreed*, and 19% *completely agreed* with the statement. Individuals indicating a higher self-assessed mobility level tend to visit the inner city more (see Figure 9). The individuals indicating their mobility as poor ('completely disagree'), rarely visit the inner city. These results are as expected, and confirm findings from the literature.

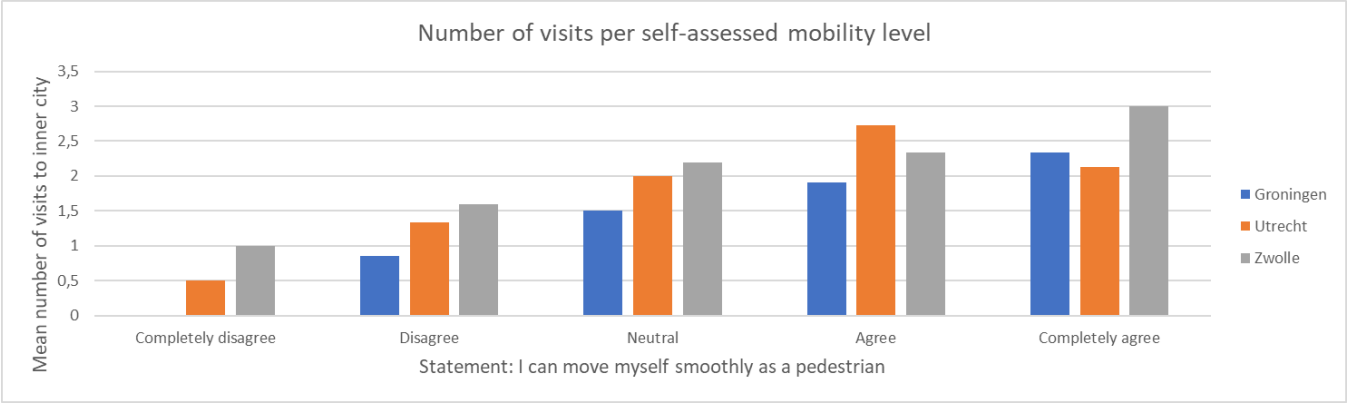

Figure 9: self-assessed mobility level and number of visits to the inner city

5.4: Behaviour of others

The third variable that influences the PRPI for older adults is the behavior of other road users. Most traffic rules are standardized in the Netherlands, such as crossings or traffic lights (excluding Groningen's four-way green for cyclists). Besides these rules, cities can have specific ones. For instance, roundabouts that give priority to cyclists over cars or time regimes in the pedestrian zone. It was not surveyed which rules are violated, making it difficult to evaluate this.

To capture the perception of this variable two statements are used: (1)"*The other road users sufficiently adhere to the traffic rules in the inner city*", and (2) "*The other road users take my reduced mobility into account*".

The results from statement one are mostly negative (see Figure 10). On average 53% disagreed, and even 25% completely disagreed. Hardly any differences can be detected between the cities, indicating that the violation of traffic rules is a widespread problem, at least this is the perception. Zwolle has unique rules in their inner city, it seems not to matter. The violation of rules is an important variable influencing walking behavior (Aceves-González et al., 2020).

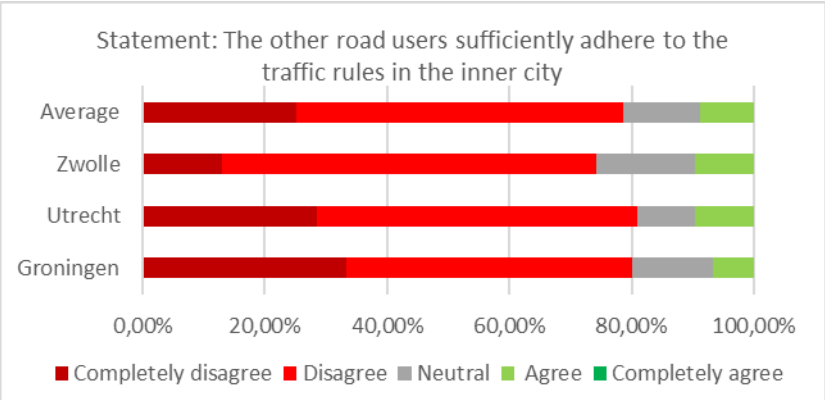

Figure 10: Results statement "*The other road users sufficiently adhere to the traffic rules in the inner city*".

The results of statement two are displayed in Figure 11. On the x-axis, the self-assessed mobility levels. The individuals who responded *disagree* or *completely disagree* are included, as they see their mobility as reduced or poor. On the y-axis, the count is divided by the two mobility levels. The results indicate that other road users do not take others' decreased mobility into account. There is one participant from Utrecht who responded *completely agree.* This could be because it is visible that the individual struggles with their mobility, for instance, due to the usage of a mobility scooter. Improving the behavior towards the less mobile would increase the perception of safety, making the city more inviting for the less-mobile citizens.

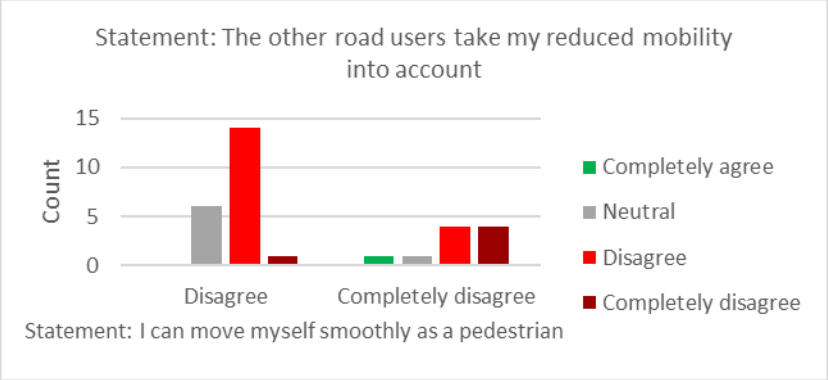

Figure 11: Results statement "*The other road users take my reduced mobility into account*"

5.5: Busyness and avoidance of the inner city

Within the introduction and context, it is discussed that Dutch cities seem to become overcrowded. To determine the perception of the older adult, the following statement was surveyed: *"It's too crowded for me in the inner city"*. Approximately 75% responded agreed or completely agreed with the statement (see Figure 12). This can thus be interpreted as something negative. There seem not be differences between the cities. the statement (see Figure 12). This can thus be interpreted as something negative. There seem not be differences between the cities.

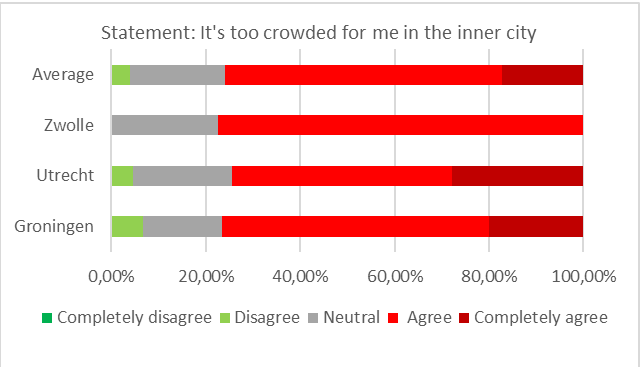

Figure 12: Results statement: *"It's too crowded for me in the inner city".* (*NOTE: the colors are reversed compared to most other statements, as this is perceived as negative)*

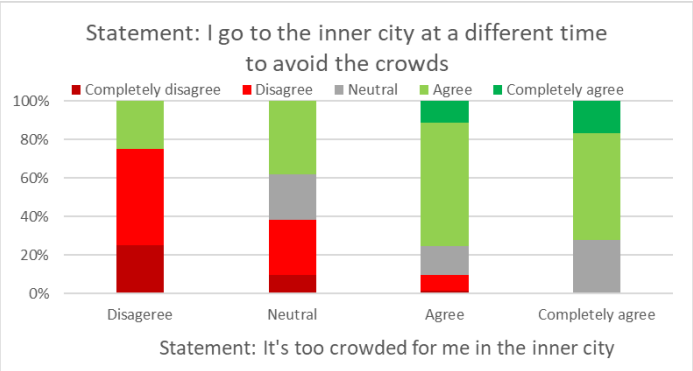

Figure 13: Results statement: "*I go to the inner city at a different time to avoid the crowds*". Answers are divided based on the answer to the statement about the perception of crowdedness

Figure 13 uses the results from the previous statement on the x-axis. The results show that people who perceive the city as 'too crowded' (agree / completely agree) tend to visit the city at time slots that are quieter, indicated with green. These are moments in the morning or at the beginning of the week. The literature describes that high pedestrian densities increase objective and perceived risk of injury, therefore it is expected that older adults try to avoid crowded moments (Schepers et al., 2017).

To determine whether the inner city is avoided due to the number of other road users, the figure below is created (see Figure 14). The results are mixed. In Groningen and Utrecht, the share of people that disagree is as large as the group that agrees. Remarkably, in Zwolle nearly a third indicated neutral. This could be because of the pedestrian zones that hardly allow bicycles. Overall, we can say that some people do avoid or limit the number of visits to the inner city due to the amount of traffic, but this is not the case for every older adult.

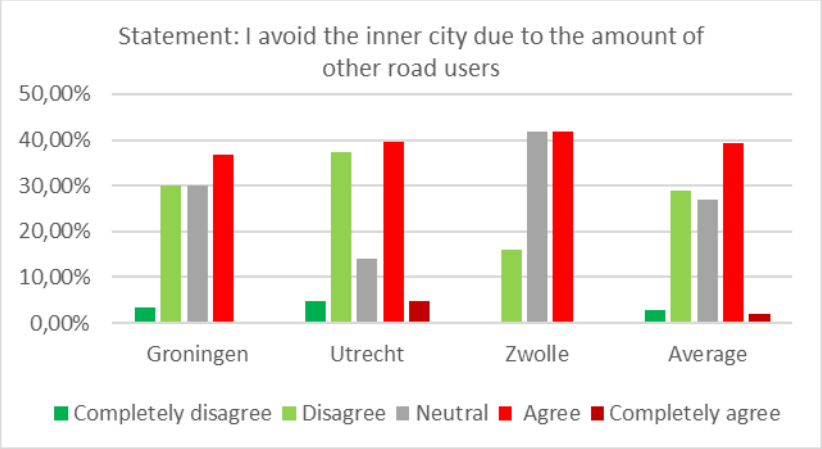

Figure 14: Results statement: "*I avoid the inner city due to the amount of other road users*". Answers are divided by city.

(*NOTE: the colors are reversed compared to most other statements, as this is perceived as negative)*

5.6: Built environment

The research of (Liao et al., 2020) shows that the three different Dutch cities score 'high' on objective walkability (see Appendix C). This is the case for most cities in the country. The objective measurements do also measure the density and diversity of the built environment. Because of the compact structure of the inner city with much land-use mix, inner cities score high on density and diversity. As described by Cho et al. (2009), density and diversity are positively related to actual risk, while density was positively associated with perceived risk, and diversity is negatively related to perceived risk.

Within chapter 2 (context), it is described how the different cities face issues with high curbs, narrow sidewalks, uneven surfaces, and obstacles. The study of Stahl et al. (2008) explained that these aspects of the built environment have an effect on the PRPI. The municipality of Utrecht described in

their own reports that these aspects desire to be refurbished to improve the walkability of their pedestrian zones. Groningen is actively removing bicycles from the street that are parked in pedestrian spaces, and seen as obstacles. Zwolle aims to have periodic maintenance of its built environment. Together with their residents, they work on solutions to improve the pedestrian infrastructure, in the form of widening paths and removal of obstacles (Gemeente Zwolle, 2019). The cities did not go into sitting places in the inner city. It is the case that these aspects have an effect on the PRPI, but to what extent is unknown.

5.7: Solutions

A bold statement was surveyed. Would the older adult be in favor of banning cyclists in the inner city? The results are mixed. In Utrecht and Groningen, it is clear that this is not a popular statement (see Figure 15). The opposite is true for Zwolle. This is likely because of their pedestrian zones and its complicatedness.

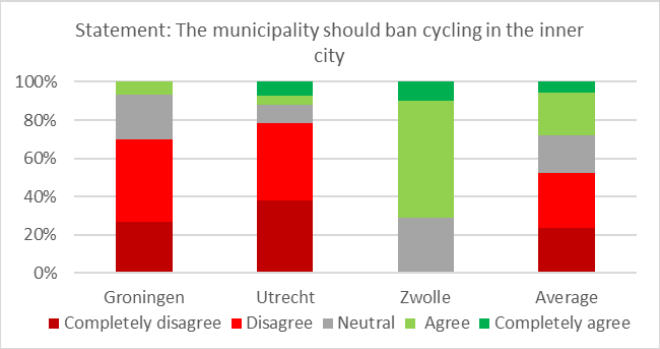

Figure 15: Results statement: *"The municipality should ban cycling in the inner city".*

The last question in the survey is which solution would be most suitable to improve the situation. They had 7 options to choose from, which were solutions taken from the different mobility visions (Gemeente Utrecht, 2021; Gemeente Zwolle, 2019; Gemeente Groningen, 2016), and the seventh option was an open spot where they could bring up their ideas. The options were (a) widening the pedestrian infrastructure; (b) Increasing the amount of mixed-use in neighborhoods; (c) Pedestrian zones in which the bicycle is 'guest'; (d) decreasing the number of barriers (highways, waterways, busy roads); (e) construction of safe crossings; (f) increase the number of law enforcement. The results are discussed per city.

5.7.1: Solutions Groningen

The residents of Groningen see bicycles 'as a guest' in the pedestrian zones (option C) as a viable solution. The widening of infrastructure and building mixed-use are also popular. Therefore, the older adults advise the city to implement a mixture of the options. The implementation of more pedestrian zones does ask for an adjustment in the behavior of cyclists, as this otherwise could have an adverse effect and increase the perception of risk.

5.7.2: Solutions Utrecht

A respondent, 75 years old, is firmly against the implementation of pedestrian zones with bicycles as a 'guest' (option C). Mixing these two modes would be very dangerous according to this respondent. The same individual was in favor of increasing the amount of law enforcement. A different participant, 86 years old, is in favor of option C but would be happier with increasing the enforcement. With a combination of giving stricter fines, the bad behavior could be adjusted. The other respondents are mixed in their opinions, indicating that a mixture of the options would be the preferred solution.

5.7.3: Solutions Zwolle

Zwolle has different answers. Figure 15 showed that the sample is in favor of banning cyclists in their inner city. Of the 31 respondents, 12 proposed to increase the enforcement of the current rules. Currently, the rules in the pedestrian zones are ignored, creating dangerous situations. They hope that this option will change the behavior of cyclists for the better. A few citizens proposed to make their inner city a pedestrian zone where no bicycles are allowed, as is already the case in the most important shopping street, or make the zones more uniform. The solutions are in line with the current practice in Zwolle, and it thus seems that they are rather satisfied, but there is still room for improvement.

The results showed that it is difficult to generalize this age group. Certainly, adults >80 or the less-mobile perceive the inner city as unsafe and avoid or limit their visits. A large share perceives the city as 'too crowded', and is negative about other road users. The group is in favor of creating pedestrian zones in which the bicycle is a guest. Though, there is also a group firmly against this. Zwolle already implemented this practice and is perceived as the safest. However, Zwolle has also issues and they proposed to increase the number of law enforcement. This would likely change the behavior of cyclists, thereby improving the PRPI.

6. Conclusion

This study examines the perception of older adults regarding walking safety. Studies show that objective walkability and perceived risk of pedestrian injury (PRPI) influence walking behavior. The first is measured via the built environment. The scores are 'high' for the case cities. The PRPI is influenced by multiple variables. Age, self-assessed mobility, and other road users' behavior are measured via the survey and are found to influence the PRPI. An increase in age and poor mobility both negatively influence the visits, as is a negative perception of others' behavior. The first sub-question: *"Do older adults avoid the inner city due to the amount of traffic?*" shows mixed results. Some older adults do not avoid the inner city, but others do. Most older adults perceive the inner city as too busy and prefer to visit the inner city at different time slots. To the second sub-question: "*What planning solutions would older adults propose to improve the situation?"* it is impossible to give one solution. The results did show that many older adults are in favor of creating pedestrian zones where the bicycle is a 'guest'. However, some other participants are firmly against this. To answer the main research question: *"What is the perception of older adults regarding the current mix of modalities on pedestrian safety in Dutch inner cities?"*, the perceptions are mixed. A group deliberately avoids the inner city as they fear injury, but others have no problems. Therefore, it is impossible to generalize the group of older adults, likely due to their diversity in age, mobility levels, and experiences in the past.

The strength of this study lies in the ability to compare cities and detect differences and find solutions from other cities, that can be implemented elsewhere. The main weakness of this research is the sample. The city of Zwolle has a relatively young sample, thereby influencing the results. A recommendation to the cities would be to include older adults in the planning processes and discuss their perceptions. From speaking to them, they feel often ignored when they hear about new planning interventions. The city of Zwolle could be taken here as an example. A suggestion for future research would be to investigate how to implement safe pedestrian zones in which cycling is allowed, without having time regimes. This study shows that well-intended planning interventions can have negative impacts on different groups in society.

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Appendix

Appendix A: The survey

Vragenlijst Bachelor Project

Wat is uw leeftijd? _____ Jaar

Hoe vaak bezoekt u per week de binnenstad? _____

Voor de volgende stellingen moet u uw mening aangeven doormiddel van het zetten van een kruisje, waarbij:

- - = Volledig mee oneens
- = Oneens
0 = Neutraal
+ = Mee eens
++ = Volledig mee eens

	- -	-	0	+	+ +
Ik kan mezelf als voetganger vlot voortbewegen					
Ik kan meedoen aan mijn gewenste activiteiten (bijvoorbeeld: winkelen, restaurant bezoeken) in de binnenstad					
Ik kan veilig wandelen in de binnenstad					
De oversteekplekken in de binnenstad zijn goed aangegeven					
De zebrapaden in de binnenstad zijn een veilige plek om over te steken					
De andere weggebruikers houden zich voldoende aan de verkeersregels in de binnenstad					
De gemeente houdt voldoende toezicht op verkeersveiligheid voor voetgangers					
Het is mij te druk in de binnenstad					
Ik ga op een ander tijdstip naar de binnenstad om de drukte te vermijden					
Ik pas de route aan om drukte te vermijden					
Ik pas de route aan om bepaalde kruispunten te vermijden					
Ik vermijd de binnenstad vanwege de hoeveelheid andere weggebruikers					
Ik vermijd de binnenstad vanwege de hoeveelheid fietsers					
De gemeente moet het fietsen in de binnenstad verbieden					
Andere weggebruikers houden rekening met mijn verminderde mobiliteit					

Ik ervaar de meeste hinder van:

Kinderen (0-12 jaar) ◯
Jongeren / studenten (12-25) ◯
Volwassenen (25-65) ◯
Ouderen (65+) ◯

Wat zou volgens u een goede oplossing zijn om de situatie te verbeteren:

a) Verbreden van voetgangersinfrastructuur
b) Functiemenging van wonen, werken en voorzieningen om de drukte in de binnenstad te verminderen
c) De fietser in het voetgangersgebied ‘te gast’
d) Opheffen of verminderen van barrières (grote wegen, trambanen, spoorlijnen, waterwegen)
e) Aanleggen van veilige oversteekplaatsen
f) Vergroting van de handhaving
g) Anders, namelijk:

Appendix B: The results from the survey

	Category	65-70	70-75	75-80	80-85	85-90
Q1 Participation by Age Category	Groningen	26,67%	36,67%	10,00%	20,00%	6,67%
	Utrecht	15,91%	20,45%	15,91%	31,82%	15,91%
	Zwolle	41,94%	32,26%	12,90%	12,90%	0,00%
	Average	26,67%	28,57%	13,33%	22,86%	8,57%

	Count	0	1	2	3	4	5
Q2 Number of visits to the inner city per week	Groningen	0,00%	21,57%	31,37%	47,06%	0,00%	0,00%
	Utrecht	0,00%	14,10%	20,51%	38,46%	20,51%	6,41%
	Zwolle	0,00%	9,09%	45,45%	45,45%	0,00%	0,00%
	Average	0,00%	14,36%	31,79%	43,08%	8,21%	2,56%

		Completely Disagree	Disagree	Neutral	Agree	Completely agree
Q3 I can move myself smoothly as a pedestrian	Groningen	3,33%	23,33%	6,67%	36,67%	30,00%
	Utrecht	13,64%	20,45%	18,18%	29,55%	18,18%
	Zwolle	9,68%	16,13%	16,13%	48,39%	9,68%
	Average	9,52%	20,00%	14,29%	37,14%	19,05%
Q4 I can participate in my desired activities in the inner city	Groningen	3,33%	20,00%	20,00%	43,33%	13,33%
	Utrecht	11,90%	26,19%	16,67%	33,33%	11,90%
	Zwolle	0,00%	0,00%	22,58%	58,06%	19,35%
	Average	5,83%	16,50%	19,42%	43,69%	14,56%
Q5 I can safely walk in the inner city	Groningen	6,67%	40,00%	23,33%	26,67%	3,33%
	Utrecht	18,18%	36,36%	11,36%	27,27%	6,82%
	Zwolle	0,00%	61,29%	38,71%	0,00%	0,00%
	Average	9,52%	44,76%	22,86%	19,05%	3,81%
Q6 The pedestrian crossings in the inner city are well marked	Groningen	0,00%	50,00%	36,67%	10,00%	3,33%
	Utrecht	2,38%	21,43%	35,71%	35,71%	4,76%
	Zwolle	0,00%	19,35%	67,74%	12,90%	0,00%
	Average	0,97%	29,13%	45,63%	21,36%	2,91%
Q7 The pedestrian crossings in the inner city are a safe place to cross	Groningen	0,00%	13,33%	30,00%	56,67%	0,00%
	Utrecht	2,33%	9,30%	23,26%	65,12%	0,00%
	Zwolle	0,00%	9,68%	58,06%	32,26%	0,00%
	Average	0,96%	10,58%	35,58%	52,88%	0,00%
Q8 Other road users sufficiently adhere to traffic rules in the inner city	Groningen	33,33%	46,67%	13,33%	6,67%	0,00%
	Utrecht	28,57%	52,38%	9,52%	9,52%	0,00%
	Zwolle	12,90%	61,29%	16,13%	9,68%	0,00%
	Average	25,24%	53,40%	12,62%	8,74%	0,00%
Q9 The municipality sufficiently supervises pedestrian traffic safety	Groningen	0,00%	43,33%	43,33%	13,33%	0,00%
	Utrecht	4,65%	55,81%	30,23%	6,98%	2,33%
	Zwolle	9,68%	67,74%	22,58%	0,00%	0,00%

	Average	4,81%	55,77%	31,73%	6,73%	0,96%
Q10 It's too crowded for me in the inner city	Groningen	0,00%	6,67%	16,67%	56,67%	20,00%
	Utrecht	0,00%	4,65%	20,93%	46,51%	27,91%
	Zwolle	0,00%	0,00%	22,58%	77,42%	0,00%
	Average	0,00%	3,85%	20,19%	58,65%	17,31%
Q11 I go to the inner city at a different time to avoid the crowds	Groningen	3,33%	16,67%	16,67%	60,00%	3,33%
	Utrecht	6,82%	18,18%	18,18%	52,27%	4,55%
	Zwolle	0,00%	0,00%	19,35%	58,06%	22,58%
	Average	3,81%	12,38%	18,10%	56,19%	9,52%
Q12 I adjust the route to avoid crowds	Groningen	10,00%	43,33%	36,67%	10,00%	0,00%
	Utrecht	12,20%	34,15%	39,02%	12,20%	2,44%
	Zwolle	3,23%	45,16%	45,16%	6,45%	0,00%
	Average	8,82%	40,20%	40,20%	9,80%	0,98%
Q13 I adjust the route to avoid certain intersections	Groningen	13,33%	50,00%	26,67%	10,00%	0,00%
	Utrecht	11,63%	34,88%	34,88%	13,95%	4,65%
	Zwolle	3,23%	61,29%	25,81%	9,68%	0,00%
	Average	9,62%	47,12%	29,81%	11,54%	1,92%
Q14 I avoid the inner city due to the amount of other road users	Groningen	3,33%	30,00%	30,00%	36,67%	0,00%
	Utrecht	4,65%	37,21%	13,95%	39,53%	4,65%
	Zwolle	0,00%	16,13%	41,94%	41,94%	0,00%
	Average	2,88%	28,85%	26,92%	39,42%	1,92%
Q15 I avoid the inner city due to the amount of cyclists	Groningen	3,33%	23,33%	30,00%	43,33%	0,00%
	Utrecht	4,65%	25,58%	16,28%	41,86%	11,63%
	Zwolle	0,00%	12,90%	22,58%	64,52%	0,00%
	Average	2,88%	21,15%	22,12%	49,04%	4,81%
Q16 The municipality should ban cycling in the inner city	Groningen	26,67%	43,33%	23,33%	6,67%	0,00%
	Utrecht	38,10%	40,48%	9,52%	4,76%	7,14%
	Zwolle	0,00%	0,00%	29,03%	61,29%	9,68%
	Average	23,30%	29,13%	19,42%	22,33%	5,83%
Q17 The other road users take my reduced mobility into account	Groningen	6,67%	56,67%	33,33%	3,33%	0,00%
	Utrecht	6,82%	36,36%	40,91%	6,82%	9,09%
	Zwolle	3,23%	35,48%	48,39%	12,90%	0,00%
	Average	5,71%	41,90%	40,95%	7,62%	3,81%

		Students/ Young Adults	Older Adults	Adults
Q18 I experience the most inconvenience from:	Groningen	53,33%	0,00%	46,67%
	Utrecht	60,98%	4,88%	34,15%
	Zwolle	48,39%	0,00%	51,61%
	Average	54,90%	1,96%	43,14%

Appendix C: A walkability score map of the Netherlands

Source: (Liao et al., 2020)