Safer Together

How do Parents Assess Street Safety when Biking with their Children?

Illustration by A. Syvak, n.d.; P. Syvak, n.d.

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Safer Together:

How do Parents Assess Street Safety when Biking with their Children?

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Abstract

The Netherlands has experienced a decline in active school travel over the last decade. This is concerning, considering that active school travel is essential to support children's health and independence. Parents' perceived traffic safety is often linked to children's mobility choices, but there is little knowledge on what factors inform parents' perceived safety in a bike-oriented context. This research employed a combination of literature reviews and interviews with mental maps, to understand what factors influenced parents' perceived traffic safety in a bike-oriented context, like the Netherlands. Overall, this research established a multitude of factors that informed parents' perceived traffic safety. These factors included, but were not limited to, complex crossings, high speed, high traffic volume, type of bike path, type of crossing, and accidents along the route. This research also highlighted that children's characteristics and parents' approach to risk mitigated parents' perception of traffic safety. The results further showed that parents' perception of traffic safety did not solely depend on the factors found along the route, but also on the interplay between factors at any specific location. These findings largely overlapped with the literature, with some important additions, which can be attributed to the bike-oriented context and use of interviews in this study. A key supposition from the study was that parents focused on minimizing the uncertainty along their travel route to feel safe. Hence, they preferred routes where their expectations matched the resulting behavior and where infrastructure elements minimized the consequences of any mistakes their children made. The conclusions in this research should be reconfirmed with a larger sample.

Keywords: *Active School Travel, Perception, Parents, Safety, Children, Mental Mapping*

Preface

Growing up in Norway I biked, walked, and skied to school. However, I never took the car. For me taking the car was not an option, and public transport was so infrequent that biking quickly became my main way of getting anywhere. So much so that I started biking year-round, come sun, rain, and snow.

Thus, when I came across a thesis topic that focused on children biking it seemed like a perfect match. Even more so when a bit of snooping showed that active school travel (e.g. biking and walking) actually is decreasing in the Netherlands. I thought it would be really interesting to understand why something, which to me was a non-negotiable growing up, is now decreasing. I especially wanted to pursue this topic, because for me being allowed to bike alone from a young age gave me independence, confidence, and the flexibility to do the activities I wanted. Therefore, I think it is important to understand why it is decreasing, because I believe that we should support children's ability to bike independently as much as possible.

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Glossary

Active Mobility/Active Transport: Active mobility refers to mobility modes which require the user to be in physical activity when traveling with the mode. For example, bikes, walking, and kick scooters. They often promote various health benefits. (Masoumi et al., 2020)

Active School Travel: This term refers to the use of active mobility when traveling to school. Most literature specifically focuses on walking and biking. (Van Den Berg et al., 2020)

Independent Mobility: Independent mobility is mostly used in the context of children. In this case it refers to the affordance/ability for children to travel on their own without parental/adult supervision. (Nevelsteen et al., 2012)

Perceived Traffic Risk/Safety: This is a subjective measurement which considers how a person evaluates a specific location based on their interpretation. Generally, this will include a variety of factors beyond accidents, such as built environment, personal demographics, traffic flow etc. (Lam, 2001). In this research perceived traffic risk and perceived traffic safety are used as equal opposites. Thus, reducing safety and increasing risk are considered the same.

Real Traffic Risk: Generally, defined slightly differently by various government bodies. However, it consistently focuses on the number of registered accidents and fatalities at a specific location. (Nevelsteen et al., 2012)

Road Actors/Users: For this research the term road actors simply refer to any other mode which uses the road. It is therefore a catch term for cars, bikes, mopeds, buses, delivery trucks etc.

Interaction Factors: For this research interaction factors refer to factors which impact parents' perceived traffic safety and relate to interactions with and the behavior of other road users. Accordingly, they include aspects of traffic which moves beyond the infrastructure and to the users.

Built environment factors: For this research, built environment factors refer to factors which impact parents' perceived traffic safety and relate to the physical infrastructure which forms the traffic situation. Thus, they include anything physical including bike paths, crossing design etc.

Bike-oriented Context: For this report this entails a context which actively focuses on developing biking infrastructure and promoting biking as a main mode of transport. Since the 80s urban areas in the Netherlands have followed such an ambition. It is important to note that this is not equivalent to no cars being present.

Fat bikes: For this research fat bike encompasses a specific type of electric bike which generally is characterized by small thicker wheels and a sturdy more rugged design.

1 Introduction

In 2023, only 60% of Dutch children between 4 and 11 years of age achieved the recommended 60 minutes of moderate activity per day (Rijksinstituut voor Volksgezondheid en Milieu Ministerie van Volksgezondheid, Welzijn en Sport, n.d.). Moreover, several studies found that active school travel for children in the Netherlands has been decreasing in the last few years (Macedo et al., 2023; Van Den Berg et al., 2020). Active school travel (AST) refers to the use of bike or walking to go to school (Katsavounidou et al., 2024; Van Den Berg et al., 2020; Vasey et al., 2022). AST is associated with numerous health and developmental benefits. First, AST supports an active lifestyle, which can reduce childhood obesity and other systemic health complications (Nyström et al., 2023; Torres et al., 2022; Vasey et al., 2022; Wangzom et al., 2023). Secondly, AST encourages independent mobility in children (Amiour et al., 2022; Macedo et al., 2023). Giving children more independence from a younger age is linked with increased confidence, higher connection to the neighborhood, and improved ability to negotiate risks (Amiour et al., 2022). Lastly, being active at a young age also positively influences activity levels later in life (Mercê et al., 2021). Because of the above-mentioned reasons, how to encourage AST is crucial to improve the overall wellbeing of children.

The current AST trajectory might be surprising considering that, since the 80s most Dutch urban areas have actively promoted biking and biking infrastructure (Buiter, 2015; Cluster Stedelijke Ontwikkeling, 2020). These ambitions include implementing e.g. car-free city centers, 30km/h zones, and separate bike paths (Gemeente Amsterdam, n.d.; Gemeente Leiden, n.d.). These initiatives have led to a bike-oriented context, where biking is a common travel mode in many Dutch urban areas (te Brömmelstroet et al., 2020). Though it does not mean that cars and other motorized vehicles are removed from the roads (Macedo et al., 2023; Van Den Berg et al., 2020).

While several factors influence the prevalence of AST, past research shows that one important component is parents' perception of traffic safety on the roads their children travel (Amiour et al., 2022; Lam, 2001; Siiba et al., 2025; Vasey et al., 2022; Wangzom et al., 2023). Perceived safety is central to travel choice, because it reflects how someone subjectively evaluates a situation (Amiour et al., 2022). Moreover, children depend on their parents' permission to travel, making parents' perspective especially important when considering AST.

As elaborated on in the literature review (Section 4.1), while there is already extensive research on the traffic safety perception of parents globally, research on the topic in the Netherlands is limited. The global studies introduced find that parents' perception of traffic safety largely depends on the built environment, demographics, direct social environment, and the traffic structure itself (Amiour et al., 2022; Lam, 2001; Siiba et al., 2025; Wangzom et al., 2023). Some relevant factors include traffic lights, designated infrastructure, speed and complexity of traffic, and controlled crossings (Amiour et al., 2022; Macedo et al., 2023; Nevelsteen et al., 2012; Rothman et al., 2015). However, there is much less research on parents' perception in the

Dutch, bike-oriented context, and the existing studies predominantly use quantitative research methods and focus on the built environment (Macedo et al., 2023; Van Den Berg et al., 2020).

Overall, most of the relevant studies identifying factors influencing parents' perceived traffic safety originate in countries where many cities do not prioritize biking, as well as biking infrastructure (e.g. Canada, Australia, USA, UK, Peru, and Chile) (Amiour et al., 2022). Since, cultural norms inform mobility behavior, there is a need for knowledge specific to contexts which already prioritizes biking in its design, like the Netherlands (Masoumi et al., 2020). Moreover, current studies in the Netherlands focus predominantly on quantitative data collection methods, hence there is a need for complementary in-depth knowledge through qualitative research methods.

Consequently, while there is considerable global work on how parents' perceived traffic safety is formed, the understanding of what this looks like in a bike-oriented context, such as the Netherlands, is limited.

1.1 Research Objective

This research aims to understand what factors inform parents' perception of traffic safety to mitigate current AST trends. This study will use a qualitative research approach, which allows for more flexibility in understanding what factors parents consider and why. The goals of the research include the following. First, to determine what factors parents value/prioritize/avoid when engaging in active mobility with their children. Second, understand how these factors impact parents' perception of traffic safety, and whether the combination of factors play a role in perceived safety. By providing evidence on the "what" and "how", this study attempts to outline potential mechanisms behind parents' perception of safety and thereby contribute to the understanding on how to encourage more AST amongst children.

1.2 Research Questions

In alignment with the research objective (Section 1.1), the following research questions will be addressed in this research:

What factors influence parents' perception of traffic safety when engaging in active mobility with their children within a bike-oriented context?

SRQ1. What factors identified in previous research have been found to influence parental perception of traffic safety when engaging in active school travel?

SRQ2. What factors do parents identify which influencing their perceived traffic safety along children's commuting routes?

SRQ3. Does the interplay of factors in a specific location along children's commuting routes alter parents' perceived traffic safety?

1.3 Scope

To ensure a similar cultural mobility context across all participants, this research will focus on urban areas in the Netherlands. Most urban areas in the Netherlands share a bike first ambition and policy (Buiter, 2015; Cluster Stedelijke Ontwikkeling, 2020; Gemeente Amsterdam, n.d.). Several cities have and are implementing infrastructure favoring bikes, including car-free city centers, 30km/h zones, and separate bike paths (Gemeente Amsterdam, n.d.; Gemeente Leiden, n.d.). As such, this allows for a relatively similar social context across all cities regarding biking culture.

This research focuses on school travel for three main reasons. School travel is a daily commuting pattern with a consistent route and timing, and hence something parents can actively make decisions about. School travel also occurs daily and thus provides an opportunity for consistent exercise for the children. Lastly, because it is a daily commute, parents have a large set of experience and knowledge to pull from when discussing their routes.

The focus is on children who are still accompanied by their parents, since parents then have the largest influence on the travel choices made. From other papers and observation this is likely primary school, group 2 through 8 (approximately 4 to 12 years old) (Molina-García et al., 2025; Siiba, 2021). Additional details about the participants can be found in Section 4.2.1.

Note that the travel mode chosen to commute remains open to cover a broader set of experiences. Parents that currently do not opt for active mobility might still describe important traffic factors which determine their choice. Also, some leeway is given for reference to other consistent commuting routes, e.g. after-school activities, since the factors described there would also be relevant if they appear on a school route.

2 Theoretical Foundation

This research relies on the PASTA (Physical Activity through Sustainable Transport Approaches) framework to provide an overview of what factors can impact active mobility choices (Section 2.1). However, parents' safety perception and AST are currently not explicit in the PASTA framework. As such, based on literature, this research alters the PASTA framework to visualize the variables and connections which are most important to parents' perceived traffic safety and AST (Section 2.2).

2.1 The Mobility Model

This research relies on the PASTA framework to visualize what factors influence active mobility and where parents' perception of traffic risk fits into this system. The PASTA model outlines broadly how active mobility choices can be made. The utility of the PASTA model, as well as a detailed overview, is provided in the following sections.

2.1.1 Utility of the PASTA Model

The PASTA framework is used in this research because it focuses on personal choice, includes external factors, provides a visual summary specific to active mobility, and the categories used overlap with other choice and mobility frameworks.

The PASTA model visualizes factors influencing individual mobility choice. This study requires a framework focused on the choice process of individuals, because it researches factors impacting parents' personal perception of traffic safety. A higher-level model which focuses on e.g. adoption of new behavior across a society would not provide enough details.

This research focuses on identifying factors along the travel routes which influence parents' perception specifically. Hence, it considers factors which occur externally to the parents and requires a model which visualizes the role of these in personal choice, such as the PASTA model. Many other behavioral models focus more on the internal characteristics of the person. For example, the theory of planned behavior by Ajzen (1991) largely highlights the link between internal opinions and behavior outcomes. Such a model would not match the need of this research.

Moreover, the PASTA framework summarizes different factors which have been found to influence mobility choice in past research. Thus, the factors mentioned are specific to mobility choice and active mobility. This type of specificity is not present in broader behavior models, such as the health belief model (Abraham & Sheeran, 2009). The health belief model outlines how perception of a situation leads to action, but uses broad concepts such as perceived susceptibility/severity.

Lastly, the broad categories mentioned in the PASTA framework overlap with several other frameworks, ensuring its relevance to understanding choice processes. For example, the health

belief model also uses the concept of individual factors (Abraham & Sheeran, 2009), while the socio-ecological mode of children's mobility also considers the natural environment, individual characteristics, and social interactions (Mitra & Manaugh, 2020).

2.1.2 *The PASTA Model*

The PASTA model compiled literature, which considered various determinants of active transport, to create a summary model understanding active mobility choice (see Figure 2.1) (Götschi et al., 2017).

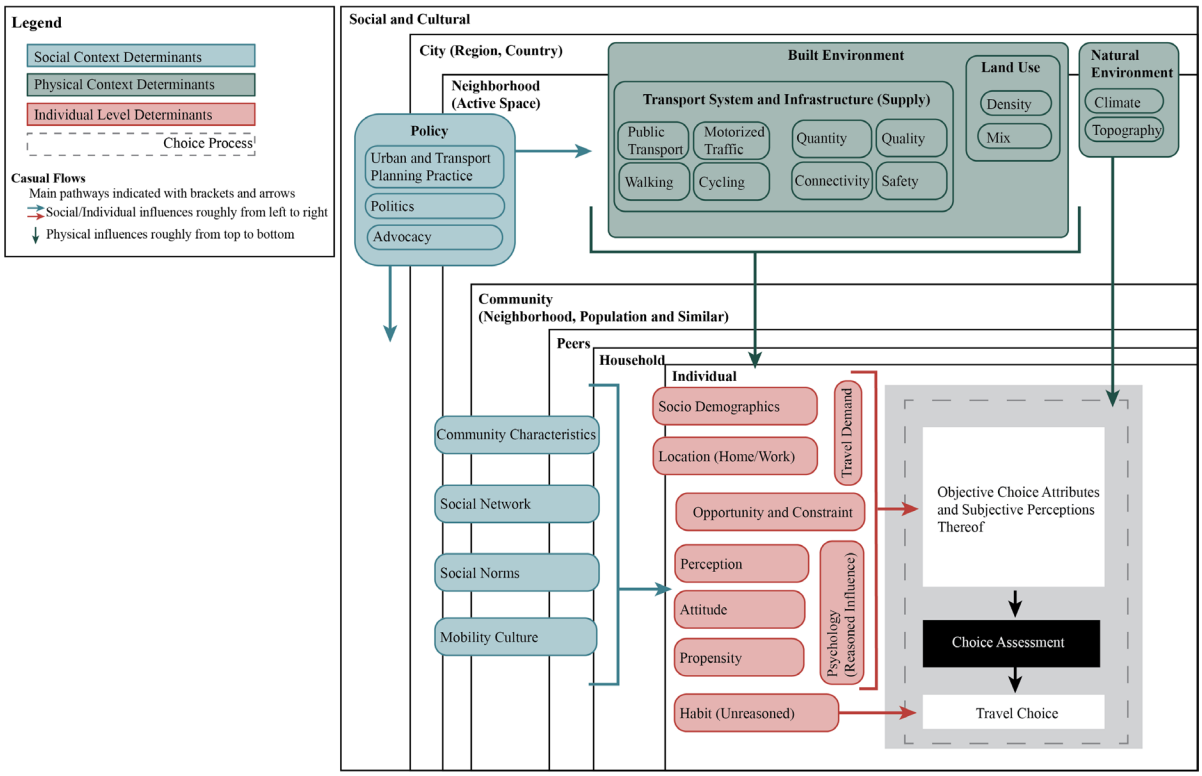

Figure 2.1: The PASTA model, which summarizes the main factors that inform active mobility choice (Götschi et al., 2017).

Götschi et al., (2017) argued that while there was much literature on how people make active mobility choices, the specific articles often only focused on one aspect of the choice. Consequently, a complete model acknowledging the diversity of factors that influence mobility choice was missing. By summarizing the different dimensions and criteria identified in other research, the PASTA model shows an overview of the choice process in active mobility (Götschi et al., 2017).

The PASTA model initially distinguishes between unreasoned behavior, also called habits, and reasoned behavior. Habits refer to things which influence the choice process in an unconscious manner. Thus, they cannot be measured when asking people to explicitly explain their mobility choice.

The PASTA model further distinguishes the different scales where choice mechanism originate from, e.g. social and cultural, neighborhood, peers, or individual. These dimensions show that many entities influence the choice process.

The most essential distinction the model makes is between the three main contexts which influence mobility choices, namely social, physical, and individual context. The social context refers to the broader societal structure, such as policy or cultural norms. The physical context relates to the built and natural environment (e.g. bike paths, weather). The individual level focuses more on personal characteristics, such as perception, demographics, attitude, and habits. The arrows in Figure 2.1 show the connections between the different dimensions and the final choice. Both the physical and social context link to the individual context, which then influences the objective choice. Only the natural environment has a direct link to the objective choice box in Figure 2.1.

Overall, the PASTA model visualizes what factors might influence active mobility decisions, and how different aspects of the decision process interact. The PASTA model demonstrates that (safety) perception, as part of the individual context, links directly to active mobility choices, and that both the built environment and social context link to (safety) perception. Accordingly, the PASTA model in its original form already indicates that parents' perceived traffic safety influences their mobility choice, and various built environment factors influence their perception.

2.2 The Conceptual Framework

This research's core focus is to understand what factors influence parents' perception of traffic safety, thus the PASTA framework is operationalized to single out the links to perception within the model. The operationalized model centers on individual factors, since these contain perception (changed to Traffic Safety Perception). Physical factors are kept in the model, because they have a direct link to the individual factors. Interaction factors are added due to their prevalence in past literature about parents' perception (seen Section 4.1). Social factors are assumed to be outside the scope of this study. Figure 2.2 shows the changes mentioned, where colored boxes highlight aspects relevant to this research, while transparent boxes are less pertinent.

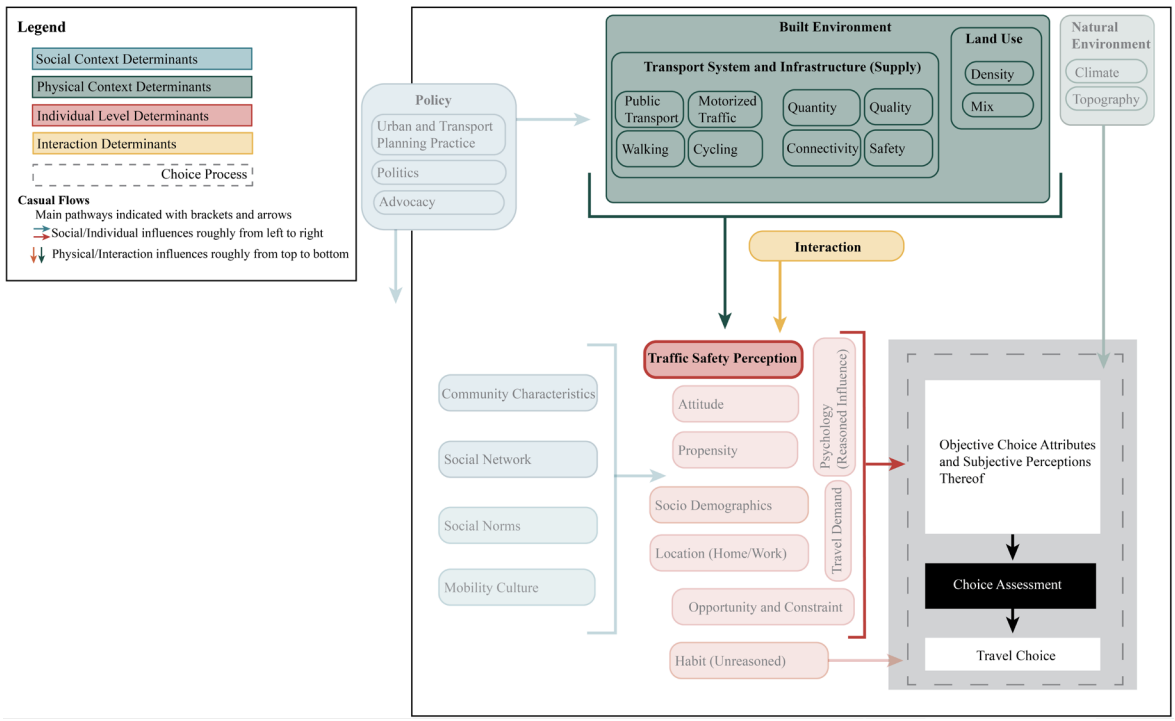

Figure 2.2: Conceptual model, adapted from PASTA model to center around traffic risk perception, and include built environment and interaction factors.

This research primarily focuses on understanding factors identified by individuals, hence the scale levels are left out of the conceptual model. Understanding the origin of the factors would be most relevant when considering where to intervene in the choice process, which is not the goal of this research.

The main factor in the PASTA model relevant to this study is perception (red). Including perception in the conceptual framework is central, because it shows perception fits into the travel choice process. For this research perception is reframed as perception of traffic safety. Other factors mentioned in the individual context are excluded, since previous research highlighted them as mitigating factors e.g. children's demographics and socio economic factors (Aliyas et al., 2022; Hermida et al., 2025; Katsavounidou et al., 2024; Kotoula et al., 2021; Kweon et al., 2021; Lam, 2001; Masoumi et al., 2020; Molina-García et al., 2025; Siiba et al., 2025; Swain et al., 2024; Zougheibe et al., 2021). Habits are also excluded, because they are unconscious components of choice which this research cannot account for. Overall, the individual context outlines the place of perception in the travel choice process.

Social context (blue) is one of the overarching components of active mobility choices in the PASTA model. As mentioned earlier, Section 1.3, these are assumed to be similar across all participants in this research. Consequently, due to this study's limited scope, social context is not an active component of the conceptual framework and therefore transparent in Figure 2.2.

Physical context (green) is included in the conceptual model, because past literature highlighted that the built environment plays a central role in parents safety perception (Amiour et al., 2022; Macedo et al., 2023; Van Den Berg et al., 2020; Wangzom et al., 2023). The arrow connecting

them to traffic safety perception highlights the link between both components. The natural environment is excluded from the conceptual framework, because it cannot be altered and links directly to travel choice. Both literature and the PASTA model confirm the link between the built environment component and traffic safety perception, cementing its place in the conceptual model.

The PASTA model is missing explicit reference to traffic interactions and their impact on perceived safety, which was mentioned in literature. Several studies cited that the behavior of other road actors influenced parents' perceived traffic safety (Aliyas et al., 2022; AlQuhtani, 2025; Amiour et al., 2022; Aranda-Balboa et al., 2021; Herazo-Beltrán et al., 2024; Hermida et al., 2025; Masoumi et al., 2020; Schicketanz et al., 2024; Vasey et al., 2022; Wangzom et al., 2023). Currently, the PASTA model only acknowledges it in the form of traffic structure. To be more open for additional factors in this study, the conceptual framework adds it as an additional component (orange), and links it to traffic safety perception.

Overall, the conceptual framework adapts the PASTA model to focus specifically on traffic safety perception and the factors which broadly influence it. Specifically, the new model leaves out the scale level and social factors mentioned in the original model. The model then uses individual factors to link perception to mobility choice. Lastly, the model acknowledges the preexisting link between perception and the built environment, and adds the link to interaction factors, based on information from literature. Overall, the adapted model provides an idea of how various factors influences each other and mobility choice, and guides the categorization and coding of factors throughout this research.

3 Research Methodology

This study will use qualitative research methodologies to explore the factors that influence parents' perceived traffic safety in a bike-oriented context. The explorative approach of this research benefits from qualitative methodologies, such as interviews, which allows for more leeway to account for unexpected responses through more flexibility within data collection than quantitative methods.

First, a literature review will be conducted to compile an overview of factors which have already been linked to parents' traffic safety perception (Section 3.1). Next, interviews with mental mapping will allow this research to identify what factors influence parents traffic safety perception in the Netherlands (Section 3.2). Processing the interviews through coding will create a systematic overview of factors mentioned in the Dutch bike-oriented context (Section 3.3). Lasty, through a co-occurrence analysis this research will explore whether the combination of factors mentioned alter parents' perception of traffic safety (Section 3.4). The steps of this research are depicted in Figure 3.1 which gives an overview of the input, methods, outcomes, and links them to the sub-research questions.

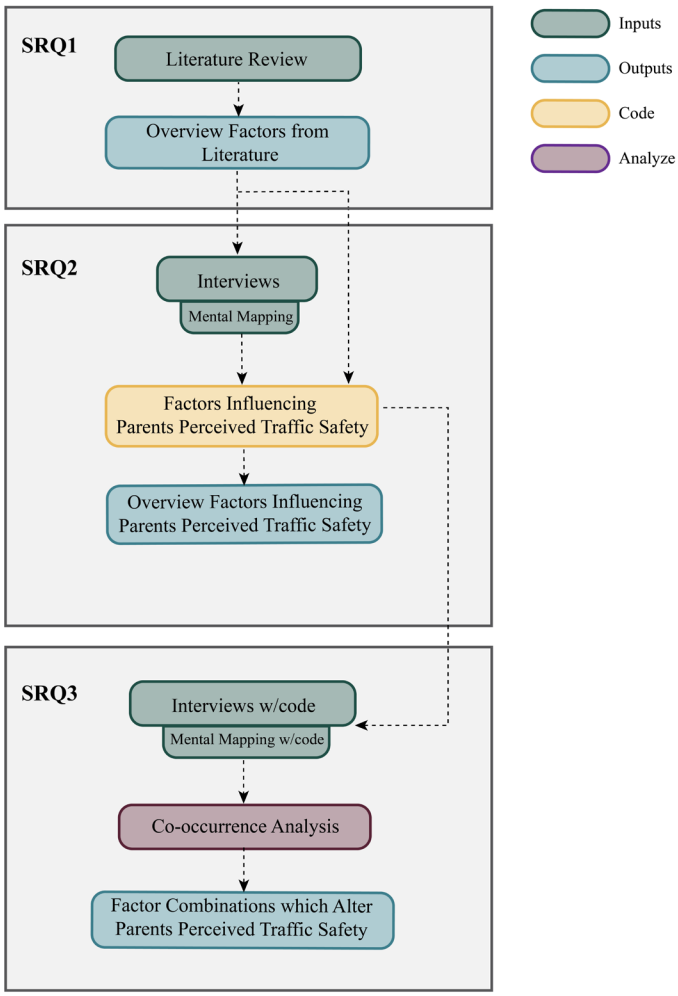

Figure 3.1: Overview of the link between the data collection method, process, analysis, and the sub-research questions.

3.1 Systematic Literature Review

The research will begin with two systematic literature reviews to identify what factors have already been linked to parental safety perception when engaging with AST. To capture the general and local factors and themes, both the global (Section 3.1.1) and Dutch (Section 3.1.2) context will be considered. A systematic literature review is selected, since it provides a reproducible and bounded way to look at previous research and identify relevant factors (Nightingale, 2009). Thus, by clearly defining what papers are relevant to the scope of this study, it can provide a methodical summary of previously identified factors. This research will do so by first defining the relevant scope and search terms, and then providing concrete steps to filter the articles.

The scope and search strings will be specified for the respective literature reviews. For each search term an extensive list of synonyms will be made to ensure that all variations of a term are covered. After the search string is applied in the search engine, the research will initially scan all titles of the articles. Titles that do not refer to AST or active mobility at all, or link it to a specific un-relevant subcategory (e.g. covid) will be excluded. The abstract will then be read, and articles are excluded if they meet the exclusion criteria outlined in Table 3.1 and Table 3.2. For the articles left after scanning, the entire article will be read. Here articles will be excluded if they make no reference to factors which influence parents' safety perception and AST. For each article a comment will be made about when it is excluded and on what grounds.

3.1.1 Global Context

Initially, this research will conduct a literature review on the global context. This allows the research to create a summary of factors that have been linked to parents' perceived traffic safety in general. To complete the literature review on the global context, a search string will be established, applied to all relevant search portals, exclusion criteria will be defined, and then all articles found will be filtered.

The global search term will identify articles which discuss AST and parents' perception of traffic safety in a global context. The global search string will include the following five subjects: active travel, risk, school, perception, and parents. These dimensions are established, both by considering past systematic literature reviews on the topic, keywords in other relevant papers, and some fine tuning through trial and error (Amiour et al., 2022; Cadima & Pinho, 2024; Siiba et al., 2025). The full search string will be the following:

PUBYEAR AFT 2020 TITLE-ABS-KEY ((Bike OR "Active Mobility" OR Walking OR "School Travel" OR "Active School Travel" OR "Active Commute" OR Pedestrian OR Cyclist*) AND (Accident* OR Risk* OR Safet* OR Hazard* OR Danger* OR Unsafe* OR Securit*) AND (School* OR Kindergarten) AND(Perception* OR Perceive*) AND (Parent* OR Father* OR Mother* OR Guardian* OR Child*))*

A detailed overview of the literature review and search term can be seen in Appendix A. The global systematic literature review will be limited to papers after 2020, since a substantial literature review of a similar topic was conducted in 2021 (Amiour et al., 2022). The search string will be applied in both Scopus and PubMed to identify a broader set of relevant articles.

The articles found will be scanned for relevance based on several exclusion criteria defining them as either relevant or irrelevant to the research. The literature review will move through all articles and scan the title, and then the abstract, and exclude all papers which do not align with the intended context. Table 3.1 shows the exclusion criteria that will be used to scan the identified articles. Some requirements will be the age range of children, the inclusion of parents' perspective, and the focus on active mobility of children without any mediating factors such as e.g. covid or disability.

Table 3.1: Exclusion criteria for articles in the global systematic literature review.

Global Systematic Literature Review – Exclusion Criteria
Does not consider parents' perception
Does not consider children between 4 and 12
Does not consider school travel
Does not consider active modes
Focused on specific illness/disability
Focused on obesity
Focused on developing new measurement design or processes
Focused on other risky behavior (smoking, drinking)
Considers AST during COVID-19
Considers modelled/predicted behavior
Consider a specific intervention

To summarize the results from the global literature review, a table will be set up which outlines what factors influencing AST are mentioned in existing research. The factors will be categorized based on the dimensions of the PASTA framework, and include built environment factors, interaction factors, children's demographic factors, direct social environment factors, and other factors. The resulting summary will be used both to answer SRQ1 and inform the interview codes.

3.1.2 Dutch Context

Secondly, this research will conduct a literature review on the Dutch context. This literature review will indicate if factors overlap between the global and Dutch context, and highlight any research gaps in the Dutch bike-oriented context. To complete the literature review on the Dutch context, a search string will be established, applied to all relevant search portals, exclusion criteria will be defined, and then all articles found filtered.

The second systematic literature review will specifically consider parents' perceived traffic safety in the Dutch context. The search string will be broader than the global literature review,

because the focus on the Netherlands greatly reduces the research available. Thus, to still establish an understanding of the research available and potential factors identified in the Netherlands the search string will not be limited to school travel. The search string will focus on active travel, risk, parents, and the Netherlands. The full string is:

TITLE-ABS-KEY ((Bike OR "Active Mobility" OR Walking OR "School Travel" OR "Active School Travel" OR "Active Commute" OR Pedestrian OR Cyclist* OR "Active Commute") AND (Accident* OR Risk* OR Safet* OR Hazard* OR Danger* OR Unsafe* OR Securit*) AND (Perception* OR Perceive*) AND (Parent* OR Child* OR Father* OR Mother* OR Guardian*) AND (Netherland* OR Dutch OR Holland OR Randstad))*

More details around the search string can be found in Appendix C. For the Dutch review, no year range will be set, since no substantial previous reviews were found. The search string will be applied to both Scopus and PubMed to find articles.

All the articles found will be examined for relevance based on several criteria defining them as either relevant or irrelevant to the research. The literature reviews will scan the title, and then abstract, and exclude all papers which do not align with the intended context. Table 3.2 shows the exclusion criteria which will be used to scan the identified articles. Some requirements will be the Dutch context and inclusion of active mode.

Table 3.2: Exclusion criteria for articles in the Dutch systematic literature review.

Dutch Systematic Literature Review – Exclusion Criteria
Does not consider children between 4 and 12
Does not consider active modes
Does not consider Netherlands
Focused on specific illness/disability
Focuses on number of accidents
Focuses on children's ability to navigate traffic
Focused on children's health
Focused on other risky behavior (smoking, drinking)
Considers AST during COVID-19
Considers modelled/predicted behavior
Consider a specific intervention

To summarize the factors found, a table will be set up which outlines what factors influencing parents' traffic safety perception are mentioned in existing research. The factors will be categorized, based on the PASTA framework, into built environment factors, interaction factors, children's demographic factors, other factors, and direct social environment factors. The resulting factors will be used both to answer SRQ1 and inform the interview codes.

3.2 Data Collection

The data collection process will use semi-structured interviews, with mental mapping as a probe. Interviews are chosen because they are a qualitative data collection method and therefore remain open for parents to explain context and introduce new knowledge. The mental mapping provides a concrete base to talk from which might trigger more detailed information. This research steers away from qualitative data collection methods, because they require a notion of the potential outcome beyond what this research can provide through the literature review (Jain, 2021).

3.2.1 Semi-Structured Interviews

This research will use interviews for the data collection due to its open and flexible approach. Other more quantitative data collection processes, such as surveys, require a more specific knowledge base and expectation of outcomes to set up exhaustive questions which this research does not have (Jain, 2021). There is currently no complete list of factors which influence parents' perceived safety within a bike-oriented context. Moreover, several current studies are survey based and do not provide an opportunity to delve into the context of parents' responses (see Appendix B and Appendix D). To extend the list of factors and understand parents' responses in-depth this research needs a data collection method which is open to discovering unexpected information, hence interviews.

This research will use semi-structured interviews. Interviews are a common qualitative data collection technique, since they capture personal knowledge and are flexible enough to find new unexpected information (Legard et al., 2003). Focusing on semi-structured interviews will provide the ability to harness specific information through pre-planned questions, while remaining open to new ideas with spontaneous follow-ups. This research will follow the Seven Steps to Conducting, Analyzing, and Reporting Semi-structured Interview Data (7s CARS-SID) as presented in Appendix E (Adeoye-Olatunde & Olenik, 2021). Doing so allows a standardized structure which outlines how the interviews will be conducted and analyzed to maximize transparency and reproducibility.

Each participant's interview will last between 30-60 minutes and contain both open-ended questions and a request to map participant's travel routes. The questions will focus on providing necessary background information, e.g. asking for the age and gender of the children and previous active mobility background of parents. Other questions will be more flexible and take the form of follow-ups to the maps drawn by parents. These questions will include, for example, asking about road materials, interactions with other road users, or places parents avoid traveling to. Combining the interviews with mapping will be essential, since the mapping can trigger parents to remember specific events, otherwise forgotten. However, mental maps alone cannot reflect the same depth of information as interviews.

The participants will be recruited by sending out a call in parents' WhatsApp groups, school newsletters, and snowballing from parents connected to the research.

To facilitate processing of the data, all interview responses will be recorded locally on the computer, transcribed through Word, and analyzed in Atlas.ti. Recording the interviews also allows for some more flexibility in the language of responses. Though the interviews will be conducted in English, the recording will make it possible to go back to the conversations to cross-reference what people said and translate correctly when Dutch words of phrases are used.

3.2.2 Mental Mapping

Mental maps will be used, not as a data collection method in itself, but as a probe to initiate and guide the interviews. Mental Maps provide a systematic way to visualize subjective experiences and opinions. Mental maps come from behavioral geography with the goal to capture personal perspectives of a place (Brennan-Horley, 2010). In mental mapping, participants map and annotate an urban area in the way they experience it. A common alternative technique is walk-along interviews, which allow an embodied shared experience of the route (Schicketanz et al., 2024). However, walk along interviews are hard to conduct when biking due to speed and relative business, leaving mental mapping as the best alternative for this research (Schicketanz et al., 2024). Mental maps will be central in the interviews, because they provide an opportunity for parents to visualize their travel routes. Moreover, asking parents to mentally walk through their travel might trigger memories they would not consider in an open-ended conversation.

This research will use mental maps which rely on a base map as a starting point, rather than free form mental mapping (see Figure 3.2 for example). This allows for easy geographic referencing along the route (Brennan-Horley, 2010). Participants will initially be prompted to simply draw their routes to and from school, on an average day. Thus, the route does not account for extreme weather, seasonal changes etc. Then they will be asked to highlight good/bad spots along the route and explain why these fall in either category. The mental mapping will be annotated with various colors and notes based on the stories parents tell (Figure 3.2). After drawing the maps, follow-up questions will be used to see if there are any other factors missing which are relevant to parents.

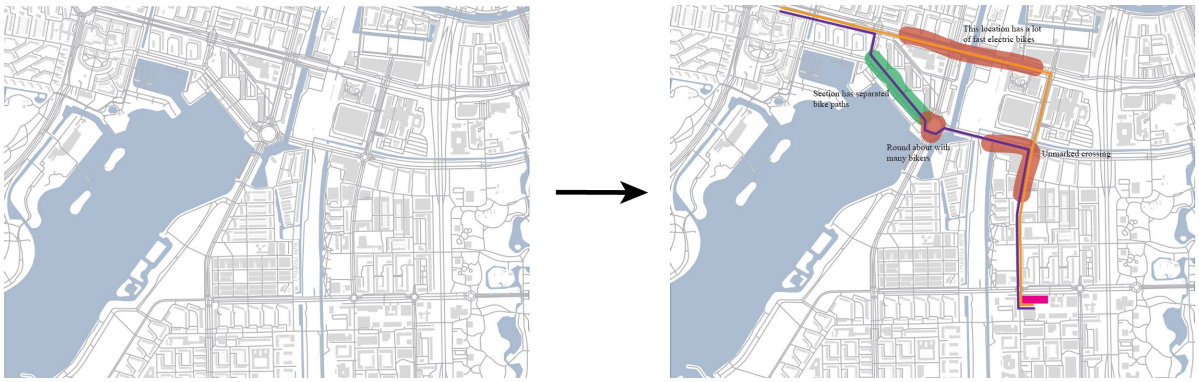

Figure 3.2: Example of what the resulting data from mental mapping could look like (not from a participant).

The maps will be formatted into pdfs through Illustrator to facilitate the coding process. Though the mental maps are not a data source themselves they will support finding spatially specific details and stories in the interviews. The maps drawn will supplement the information from interviews with spatial insights to answer SRQ3.

The maps will not be aggregated or analyzed for quantitative information in this research, because the small sample means that route data might identify participants. Considering the relatively small school communities, and the small sample collected, the routes can be associated with the families. To mitigate this concern, larger parts of the routes will not be published. Only small snippets of specific locations along the route will be considered for SRQ3.

3.3 Data Processing

To be able to summarize and quantify the responses from the interviews in a systematic manner they will be processed through coding. Initially the interviews and mental maps will be coded for content in a hybrid manner.

To develop the codes the research will use hybrid coding, which leans on a combination of predefined codes and exploration to find new codes (Fereday & Muir-Cochrane, 2006). The predefined codes will take their origin in factors identified in the systematic literature review. The main predefined codes identified can be seen in Table 3.3, for all codes see Appendix F. The codes will focus on the content and thus summarize what is directly mentioned in the text (Prasad, 2008). The goal of the coding will be to create a summary of the different factors parents consider when evaluating the safety of roads on behalf of their children and how often various factors are mentioned. This summary is used to answer SRQ2.

Table 3.3: The overarching codes used as a starting point to look for the interaction/dynamic factors in interviews and mental maps, based on the systematic literature review.

Codes of Built Environment Factors	Codes of Interaction Factors
Complex crossing	Speed related issues
Safe Crossing	High volume
Unsafe crossing	Other actors along route
Type bike/walking path	Conflict with other modes
Design bike/walking path	Behavior which breaks traffic rules
Road features	Others anticipate need
Maintenance	Crime in neighborhood
Road Surface	Unpredictable situation
Construction	Calm/slow traffic

3.4 Data Analysis

To create an in-depth understanding of the factors found in interviews and how they form parents' perceived safety, a co-occurrence analysis will be conducted. The research will conduct a co-occurrence analysis in Atlas.ti on all documents, interview transcripts and mental maps.

A co-occurrence analysis sets up a matrix of pairwise comparisons between codes. In essence the analysis shows how often two different codes are mentioned together in one quote or location. This analysis will allow the research to see whether various factors frequently appear together.

For factors which do frequently appear together the research can then consider the quoted context in more depth to see if the combination of factors mentioned play a role in how parents frame their risk perception. This will provide insight for SRQ3 about whether factors interact with each other to alter parents' perceived traffic risk.

4 Results

This section addresses the research question, by answering each sub-research question with the previously described methodology and the ensuing results. First, relevant factors to parents' perceived traffic risk described in literature were identified through two systematic literature reviews focusing on both the Global and Dutch context (Section 4.1). Second, the research identified what factors were mentioned by parents in the Dutch bike-oriented context through interviews and mental maps (Section 4.2). Then the research explored if the interplay between different factors mentioned by parents amplified parents' perceived traffic risk (Section 4.3).

4.1 Factors Found in Literature Review

This section summarizes previously identified factors by initially delving into the factors identified in the global literature review and then the factors from the Dutch literature review. For the selection process the global and Dutch literature review initially applied their respective search string in Scopus and PubMed, and then filtered according to the process outlined in Section 3.1. This ensured that all the final selected papers were relevant to the research. The factors found were sorted based on the categories of the conceptual framework for easy overview. The main categories were the built environment factors, interaction factors, and the children's demographic factors. Other mediating factors were also kept in mind through the direct social environment and other columns.

4.1.1 Global Context

The global systematic literature review attempted to summarize the factors linked to parents' perceived safety when engaging with AST in past literature.

The global literature review initially found 99 articles, which were filtered down to 26 articles across Scopus and PubMed. Figure 4.1 shows an overview of the selection process and number of articles excluded at each step (for details see Appendix A). All the final selected articles can be found in Appendix B.

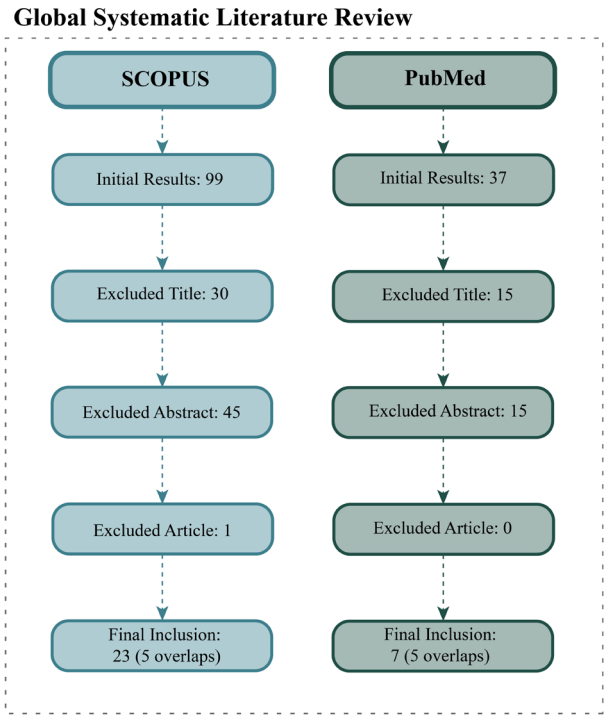

Figure 4.1: Overview exclusion process of the global systematic literature review.

The selected articles were scanned for factors related to parents' safety perception and AST. The next sections discuss the various factors found in the literature and summarizes them in Table 4.1 at the end.

4.1.1.1 Built Environment Factors

Several studies outlined many factors from the built environment which influenced parents' perceived traffic safety. The main split was made between factors which decreased or increased parents' perceived traffic safety.

In past literature, lack of designated active mobility infrastructure, poor maintenance of infrastructure, narrow infrastructure, construction, many crossings, unsecure crossing, street parking, and isolated roads reduced parents' perceived traffic safety. Lack of dedicated biking and walking infrastructure was concerning to parents' in regard to AST (AlQuhtani, 2025; Amiour et al., 2022; Aranda-Balboa et al., 2021; Herazo-Beltrán et al., 2024; Katsavounidou et al., 2024; Kotoula et al., 2021; Kweon et al., 2021; Masoumi et al., 2020; Siiba, 2021; Siiba et al., 2025; Swain et al., 2024; Vasey et al., 2022; Wangzom et al., 2023). AlQuhtani (2025) showed that lack of sidewalks can make parents twice as likely to refuse AST. However, even if there was designated infrastructure available, if it was poorly maintained parents felt less safe (Chinkonda et al., 2024; Vasey et al., 2022). Narrow biking/walking infrastructure, where it was not possible to bike or walk next to each other, discouraged AST (Amiour et al., 2022; Katsavounidou et al., 2024; Schicketanz et al., 2024; Swain et al., 2024). Construction on the designated infrastructure, although temporary, also reduced the perceived safety of the path (Torres et al., 2022). Moreover, many crossing along the school route generally led to a decrease

in the safety perception of parents (Kweon et al., 2023; Masoumi et al., 2020; Torres et al., 2022; Von Stülpnagel et al., 2024). Unsecure crossings on the way to school was also a central concern, with varying causes (Aliyas et al., 2022; Cadima & Pinho, 2024; Herazo-Beltrán et al., 2024; Hermida et al., 2025; Swain et al., 2024; Wangzom et al., 2023). Some mentioned in research include, reduced visibility, no crossing guard, free right turn, no traffic light, and complex/multilane crossings (Amiour et al., 2022; Chinkonda et al., 2024; Schicketanz et al., 2024; Swain et al., 2024). In addition, the existence of street parking led parents to see a road as less safe (Amiour et al., 2022). Lastly, more isolated roads or roads which were dead ends were also generally seen as less safe (Amiour et al., 2022; Vasey et al., 2022). In conclusion, a multitude of factors decreased parents' perceived traffics safety in literature including lack of designated active mobility infrastructure, poor maintenance of infrastructure, narrow infrastructure, construction, many crossings, unsecure crossings, street parking, and isolated roads reduced parents' perceived traffic safety

Having a buffer between the active mobility infrastructure and roads, speed managing infrastructure, and road sign increased parents' traffic safety perception. Providing a buffer between the active mobility infrastructure and road, especially with trees, increased perceived safety (Kweon et al., 2021). Two other factors were the presence of speed managing infrastructure such as speed bumps, and presence of road signs, which could clarify an otherwise chaotic situation (Chinkonda et al., 2024). Thus, speed managing infrastructure, traffic signs, and buffer between the active mobility infrastructure and roads positively influenced parents' perceived traffic safety.

Overall, past literature highlighted an extensive set of factors in the built environment that influenced parents' safety perception. The main focus in literature was on the quality and availability of designated walking and biking infrastructure, and on the frequency and safety of crossings along the route.

4.1.1.2 Interaction Factors

Past research highlighted several interaction factors which influenced parents' perceived traffic safety, most of which were negative. The factors which reduced parents' perceived safety were categorized into neighborhood safety, traffic flows, and the presence of others. Trusted travel companions, however, had a positive impact on parents' perceived traffic safety.

Research showed that if parents perceived a neighborhood as unsafe, they allowed less AST (Ammar & Derbel, 2024; Kweon et al., 2023; Zougheibe et al., 2021). Experiencing or hearing about crime in the area decreased parents' tendency to allow AST (Aranda-Balboa et al., 2021; Hermida et al., 2025; Katsavounidou et al., 2024; Nyström et al., 2023; Torres et al., 2022; Vasey et al., 2022). Nyström et al., showed several interview responses where parents mentioned e.g. hearing of drugs being sold in the area and thus not allowing independent mobility (2023). Stranger danger also reduced AST, which could be reinforced by parents not knowing the neighborhood and perceiving others as strangers, even if there was no real crime

risk in the neighborhood (Chinkonda et al., 2024; Swain et al., 2024, 2024; Wangzom et al., 2023). Consequently, literature showed that if parents perceived a neighborhood as unsafe, grounded or not, it reduced their willingness to allow AST.

The primary safety concern of parents in traffic was speed and density, but previous accidents and unlawful driving also had an impact. Fast moving traffic was a risk to parents because of the increased chance for accidents (Aliyas et al., 2022; AlQuhtani, 2025; Amiour et al., 2022; Hermida et al., 2025; Siiba, 2021; Swain et al., 2024; Torres et al., 2022; Vasey et al., 2022; Von Stülpnagel et al., 2024; Wangzom et al., 2023). High traffic density concerned parents, because it was harder for children to navigate (Aliyas et al., 2022; AlQuhtani, 2025; Amiour et al., 2022; Aranda-Balboa et al., 2021; Herazo-Beltrán et al., 2024; Hermida et al., 2025; Masoumi et al., 2020; Schicketanz et al., 2024; Vasey et al., 2022; Wangzom et al., 2023). Experiencing traffic accidents also raised parents' perceived risk (Torres et al., 2022; Wangzom et al., 2023). Lastly, traffic actors who broke the rules decreased parents' safety perception (Cadima & Pinho, 2024; Chinkonda et al., 2024; Katsavounidou et al., 2024). Thus, literature showed that several elements of the traffic structure itself impacted parents' safety perception, including high speed, volume, accidents, and unlawful behavior.

Lastly, previous research reflected that children's interaction with other road actors, as well as their own behavior, played into parents' overall safety perception. For fear of bullying parents were wary of many older children hanging around school routes (Siiba et al., 2025; Vasey et al., 2022). Also, if parents saw their children engage in risky road behavior, they felt less safe and were less inclined to allow AST (Chinkonda et al., 2024). Hence, strangers along the route and children which acted riskier reduced parents' perceived traffic safety.

One positive factor brought up in literature was the role of trusted travel companions. Parents were reassured if there were siblings or trusted adults which could accompany the child (Schicketanz et al., 2024; Vasey et al., 2022). Schicketanz et al. (2024), mentioned that several parents outlined that when they first transition children to walking alone they specifically set up trusted walking groups. Overall, literature reflected that parents perceived traffic as safer if their children had trusted company with them along the travel route.

Past research demonstrated that interaction with other road actors and their behavior influenced parents' perceived traffic safety. Crime and accidents within the neighborhood, high speed and large volumes of traffic reduced parents' perceived safety, since it increased the complexity of the traffic situation. Conversely, trusting the child's ability to act correctly and having trusted people to accompany the child increased perceived safety.

4.1.1.3 Children's Demographics

The global literature highlighted that the age and gender of the children influenced whether parents allowed AST and independent mobility, though not safety perception directly. Past research showed that boys are allowed more freedom to travel both actively and independently

to school than girls (Aliyas et al., 2022; Kweon et al., 2023; Masoumi et al., 2020; Molina-García et al., 2025; Siiba et al., 2025; Swain et al., 2024; Zougheibe et al., 2021). Swain et al. (2024) found that boys are 2.41 times more likely than girls to walk to school. Molina-García et al., (2025) found that in general parents perceived their daughters as less safe in an area than their sons. As the age of a child increased so did the amount of AST they were allowed (Hermida et al., 2025; Katsavounidou et al., 2024; Kotoula et al., 2021; Siiba et al., 2025). Katsavounidou et al., (2024) showed that for children in the age group 9-12, 20.39% of the sample walked alone, while in the group 11-12, 43.10% walked alone. Hence, the gender and age of the children played a role in AST, and maybe also in how the environment was assessed.

4.1.1.4 Direct Social Environment

Literature showed that the direct social environment influenced AST through socio-economic factors and cultural background, though the direction of the influence was sometimes uncertain. The role of socio-economic status (SES) of neighborhood and parents in AST was complicated and often linked with the society around it. For example, Aliyas et al., (2022) found that a higher SES led to less AST despite few perceived barriers, likely due to the ability to afford a car. Siiba et al., (2025) highlighted that having a car in the family decreased AST, which was related back to socio-economic status. On the other hand, Nyström et al., (2023), showed that parents in low-income neighborhoods found it challenging to support AST due to the cost of providing, safely storing, and maintaining a bike. Hence, SES played a role in AST, however the direction was unclear and context dependent. The cultural backgrounds of parents also played a role in AST. Nyström et al., (2023), reflected that immigrant families sometimes lacked the skills to bike themselves and consequently could not pass on the knowledge. Cultural norms also mattered. In general, if everyone else biked and walked then parents were also more inclined to let their children bike or walk (Herazo-Beltrán et al., 2024). Thus, in literature socio-economic status, parents cultural background, and social norms played a role in AST adoption, but were less closely linked to perceived traffic safety.

4.1.1.5 Other Elements to Consider

Some other factors relevant to AST mentioned in literature, include the distance travel, time available to parents, and skills of children. Distance was mentioned in several papers as being relevant in whether or not AST was allowed (Aliyas et al., 2022; AlQuhtani, 2025; Ammar & Derbel, 2024; Aranda-Balboa et al., 2021; Herazo-Beltrán et al., 2024; Nyström et al., 2023; Siiba, 2021; Siiba et al., 2025; Von Stülpnagel et al., 2024; Wangzom et al., 2023). In general, the greater the distance the less likely parents were to allow AST. However, at what point a distance became too large was culturally specific (Wangzom et al., 2023). In the Netherlands the general distance was around one kilometer while in Japan the distance for AST could be up to three kilometers (Wangzom et al., 2023). Moreover, how much available time parents had also played a role (Nyström et al., 2023; Vasey et al., 2022). Parents with less time in the morning might choose the car, because it was perceived as more convenient (Nyström et al.,

2023; Vasey et al., 2022). Lastly, how parents perceived children's ability to navigate traffic was important (Cadima & Pinho, 2024; Chinkonda et al., 2024; Siiba, 2021; Vasey et al., 2022). If parents perceived better biking skills, then they would be more inclined to allow their children to bike. Thus, as seen in Section 2 active mobility choices are complex. Previous research reaffirmed this by outlining several variables which influenced parents' mobility choice, but did not directly link to their perceived traffic safety.

4.1.1.6 Summary Global Context

Table 4.1 provides a simplified overview of the various factors influencing parents' perceived safety found in literature. Negative factors decreased the safety perception, positive factors increased the safety perception, while uncertain factors had mixed responses. The built environment and interaction factors directly influenced parents' perceived traffic safety. The direct social environment and other factors were often linked more to AST or parents' choice, rather than parents' safety perception directly.

Table 4.1: Overview of factors which impacted parents' perceived traffic safety and AST based on the global systematic literature review. The impact is related to parents' perceived traffic safety unless otherwise specified.

	Negative	Positive	Uncertain
Built Environment Factors	Unmaintained infrastructure	Separate bike/walking path	
	Isolated bike/walking paths	Buffer between active mobility infrastructure and road	
	Narrow biking/walking infrastructure	Speed managing infrastructure	
	Construction along the road	Road signs	
	Presence of many crossings	Streetlight	
	Complex crossing	Bike parking	
	Reduced visibility at crossing		
	Unsecure crossings: - No traffic lights - No crossing guard - No zebra crossing - Free right turn for cars		
	Presence of car street parking		
Interaction Factors	Low neighborhood safety	Trusted adults/siblings to travel with	
	High crime rates		
	Perception of stranger danger		
	High traffic density		
	High speeds		
	Presence of larger vehicles		
	Many older children along route		
	Road users which do not follow the rules - Scooters using pedestrian spaces		
	Children which engage in risky behavior themselves		
Childs Demographic Factors		Older children more AST	
		Boys more AST than girls	
Direct Social Environment Factors	When other friends/parents do not bike or walk reduces AST	Cultural biking background increases AST	Income can influence AST
Other Factors	Perceived low biking/navigating skills in children		Distance influences AST (depending on culture)
	Little time available to parents reduces AST		

4.1.2 Dutch Context

The Dutch systematic literature review summarized the factors mentioned in past research, influencing active travel and parents' perceived traffic safety in the Netherlands.

The Dutch literature review initially found 96 articles of which five remained relevant after filtering. Figure 4.2 shows an overview of the selection process for the Dutch systematic literature review (for details see Appendix C). All the final selected articles can be found in Appendix D.

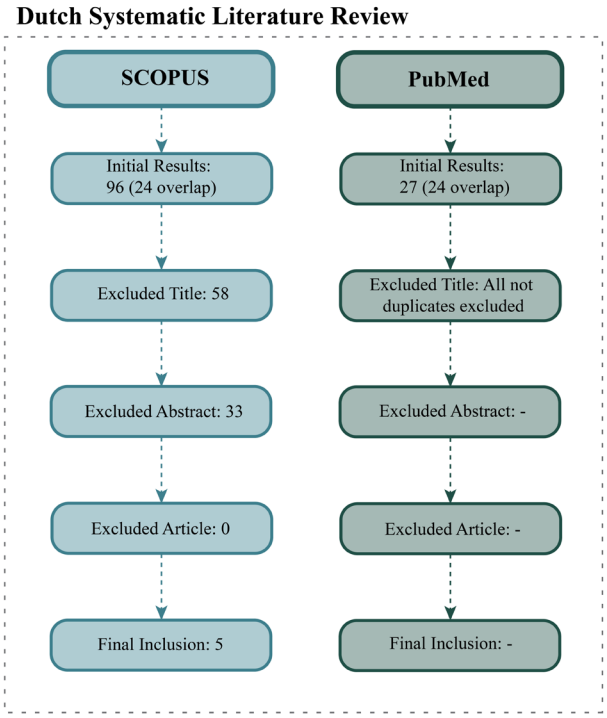

Figure 4.2: Overview exclusion process of the Dutch systematic literature review.

The next sections discuss what factors did and did not appear in the literature and summarizes them in Table 4.2 at the end.

4.1.2.1 Factors Found in the Dutch Context

Overall, for the Dutch context there was a lot less research, than in the global literature, especially on factors influencing parents' perception of traffic safety. When considering elements of AST broadly, a few factors could be identified as seen in Table 4.2.

The literature identified that the presence of bike paths was central for AST, while large roads, previous accidents, lack of social cohesion, and stranger danger decreased AST. Primarily the literature showed that the presence of high-quality cycle paths was central to support parents' perceived traffic safety and AST in the Netherlands (Van Den Berg et al., 2020). The presence of major/large roads, which could feel more unsafe, were a hindrance to AST and perceived safety (Helbich et al., 2016; Macedo et al., 2023). Previous accidents especially involving children reduced parent' perceived safety and thus AST engagement (Macedo et al., 2023). Past

literature also indicated that the social cohesion in the neighborhood and overall perceived social safety impacted AST (Aarts et al., 2013). Moreover, stranger danger had some effect on parents' willingness to allow AST (Van Kann et al., 2016). The only mediating factor, where the influence on AST deviated in the Netherlands from the global context, was gender. While gender seemed to influence the amount of walking permitted for children, it did not influence biking in the Netherlands (Macedo et al., 2023). This might be due to the ingrained biking culture.

Overall, there was less research on AST and parents' safety perception in the Dutch context, but the factors found largely aligned with the global literature, except for the impact of gender on biking.

4.1.2.2 Factors Missing from the Dutch Context

Several factors which would have be expected in the Dutch context, based on municipal policy and research in active mobility, were missing from the literature. These included issues with speed variation on bike paths, insufficient biking infrastructure, and conflict with large vehicles.

Many municipalities have struggled with the variability of speeds on and around the cycle lane. Several policy discussions and news articles have investigated the challenges associated with the introduction of fast electric bikes and scooters (Amsterdam Bike City, 2024; Bremmer, 2025; Provincie Utrecht, n.d.). Amsterdam has specifically started a trial where fast bikes, going more than 20km/h, can reroute to the normal road to reduce speed variation on the bike path (Amsterdam Bike City, 2024). Consequently, this variation in speed, especially when considering slower traveling families, would be an expected risk factor for parents.

Similarly, the volume of bikers, pedestrians, and cars has led to challenges in light of the limited infrastructure in many cities (Algemeen, 2022; Amsterdam Bike City, 2024; Bremmer, 2025; Provincie Utrecht, n.d.; te Brömmelstroet, 2014). Research from Amsterdam reflected that some crossings and roundabouts create congestion in traffic and thus might function as bottle necks in the infrastructure (te Brömmelstroet, 2014). Utrecht has seen an increasing diversity and volume of users on their bike paths leading to conflicts and sometimes forcing more vulnerable users to avoid specific routes (Algemeen, 2022). Considering that children are especially vulnerable in traffic, the increased volume would be an expected challenge for parents' perceived safety.

Lastly, several news articles from various Dutch cities have reported on accidents with large vehicles, such as buses and trucks in the last few years (Naber, 2021; Redactie, 2023, 2025). Though not as frequent, these accidents are quite prominent in the social environment due to news coverage and would be expected to shape parents' perception of safety.

These types of factors would have been expected to also appear prominently in the Dutch literature. The fact that they are missing highlights the need to use the more extensive list from the global literature as the foundation for this research.

4.1.2.3 Summary of Dutch Context

Table 4.2 shows a summary of the factors which influenced parents' perceived safety found in the Dutch literature review. Similarly to the global context, the direct social environment and other factors predominantly impacted AST, rather than going via parents' perception.

Table 4.2: Overview of factors which impacted parents' perceived traffic safety and AST based on Dutch systematic literature review. The additional information specifies if the impact was mentioned for parents' perceived traffic safety, AST, or both.

	Negative	Positive	Uncertain
Built Environment Factors	Green areas - walking	City type neighborhoods - perceived traffic safety and AST	
	Major roads decrease - perceived traffic safety and AST	High quality active mobility infrastructure - perceived traffic safety	
	Lack of cycling paths - perceived traffic safety and AST	Good connectivity between home and school - perceived traffic safety	
Interaction Factors	Stranger danger - perceived traffic safety and AST		
	More accidents decrease perceived traffic safety		
Childs Demographic Factors		Older children - perceived traffic safety and AST	Gender impacts permission to walk, but not biking
Direct Social Environment Factors	Parents with less time - AST	Good social cohesion – perceived traffic safety and AST	Parents travel habit - AST
	Parents with lower income - perceived traffic safety		
Other Factors	Larger distance - perceived traffic safety and AST		

4.1.3 Summary

Previous research into AST established that parents' perceived traffic safety impacts AST behavior, while also identifying a broad set of factors which parents considered when evaluating road safety. The factors influencing parents' perception of traffic safety were largely categorized into the built environment and interaction factors. Other relevant factors mentioned in literature were included through the children's demographic factors, direct social environment, and other columns.

The built environment factors mentioned in the global literature both increased and decreased parents' perception of traffic safety. Built environment factors decreasing parents' perceived traffic safety included lack of designated active mobility infrastructure, poor maintenance of infrastructure, narrow infrastructure, construction, many crossings, unsecure crossing, street parking, and isolated roads. Built environment factors which increased parents' perceived

traffic safety include having a buffer between the active mobility infrastructure and roads, speed managing infrastructure, and road signs.

Similarly, interaction factors which decreased parents' perceived traffic safety include unsafe neighborhoods, presence of strangers, high speeds, high density, accidents, unlawful driving, and children's risky behavior. Though trusted travel companions increased the perceived traffic safety of parents.

Children's demographics and the direct social environment predominantly influenced AST choices in the global literature. In general, boys, older children, and children with better biking skills were allowed more AST. SES was related to AST though the direction was uncertain, while a widespread biking culture increased AST. Lastly, larger distances and less time available reduced AST.

The Dutch literature review revealed that the research on the topic was very limited, though the factors found largely overlapped with the global context. Looking into grey literature from municipalities, some factors which would have been expected, but were not found in the literature included challenges with speed variations, volume, and accidents with large vehicles.

4.2 Factors Found in Interviews and Mental Maps

The following section outlines what factors influenced parents' perceived traffic safety in the Dutch bike-oriented context, while also identifying if the influence was positive or negative. The factors identified in interviews were sorted into the overarching categories from the conceptual framework (interaction factors, built environment factors and other factors).

First, the characteristics of the participants from the interviews are described (Section 4.2.1). Second, an overview of the main built environment factors mentioned by participants is provided (Section 4.2.2). Third, the main interaction factors mentioned by parents are summarized (Section 4.2.3). Lastly, due to the open-ended approach of interviews some other relevant factors mentioned by parents were discovered, which are briefly summarized (Section 4.2.4).

An overview of all the factors coded, the number of times they were mentioned across all interviews, and how many interviews mentioned a specific factor can be found in Appendix G.

4.2.1 Participants

The interviews and mental maps focused on understanding the travel routes of participants and were conducted with 18 parents, representing 39 children across several Dutch urban areas.

In the interviews all participants were asked a set of context/demographic questions including the age and gender of their children as well as their travel habits, to establish a base understanding. All participants drew their travel route (mental maps) and discussed parts of the route they found safe or unsafe. Follow-up questions were catered to the specific interview to make sure that parents did not forget any factors influencing their perception. All interviews lasted between 30-60 minutes.

33% of the parents interviewed were male and 66% were female (Figure 4.3). The parents came from a variety of larger urban areas in the Netherlands, but the majority where from Leiden and Utrecht.

Figure 4.3: Gender Parents

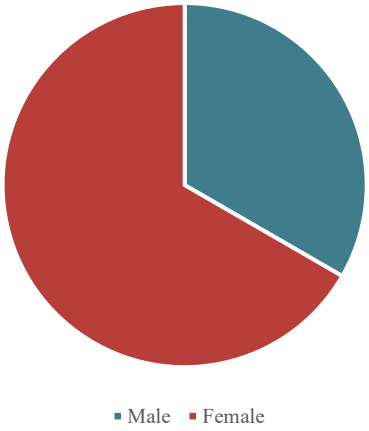

Figure 4.3: This graph shows the gender distribution of parents from interviews.

These parents represented 39 children in total. Of the children 51% were boys and 49% female (Figure 4.4). These were 2-3 years old (8%), 4-5 years old (12%), 6-7 years old (23%), 8-9 years old (36%), 10-11 years old (13%), and 12-13 years old (8%) (Figure 4.5).

Figure 4.4: Gender Children

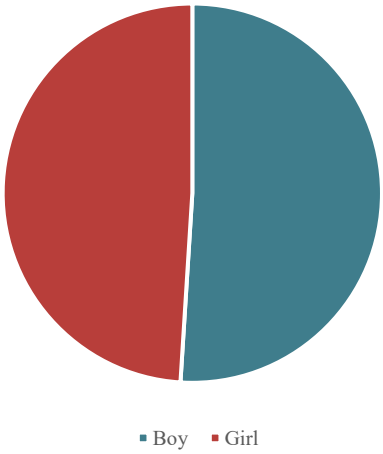

Figure 4.4: This graph shows the gender distribution of the children parents represented in interviews.

Figure 4.5: Distribution Childrens Age

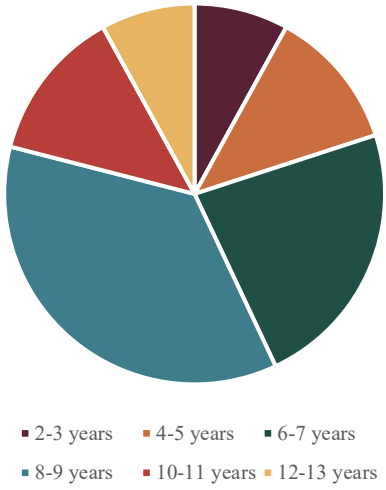

Figure 4.5: This graph shows the age distribution of the children parents represent in interviews.

4.2.2 Built Environment Factors

Throughout the interviews parents mentioned several built environment factors which influenced their perceived traffic safety. A summary of the main built environment factors mentioned and their directional influence on perceived traffic safety can be seen in Table 4.3. The following sections provide more in-depth information on crossing design, crossing type,

bike path design, bike path type, construction, road surface, and road design factors in more detail.

Table 4.3: Overview of built environment factors which influenced parents' perceived traffic safety mentioned in interviews and mental maps. They are sorted into negative which decreased perceived safety, positive which increased perceived safety, and uncertain where responses varied.

	Negative	Positive	Uncertain
Crossing Type	w/outlines only	w/traffic light	w/zebra crossing (for pedestrians)
		w/Crossing Guard	
Crossing Design	Little overview	Speed managing infrastructure	
	Many crossings	Over/underpass	
	Many lanes		
Bike Path Design	Narrow bike path	Wide bike path	Two-way bike path
	Cross traffic bike path	Physical barrier to road	
Bike Path Type	No walking/bike path	Bike path without car road	Bike first street
	Drawn bike path	Separated/raised bike path	
Construction Work	Changing path		
	New road actors		
Road Surface	Cracks/holes in the road		Asphalt
			Cobblestone
Road Design	Travel against traffic	Travel with traffic	
	Narrow road	One-way traffic	
	Parked cars		

4.2.2.1 Type of Crossing

Traffic crossings were brought up by most parents. Specifically, the type of crossings their children encounter on their school routes impacted parents' perceived traffic safety. All crossing types had both positive and negative stories. However, across the board traffic light crossings mostly improved parents' perceived traffic safety, while zebra crossings remained split.

In the interviews, crossings with traffic lights were predominantly related to higher perceived safety by parents. Participant 11 explained that traffic lights were easy to navigate: *"Yeah, and then there's traffic lights. So, it's also very clear for our kids. OK, it's red so we can't go, or it's green and we can go."* Participant 16 also mentioned that if the traffic light frequently switched children did not get impatient waiting: *"...and the big crossing over here, when the traffic lights are on, ...they really deal well with cyclist. Because we get often green lights and it's going very fast. So, the children always, they know that the green lights will come soon. So, they all wait for the green light ..."* Nonetheless, participant 18 mentioned that short green periods decreased the safety of the crossing, because they needed to move quickly. Participant 13 further revealed that sometimes the traffic lights were not respected: *"There are traffic lights here. This intersection, yeah. ...It has traffic lights. But, cyclists going this way and that way ignore them."* Therefore, while interviews showed that crossings with traffic lights generally

increased the perceived traffic safety, this was not the case if the green period was short or the light was not respected.

In interviews the impact of zebra crossings on perceived safety was more ambiguous. Some parents considered them safe: *"So, like here there's like, a zebra crossing. So, you know, also at a certain point, the cars will stop. You know if somebody's crossing, they will stop. … They do respect it.*" (Participant 3). Several parents mentioned teaching the children to walk across the zebra holding the bike to increase their perceived safety: *"There's a zebra crossing for people who walk. So, I teach them that if they want to go to school by themselves, and if they have doubts, they can always go on the, on the pavement and then take the zebra crossing to the other side. Then you continue by bike."* (Participant 18). Similarly, Participant 5 explained: *"So, we asked them to cross walking. So even if they cycle, they need to cross at the zebra crossing with the bike in the hand."* However, several interviews also highlighted parents' concern with zebra crossings, especially if they were not respected by other road users. Participant 5 explained: *"There's a 50 km/h road with three zebra crossings, that no one actually stops for. So no, in the morning I wouldn't even consider this a route."* Likewise, Participant 13 recounted a story from a road with two zebra crossings and a middle island splitting the road. A pedestrian had already crossed halfway but was unable to cross the second half because no bikes stopped for them. Lastly, Participant 15 reflected that while adding zebra crossings in their school zone in principle would be positive, it might also cause children to expect cars to stop and thus be less careful when they cross the road, which was a concern to them. Thus, interviews and mental maps indicated that zebra crossings could benefit parents' perceived safety, when children used them walking. However, parents did not always feel confident that other vehicles would stop at the crossing muddling the positive impact on perceived traffic safety.

Overall, interviews suggested that the type of crossing plays a role in parents' perceived traffic safety, where traffic lights were mostly positive, while zebra crossing remained uncertain. Though, for all crossing types it was important that parents trust that other road users will respect the crossing.

4.2.2.2 Crossing Design

Many parents also outlined crossing designs which both increased and reduced their perceived traffic safety. Low visibility and many lanes in the crossing decreased perceived safety, while crossings which circumvented traffic or had speed managing infrastructure improved the perceived safety.

Low visibility/overview was mentioned in nearly all interviews and reduced parents' perceived traffic safety. Participant 3 outlined: *"You know they (cars) want to go as fast as they can. And so, they drive at least 50 km/h, but it's like a hill. It's on top of the hill. So, you see them coming very late. You can hear them, but you cannot see them coming."* Participant 12 further explained: *"There's one intersection. This intersection where you can't see the other traffic*

coming this way until like very late. So, it's hard to like, because also you're actually going downhill right here. So, you come into this kind of quick and then sometimes it'll be a car coming in all of a sudden. And they like slam on the brakes." Accordingly, interviews showed that low visibility in crossings made parents feel less secure coming into the crossing with their children, probably because it prevented others from seeing the children and vice versa.

Similarly, around half the parents mentioned crossing multiple lanes with their children as a risk factor. Participant 4 explained that having to navigate multiple lanes made them uncomfortable. Participant 10 also expressed a wish to break up larger crossings for easier navigation: *"I really would love it if they would have an island or…. Yeah, something in the middle. Because this is a bike lane, two-way street, and then a bike lane."* Hence, interviews indicated that multilane crossings felt more uncomfortable to parents and increased their perceived traffic risk.

A handful of interviews indicated that crossings which avoided traffic altogether (bridges/tunnel) or were preceded by speed managing infrastructure increased parents' perceived traffic safety. Participant 2 discussed how they felt safe biking in their area, because bike crossings were mostly built as either over- or underpasses avoiding cars: *"Yeah, and there's hardly any crossings. So typically, there's underpass or overpass…. So, that's also very helpful."* Participant 11 reflected on choosing a different location to cross a road, because it was preceded by speed bumps, forcing cars to slow down: *"But if we go like this then here there are speed bumps for the cars, so they have to slow down and then the crossing is easier."* Thus, crossing designs which forced traffic to slow down or allowed parents to avoid traffic altogether increased their perceived traffic safety.

Accordingly, interviews indicated that while multilane crossings and crossings with little overview reduced parents' perceived traffic safety, speed managing infrastructure and crossings which avoid cars increased the perceived traffic safety.

4.2.2.3 Type Bike Path

In interviews parents differentiated between bike path types when linking them to their overall perceived traffic safety. The main distinction was between bike paths which did not separate from the car traffic (no bike path or drawn bike path) which had a negative impact, and bike paths which split from traffic (separate bike paths and stand-alone bike paths) which had a positive impact on perceived traffic safety. Bike first streets, which are streets where bikes have priority but cars and buses are allowed, were more divisive and had a variable relation to parents' perceived traffic safety.

In general parents viewed bike paths which had no physical delineation from other traffic as less safe and tried to avoid them. This generally referred to situations where roads had no bike path or the bike path was only drawn on the road. For example, Participant 12 mentioned: *"And there'll be times bus is coming in so fast. I don't want my kids standing there with paint*

protecting them. It's just a little too much going on there." Participant 7 also expressed concern: *"In town there is like this really busy road where the buses go two ways and two directions, and there's, there is no separate cycling lane. So, then we don't go there."* Consequently, interviews suggested that bike paths which did not physically separate the bike infrastructure from the other traffic infrastructure increased parents' perceived risk.

However, bike paths which were separated from the car infrastructure had overwhelmingly positive responses. Participant 7 explained picking a path specifically because there were no cars around: *"And then if, so, if we all cycle, we go like this, because there are no cars here. … Actually, it's walking only, but it's allowed to cycle."* Similarly, Participant 4 chose a bike path because it had a physical split from the cars when biking with their child: *"And you know, my child can go ride their bike without a problem, because it's cars, grass, my bike path. And I can go in parallel with them."* Interview responses also indicated that parents felt safer on these paths: *"So, here you're separate from the cars. So, you're, you're safe. (chuckle) Well, I'm laughing about it, but actually it feels like that, if you arrive on the cycling path."* (Participant 11). Separation could also support parents' engagement in independent mobility: *"But we let them cycle alone home already for three years I think because all the cycle paths are separate and only the bus crossing, we practice it with them and then it's safe."* (Participant 16). Thus, interviews suggested that the availability of bike paths which were separated from other road actors improved parents' perceived traffic safety.

Bike first streets had contradictory responses and hence were both positive for parents' perceived safety due to size, and negative due to traffic integration. Some parents indicated that the width of the streets as well as flat road made the bike first street easy to navigate: *"I find the bike first street, which is also level, so much more relaxing because there's just more space."* (Participant 9). However, Participant 3 explained that to them the bike first street appeared less safe, because their children were uncomfortable cycling there alone. The integration with cars on the street created pressure for the kids to bike faster. Participant 6 also explained that the bike first street could get quite busy with traffic jams, which was problematic when biking there. Hence, bike first streets had a more uncertain relation to perceived traffic safety which depended on the parents' experience.

To conclude, the interviews and mental maps indicated that biking paths which integrated with other road actors decreased parents' perceived safety, while bike paths which remained separate from other road actors improved parents' perceived traffic safety. The main exception was bike first streets which had a more variable relation to traffic safety.

4.2.2.4 Design of Bike Path

Interviews indicated that when considering the design of bike paths, the main factors mentioned by parents were cross traffic, the size of, and the travel direction(s) on the bike path.

Cross traffic on the bike path decreased parents' perceived traffic safety in a few interviews. Parts of the route where the separated bike paths had cross traffic were considered less safe: *"…But you pass by a gas station. And if you are very awkward, you could say, well, that place is a little bit less safe, because cars are entering and leaving the gas station and then crossing the bike lane."* (Participant 17). Participant 6 also mentioned how two different stretches of the same bike path felt more and less safe, because the latter had cars crossing the bike lane coming out of an underground parking lot. Accordingly, interviews suggested that allowing cross traffic over the bike path decreased parents' perceived traffic safety.

Overall, interviews indicated that wider bike paths improved, while narrow bike paths reduced parents' perceived safety. Several parents mentioned the positive impact of wider bike paths: *"And it's very separated and there's a lot of space, so that's a nice spot to... It's easy to bike right next to each other and chat."* (Participant 10) and *"Yes, and I find the bike first street, which is also level, so much more relaxing because there's just more space."* (Participant 9). Conversely, narrow bike paths concerned parents: *"And basically, that's also because the bicycle path isn't big enough, but also on your side, there's no room for error. So, there is this curb. And if you get close to the curb, then your pedal can actually kick the, kick the curb. And then you… So, you have little margin with respect to the curb."* (Participant 5). Participant 9 discussed driving into town: *"I find that super hairy. But I've always found it very hairy, because the bike path is so small. Yeah, and then there's this ridge.... Yeah, you would fall off, or you fall against the curb."* Hence, interviews indicated that wider bike paths in general improved parents' perceived safety, while narrow bike paths had the opposite effect.

In a few interviews parents also discussed concerns with two-way bike paths. However, most parents did not specifically see it as a worry. Participant 5 outlined that the challenge with two-way bike path was people veering into your lane with little space to move: *"Because in this part it's two way traffic and here it's one way traffic. So here, you have the problem that they are coming towards you, but then three wide on your side of the bicycle path."* Thus, two-way bike paths decreased the perceived traffic safety of some parents, because traffic could deviate into their lane.

Overall, the interviews showed that allowing cross traffic across a bike path and narrow bike paths decreased the perceived traffic safety of parents at that location. However, wider bike paths improved parents' perceived traffic safety. Two-way bike paths had less conclusive responses, but for a few parents they did have a negative effect on perceived traffic safety.

4.2.2.5 Construction Work

Several parents mentioned that construction along the travel routes, although temporary, decreased their perceived safety. The focus of responses was on new road actors and changes in the bike paths.

Several interviews mentioned that construction introduced new road actors to an area which parents' perceived as negative to traffic safety. Participant 11 explained how traffic was rerouted through the neighborhood during construction creating much more car traffic: *"They have these little poles inside of the road so that if the police have to go through or the fire department, they just can go through. But when there was construction over here, they put the poles down. So, so, there was a lot of traffic going this way."* Similarly, Participant 5 described the introduction of trucks in the neighborhood during construction, preventing outdoor play: *"So, with the revamping of the neighborhood this is a big thing. So currently we have lorries with sand traveling our street. And they (the children) are used to playing on the footpath. Yeah, that's temporarily, a no go. Because, well, the truck isn't going to stop for your ball. No, it's difficult to explain."* Thus, interviews showed that the sudden introduction of new road actors, due to construction, reduced parents' perceived traffic safety.

Another challenge with construction identified by some parents was the continuously changing travel path. Participant 2 explained that they had one crossing which, while they live in the area, never functioned as intended. This required them to change how they navigated the crossing every few weeks. While this was not a problem for the parents, the children found this very confusing. Consequently, interviews indicated that construction which continuously changed the travel path decreased parents' perceived traffic safety.

Overall, interviews suggested that construction increased parents' perceived traffic risk, because it introduced new and changing situations which were hard to teach the children.

4.2.2.6 Road Surface

While not as central as other factors, most parents discussed road materials' influence on parents' perceived traffic safety. The main materials discussed were asphalt and cobblestone.

Interviews highlighted that cobblestone was a less comfortable material to bike on, though it usually did not have a negative connection with parents' perceived safety. The majority of parents considered cobblestone in a positive context, because they were associated with slow and smaller roads. Participant 2 explained that cobblestone was uncomfortable: *"So, cobblestone is not nice. I guess the smaller your wheels are, the more annoying they are because they tend to affect your wheel."* However, the cobblestone forced cars to slow down as mentioned by Participant 5: *"So, they made it now 30 km/h and the cobblestones are really bumpy. So as a car you also can't really go faster without losing your feeling."* Thus, interviews indicated that while cobblestone was an uncomfortable material, its association with slow roads negated its potential negative impact on perceived traffic safety.

Similarly, in the interviews asphalt was described as comfortable and easy to navigate, though it was also associated with higher speeds, reducing the potential positive impact on perceived traffic safety. Participant 5 explained having two different route options, one with asphalt and one through the neighborhood. They chose the asphalted one when traveling with their kids in

a cargo bike, since it was more comfortable and faster, but also had more traffic. Participant 6 explained that they preferred a road due to asphalt: *"So even though there are cars that come out, even though there are underground parking garages it just it. Because it's sort of wider and also asphalt, like red asphalt, so it's bike priority, but also smooth and new, so it just feels good."* Hence, interviews and mental maps indicated that the asphalt was positively related to perceived traffic safety, because it was more comfortable to bike on. However, it was also linked with high volume and speed, reducing the positive impact.

Overall, the material chosen did not have a clear association one way or another with perceived safety. While asphalt itself was preferred over cobblestone as a material, the association with fast and slow traffic respectively, muddled their relation to perceived traffic.

4.2.2.7 Road Features

Beyond biking infrastructure several interviews indicated that road design also affected parents' perceived traffic safety. Interviews mainly discussed the presence of car parking and road size.

Car parking on the road was mentioned by a handful of parents as a concern for safety. Participant 3 explained that they were worried when biking past parked cars next to the bike path, because if the cars opened their door, it could easily lead to an accident. Participant 5 outlined the risk of parked cars not seeing the children in time: *"And in both places, the problem is that the parked cars also lose sight of who's were, because it's just such a mess. So especially when they start driving, or they need to stop and then start up again. Yeah, that's a really tricky situation."* Thus, interviews indicated that parked cars increased parents' perceived traffic risk, possibly because parked had less awareness of their surroundings.

Around half the parents mentioned that narrow roads reduced their perceived traffic safety. Several parents mentioned narrow roads being too small to accommodate both bikes and other road actors: *"I don't like this route at all. … Because this road is, is actually a bit too small for having both cyclists and cars."* (Participant 11) and: "*So that's why I don't like going this way on that street, because then you're, because what happens all the time is like. It's barely wide enough for one bike and one car. Yeah, actually, it's not even wide enough for one bike and one car.*" (Participant 6). Participant 8 also discussed how narrow roads made it harder to protect children against other traffic: "*That is difficult when you are with your child and, say, cars coming down. There won't be enough space to be next to them to protect them. And I think that will be difficult.*" Hence, interviews and mental maps reflected that in general narrow roads decreased parents' perceived traffic safety.

To conclude, both parked cars and narrow roads decreased parents' perceived traffic safety in interviews. The former because drivers might have less overview, and the latter because it left less room for parents to navigate with their children.

4.2.3 Interaction Factors

When discussing perceived road safety in the Dutch bike-oriented context several factors mentioned related to the behavior of, and interaction with other road users. This section explains the main interaction factors mentioned by parents in interviews and mental maps, and shows their directional association with parents' perceived traffic safety. Table 4.4 provides a summary of the factors mentioned and whether they had a positive or negative influence on parents' perceived traffic safety.

Table 4.4: Overview of interaction factors which influenced perceived safety mentioned in interviews and mental maps. They are sorted into negative which decreased parents' perceived safety, positive which increased parents' perceived safety, and uncertain where the impact is ambiguous or not specified.

	Negative	Positive	Uncertain
Speed	High/variation in speed on road	Slow traffic	
	High/variation in speed in crossing		
Volume	Large volume on road	Calm traffic	
	Large volume in crossing		
Conflict with Other Actors	Bikes		Pedestrian
	Cars		
	Bus		
	Delivery drivers		
	Electric bikes		
	Fat bikes		
	Large vehicles		
	Scooter		
	Youth groups		
	Many different modes		
Illegal/Dangerous Behavior	Cut turn		
	Illegal behavior by children		
	Illegal behavior by other road users		
	Unclear right of way		
Other	Unpredictable situation	Ability to keep right turn	
	Accidents	Others think along	
	Crime occurrence	Neighborhood cohesion	

The following sections provide in-depth information on the most prominent factors identified in interviews, including speed, volume, conflict with other actors, illegal/dangerous behavior, unpredictable situations, accidents, right turns, and anticipation of other road actors.

4.2.3.1 Speed

Most parents mentioned that high speed negatively impacted their perceived traffic safety. They initially mentioned both high speed and variation in speed as prominent issues, though for both the main challenge was the difference in speed between the children and other road actors.

Thus, this section explores how integrating with and crossing fast-moving traffic reduced parents' perceived traffic safety.

Most parents mentioned feeling unsafe when navigating fast moving traffic with their children. Participant 3 explained how they usually bike next to their child, which allows little space for faster bikers to pass them, creating an uncomfortable situation: *"People go fast, so it's also stressful. I have often, I have many people behind me. And I feel like, OK, I go 25 km/h already. I am here with my child. I will not leave them for you. No, just wait for one minute."* Participant 8 reflected how fast cars had a negative impact on their safety feeling even when there was a bike path: *"It's a big road. So, there is a lot of space, and the cars then go quite fast. So even though it has a cycle path, it just feels unsafe to go here."* Hence, most parents reflected that the presence of fast-moving road actors, across various travel modes, increased their perceived traffic risk.

Similarly, many parents found crossing fast moving vehicular traffic concerning. Participant 9 explained how some cars came into their roundabout at a high speed, because they came from the highway. This required more attention from the children when crossing. Participant 5 explained a similar challenge when crossing bike traffic to get to school: *"Before you come at the, at the cars you need to cross that bicycle flow that goes roughly 25 to 30 km/h."* Likewise, Participant 16 expressed concern when their children needed to cross a bus road: *"...but the children have to go to this. Go cycling on this through going road where there's a bus really speeding with 50-60 km/h."* Responses from parents showed that crossing fast moving traffic of any kind was a major concern along their commute.

To conclude, in most interviews parents discussed how both integrating with and crossing fast traffic reduced their perceived traffic safety when biking with their children. The underlying causes for the concern were not always explicit. However, some quotes indicated that high speeds required more awareness from kids and parents.

4.2.3.2 Volume

The density of actors on the road influenced the perceived traffic safety of most parents interviewed. Parents distinguished between high traffic density which was challenging when integrating with or crossing traffic flows, and calm traffic situations which increased the perceived safety of the route.

Most parents mentioned that high traffic density decreased their perceived safety, though the importance of the factor varied between parents. Some parents avoided busy roads altogether: *"And I avoid this street, which is very busy."* (Participant 11). For others it contributed to their perceived traffic safety, but did not define their choice. Participant 12 explained: *"This one is super busy too. ... And it's, and it's a relatively narrow bike path. So, they are not going super-fast, the kids. We're getting blasted by people trying to pass. It is just busy, not necessarily problems, but it's like hey guys stay right because we're getting passed."* Participant 4 also

mentioned how parents sometimes need additional space when they teach their children to bike, because they frequently biked next to them, making high density more challenging. Overall, the interviews and mental maps indicated that for most parents high traffic volumes decreased their perceived traffic safety, maybe also because they needed more space navigating traffic with their children.

Unsurprising, crossings with large volumes passing through also worried parents in interviews. Several parents mentioned trying to avoid busy crossings with their children: *"This is actually a well-regulated intersection with traffic lights for everyone. It's just really big and there is lots of traffic going on. So, like whenever I can I just avoid it, especially with my child."* (Participant 13). Participant 3 further explained that the large volume created confusing situations at crossings: *"There's an equal crossing here. This is, this is impossible, because you feel like you're the one coming from the right and can go first. But then you know, there's so many cars. So, at a certain point, nobody knows who has to go first."* Participant 10 also mentioned how the mismatch between volume and infrastructure could generate a bottleneck: *"But these places where you can stand and wait are quite small, and a lot of people with kids have to go in that direction. Meaning that if you are standing to wait to cross the street, you always have to, you also have to take into account if there are already people waiting there."* Consequently, interviews highlighted that high traffic volumes at crossings in general decreased parents' perceived safety.

It follows that most parents discussed how calm roads with low traffic density increased their perceived safety when traveling with children. Generally, parents mentioned that calm routes were more relaxed and easier to navigate: *"It's very calm and a lot, and enough space. And we always are very relaxed on that, that part. And so that. I think that's it.*" (Participant 10). Participant 6 explained: *"It's a little bit more restful. There's not a lot of through traffic happening. There's almost primarily only bikes here or very slow-moving cars and it's, it's very contained."* Thus, the interviews reflected that for most parents calm traffic was something they specifically looked for to increase their perceived traffic safety.

Consequently, in interviews most parents referred to large traffic volumes as a factor which decreased their perceived traffic. Likewise, low-density traffic increased parents' perceived traffic safety.

4.2.3.3 Conflict with Others Along Route

Conflict with other road actors was a concern mentioned in nearly every interview, though the type of actor and the context of the conflict varied greatly. In this case conflict is simply broadly an issue or challenge with a specific category of road actors (e.g. cars, buses etc.). This factor had a complicated association with perceived traffic safety. Some parents mentioned various road actors in a negative context, while other parents treated road actors as more neutral factors. Therefore, while their impact on parents' perceived traffic safety was predominantly negative,

this association was not the case for all parents. A few road actors discussed in more detail are fat bikes, buses, and cars.

Fat bikes were referred to as a challenge by around half the parents and decreased their perceived traffic safety. Participant 10 explained: *"So, in this spot, it's a nice spot to bike. But we always pass, in the morning, one or two of these fat bikes with very young children on them. And that's, I always find it very scary because they will never watch out. They go way too fast. And sometimes they are with two or three on one bike."* Participant 4 further discussed the impact of fat bikes on AST engagement: *"If someday my child goes alone to school, it's something you cannot control. Maybe you will decide, don't go alone, I will go with you, because of these bikes. Because my child can do everything perfect and still have an accident."* Consequently, in general the interviews showed that the presence of fat bikes decreased parents' perceived safety. Through the quotes indicated that an underlying worry for parents were the user group and their behavior.

Buses were mentioned as problematic by around half the parents. Participant 5 mentioned preferring their children to take a bus free route when traveling alone: *"Well, if they go alone, I actually prefer them to be on this one (bus free). Oh, cause here is the bus on this 'brilliant' path. And the bus is, well yeah, basically has little room. So, if there's a bus and a car you're screwed as a cyclist."* Participant 16 outlined issues with accidents and buses: *"So, the buses go on with a very high speed, 50 km/h. And the children just cycle on the road like it's just still a cycle path. So, they go like whoosh through it and then lots of accidents happen there with buses and children."* Participant 11 explained that while they did not see the bus as an issue, it made their children feel uncomfortable when it drove behind them, especially if it did not immediately pass them. Thus, interviews showed that while buses were not perceived as an issue by all parents, it still decreased the perceived traffic safety of several parents and sometimes even caused them to re-route.

Lastly, all parents mentioned conflict with cars as a factor which decreased their perceived traffic safety. Participant 16 explained: *"So, this is a very small crossing and on the on the crossing there's a parking area for a small supermarket. So, a lot of people come and park the car, go backwards, then other cars go with a high speed around the cars that are going backwards, and then you cycle and that's a little bit unsafe."* Participant 7 discussed how the number of parents which chose to still bring their children to school by car created a dangerous situation with cars in the school zone. Interviews showed that in general conflict with cars along travel routes reduced parents' perceives safety, probably because cars can lack overview or engage in risky/illegal behavior.

Overall, the interviews indicated that conflict with other road actors negatively impacted parents' perceived traffic safety. Though, the quotes suggested that most issues with other road actors did not per se originate in the road actors themselves, but it was rather their behavior

which resulted in increased concern. Therefore, while conflict with road actors impacted perceived safety one might have to look at the behavior to understand the context.

4.2.3.4 Dangerous/Illegal Behavior

Most interviews showed that experiencing illegal behavior in traffic reduced parents' perceived safety. In the interviews parents predominately delineated between illegal behavior by children and illegal behavior by other road actors.

In interviews parents mentioned several scenarios where other road actors acted illegally, creating an unsafe situation. A common behavior cited by parents was cars speeding through 30 km/h zones: *"I think it's allowed to go 30 km/h, but yeah, nobody actually does that. So, I think, yeah, I think that that is the main reason why I take the car."* (Participant 15) and *"Even then, there's too much, because in my neighborhood they are allowed to drive 30. ... But they are not doing that."* (Participant 14). Participant 10 also mentioned how one of their side streets fans out into the main road, which led cars and bikers to cut the corner and end in the wrong lane when turning. Lastly, Participant 6 explained how bikes went against traffic to reach their destination faster: *"The other one that's scary is here and here. This because a lot of people leave the sports facility and bike backwards against traffic."* Overall, the interviews demonstrated that for many parents illegal behaviour by other road actors decreased their perceived traffic safety, probably because it created false expectations and uncertain situations.

Likewise, parents also worried about the children engaging in dangerous behavior, especially in the context of independent mobility. Participant 15 for example reflected on unsafe behavior by other children: *"So, when they are in a hurry, especially in the morning next to school, there are a lot of kids that just cross the roads without looking. And when a car goes too fast. And I don't know it's, it's just, I get pictures in my head that that's making me nauseous."* Participant 3 also highlighted the link between being distracted and risky behavior: *"A lot of people, a lot of children, they are just busy with being on time in school and not busy with crossing the road and directly looking."* Thus, the quotes showed that if parents were worried about their children engaging in illegal behavior, they also perceived the route as riskier. Though, this might be more relevant for an independent mobility context.

Overall, the interviews indicated that illegal behavior both by children and other road actors decreased parents' perceived traffic safety. The context of the quotes implied that parents' concern was related to the unpredictability and inconsistency which came with the illegal behavior.

4.2.3.5 Accidents

Traffic accidents were another factor which reduced perceived traffic safety, mentioned in about half the interviews. Based on interview responses, severe traffic accidents had a large impact on perceived traffic safety, often acting as a deciding factor to avoid certain areas. For example, Participant 7 explained: *"We don't go into town because, yeah, it's too dangerous.*

Yeah, I think like four years ago one of the children from school was hit by a bus. And they died. So, the awareness is really high." Similarly, Participant 17 mentioned: *"My partner tends to avoid that area, especially with the children. Because close by the station, not last year, but the year before, a little child was killed by a bus there."* Consequently, interviews and mental maps indicated that traffic accidents negatively influenced parents' perceived traffic safety and even acted as a deciding factor in route choice if severe.

4.2.3.6 Free Right Turns

A hand full of parents discussed how the ability to keep a right turn, avoiding crossing traffic, increased their perceived traffic safety. Participant 9 outlined how a route was safer on the way home, because they did not need to cross traffic: *"That's the most difficult. And that's on the way in, you have, so, you have all these crossings. But on the way back you can, you can just take the inner corner of the roundabout and you don't have to do any crossings, and that's way easier."* Participant 3 explained a similar situation: *"So, I would say this crossing is a big worry for me. But on the way to school, this is not a problem, because you stay on the right side."* Overall, a few parents indicated that maintaining right turns along the route increased their perceived safety, because it allowed them to avoid crossing traffic.

4.2.3.7 Anticipation of other road actors

Several interviews indicated that other road actors anticipating children's traffic behavior, and adjusting their choices accordingly, increased parents' perceived traffic safety. In several interviews parents mentioned that other road actors showed awareness of children in school areas. Participant 11 explained how they needed to cross a fast-moving bike stream directly in front of the school. However, since most people knew that the school was there, they were aware of them and adapted their biking style. Similarly participant 18 mentioned: *"It's quite busy, but everything works because everyone knows. Everybody wants to have their children safe at school. Sometimes you get right of way even if the cars come from right."* Thus, interviews indicated that road actors which were aware of the children and adjust their behavior accordingly increased parents' perceived traffic safety.

4.2.3.8 Unpredictable Situations

The last interaction factor discussed in most interviews, unpredictable situations, was less specific, but often described as a root cause which reduced parents' perceived traffic safety. Unpredictable/chaotic situations were more abstract in that they could not be associated with a specific road actor or behavior. Nonetheless, because several parents mentioned chaos as a factor which increased perceived traffic risk, it is briefly discussed. For example: *"So, it's, it's everywhere. Traffic is behind your back, it's in front of you, kids are everywhere. It's just big chaos."* (Participant 5) and *"So, in this case, not the amount of cars, not the amount of people, the amount of bikes, or that you have to cross, but the chaotic feel of it, that's what makes it unsafe."* (Participant 10). The challenges of unpredictable situations were mentioned by several

participants. Participant 4 explained that a concrete rule can be easily explained to the children, but teaching children to cross when a place feels safe is difficult. Participant 10 further elaborated: *"I think the only way you can deal with chaos is if all the rest is automated. So not only the technical, but also the looking around and the looking over your shoulder and pointing your direction. All of that has to be, go automatic. So that you don't have to think about all of these things, and for kids this is not an automatism. Yeah, so they have to also think about that. Can you imagine how chaotic it then becomes?"* Interviews suggested that experiencing traffic situations which were seen as chaotic or unpredictable in traffic reduced parents' perceived traffic safety. The role of uncertainty in parents' perceived safety is elaborated on further in the discussion (Section 5.2).

4.2.4 Other Non-Route Specific Factors

While not a core focus of this research, the flexible nature of the interviews allowed parents to share other factors which influenced how they assessed road safety. Scanning the interviews more broadly showed that many parents brought up their children's characteristics and their own approach to risk as elements which changed their traffic safety perception.

4.2.4.1 Children's Characteristics

Interviews indicated that how parents' perceived their children's biking skills and ability to navigate traffic influenced what situation parents considered risky and the amount of AST they would engage with. The age and gender of the children was mentioned as non-essential, because parents usually travel with all their children as a unit.

In general, interviews indicated that if parents assumed their children lacked biking skills, they would be more cautious when engaging with AST. For example, Participant 1 explained how children can still make mistakes when biking: *"But generally, roads where there are trucks or where cars drive fast. … That would, I would avoid. Yeah, because children, they fall sometimes."* Similarly, Participant 11 explained that they changed to an easier route when they traveled with all children: *"So, that's one of the reasons and the other reason is that my youngest child, yeah, they are very experienced at biking, but less experience than my oldest child. So, it's more comfortable to go along with the traffic."* Lastly, Participant 16 reflected on seeing other parents opt for cars, because their children were less confident bikers: *"I know there's a lot of other people, they just take the car because their children are, like wobbling with cycling …"* Consequently, interviews indicated that children's biking skills influenced how safe or unsafe other factors felt to parents.

In the interviews parents also discussed children's ability to safely navigate traffic. The navigation skills depended on children's traffic focus. For example, Participant 10 explained the difference between their children: *"The oldest is very on task. So, if their task is to drive safely to school or back, yeah, they will pay attention to this. My youngest is a dreamer. And that's very different. So, they are younger, of course. I don't know how they are going to do,*

what they are going to do when they are 10-11 years old. But they want, they have a big sibling, they want to drive to school by themselves as well. That's not possible because they are a dreamer. They can still be busy with their Pokémon in their head while biking and not paying attention to anything. So, that guides my decision." Similarly, Participant 16 reflected how caution and focus allowed them to feel confident in allowing independent mobility: *"I think the choice you make, or the, the, the things you let your children do is also dependent on the character and the, the person your child is. So, my children are both very cautious with crossing. If I say you really have to watch this crossing very well, they also do that. So, when they go to friends somewhere in town they just go there and come back home alone. I'm not that scared, because they will always take a safe path and when they have a dangerous crossing, they always look very well. So, it's also, my choice is also depending on how my children react to the traffic."* Participant 16 further explained that for many parents the cycle diploma represents a form of transition point where children must demonstrate navigation skills: *"So, in seventh grade, when they're 10 or just 11, they all have this cycle diploma. And that's also most of the time the swapping point for parents to let their children cycle alone to school or not. So, the classes one till six, they don't have the exam, so they cycle with their parents. And seventh and eighth grade when they have this cycle diploma that's normally the point that the parents say: OK, now you know how to cycle and you know the rules, so, you can go by yourself."* Consequently, children's ability to focus and have an overview of traffic, altered how risky a situation appeared to parents when traveling with their children.

Lastly, most parents interviewed in this project had more than one child and made decisions about AST as a group. Participant 13 for example explained: *"Generally, with me, my eldest goes by themselves when the timing doesn't line up. Twice a week they also go home alone. I think I would just let them go by themselves all the time, if it wasn't for my youngest who I have to bring anyway."* Thus, this research could not set up a link between age and parents risk evaluation. Though this result might imply that if parents do not distinguish then neither should traffic design.

In conclusion, the quotes suggested that children's ability to bike mitigated parents' perceived safety and therefore likely how they engaged in traffic. Children's ability to navigate traffic linked more closely to the trust that children could handle a risky situation themselves and therefore probably independent mobility.

4.2.4.2 Parents' Characteristics

Interviews indicated that parents' personal approach to traffic risk also played a role in what they considered risky, but more importantly how they navigated the situations. Parents' approach to risk was predominantly split into teaching or avoiding risky situations. Most parents combined both approaches.

Several parents mentioned focusing on teaching risky traffic situations, to allow children to navigate them safely. Participant 18 explained how the children learned to navigate the garbage

truck in the area: *"They have to learn. And now they know that you can go on the sidewalk for a little bit and then you can pass, or, if there's room, you can check whether it moves or it's busy with the garbage cans, and then you can just pass because it won't move. Yeah, I think if there is a problem they have to learn. And that's the only way to teach them how to hand the traffic if I'm not around."* Similarly, Participant 3 discussed teaching children how to cross correctly: *"And I always tell the children, you need to look at the driver. If they see you. When you have eye contact, then it's OK. Otherwise, don't go. So, it's, they really need to learn, so, to put their hands, like almost up."* Participant 18 outlined that rather than considering traffic unsafe, they simply framed it as harder and easier to teach. In all examples, parents followed an ambition to reduce the potential risk, by teaching their children how to handle harder situations.

Alternatively, interviews also indicated several situations which parents avoided, to decrease the overall risk. This was usually related to substantial danger. For example, one parent outlined that to them some roads were simply too risky due to busy traffic: *"Yeah, but I definitely wouldn't do the road with the kids. No. Many people would, but we wouldn't. It's really busy with traffic."* (Participant 8). Similarly, Participant 5 outlined a route they would avoid, which also had been the scene of traffic accidents in the past: *"There's a 50 km/h road with three zebra crossings, that no one actually stops for. So no, in the morning I wouldn't even consider this a route."* In both scenarios parents avoided situations which they deemed too risky for their children, based on their understanding of the traffic.

Overall, interviews indicated that parents approached a risky traffic situation either by avoiding it or by teaching their child. Which one they opted for defined how they interacted with the situation, and likely also the extent to which they engaged with AST. However, most parents used a combination of both teaching and avoiding.

4.2.5 Summary

Overall, the interview and mental maps highlighted a wide variety of factors which influenced parents' perceived traffic safety both positively and negatively (see Table 4.3 and Table 4.4).

The main built environment factors mentioned were crossing design, crossing type, bike path design, bike path type, construction, road surface, and road design. Interviews indicated that the type of crossing played a role in parents' perceived traffic safety, where traffic lights generally had a positive impact, while zebra crossings were more uncertain. Moreover, multilane crossings and crossings with litter overview decreased parents' perceived traffic safety, while speed managing infrastructure and crossings which avoided cars reduced the perceived traffic risk. The interviews and mental maps also indicated that biking paths which integrated with other road actors decreased parents' perceived safety, while bike paths which remained separate from other road actors improved parents' perceived traffic safety. Additionally, no cross traffic as well as wider bike paths in general improved parents' perceived

traffic safety. Overall, the interviews indicated that construction, parked cars, and narrow roads decreased parents' perception of traffic safety. Lastly, the material chosen was not a direct indicator one way or another for parents' perceived traffic safety.

The main interaction factors mentioned were speed, volume, conflict with other actors, illegal/dangerous behavior, unpredictable situations, accidents, right turns, and anticipation of other road actors. Parents mentioned that integrating with and crossing fast traffic, as well as large traffic volumes decreased their perceived traffic safety. Illegal behavior both by children and other road actors, unpredictable situations, and accidents also negatively impacted parents' perceived traffic safety. Furthermore, parents discussed a multitude of road actors which concerned them when biking with their children, though the direction of influences varied between responses. As one might expect given the above, interviews reflected that low traffic density, as well as maintaining right turns, and anticipation by other road actors increased parents' perceived traffic safety.

Parents also introduced the role of their personal approach to risk and children's characteristics as factors which influenced the overall magnitude of their risk perception in interviews. Parents' own approach to risk mediated what situations they were willing to engage in and how, while children's characteristics mediated how risky a specific situation appeared to parents.

4.3 Interplay Between Factors

As indicated in the quotes in Section 4.2 the various factors influencing parents' perceived safety were rarely mentioned in isolation. This section explores this tendency to see if the interplay between factors plays a role in parents' perceived traffic safety. Figure 4.6 shows the network diagram of the number of times two codes (e.g. accidents and buses, or illegal behavior and bikes) were mentioned together. The thicker/darker the line the more frequently the code pair was mentioned together, while the size of the circle is how often the specific code (e.g. buses) was mentioned in general (See Appendix H for the complete co-occurrence matrix). However, simply being mentioned together does not necessarily mean that the factors influenced each other. Thus, this research dove deeper into some of the factors which were frequently mentioned together, to see if the co-occurrence amplified the impact of the individual factors on parents' perceived traffic safety. Based on a scan of the co-occurrence matrix from Atlas.ti this section explores the links associated with low visibility crossings, narrow bike paths, fat bikes, and buses.

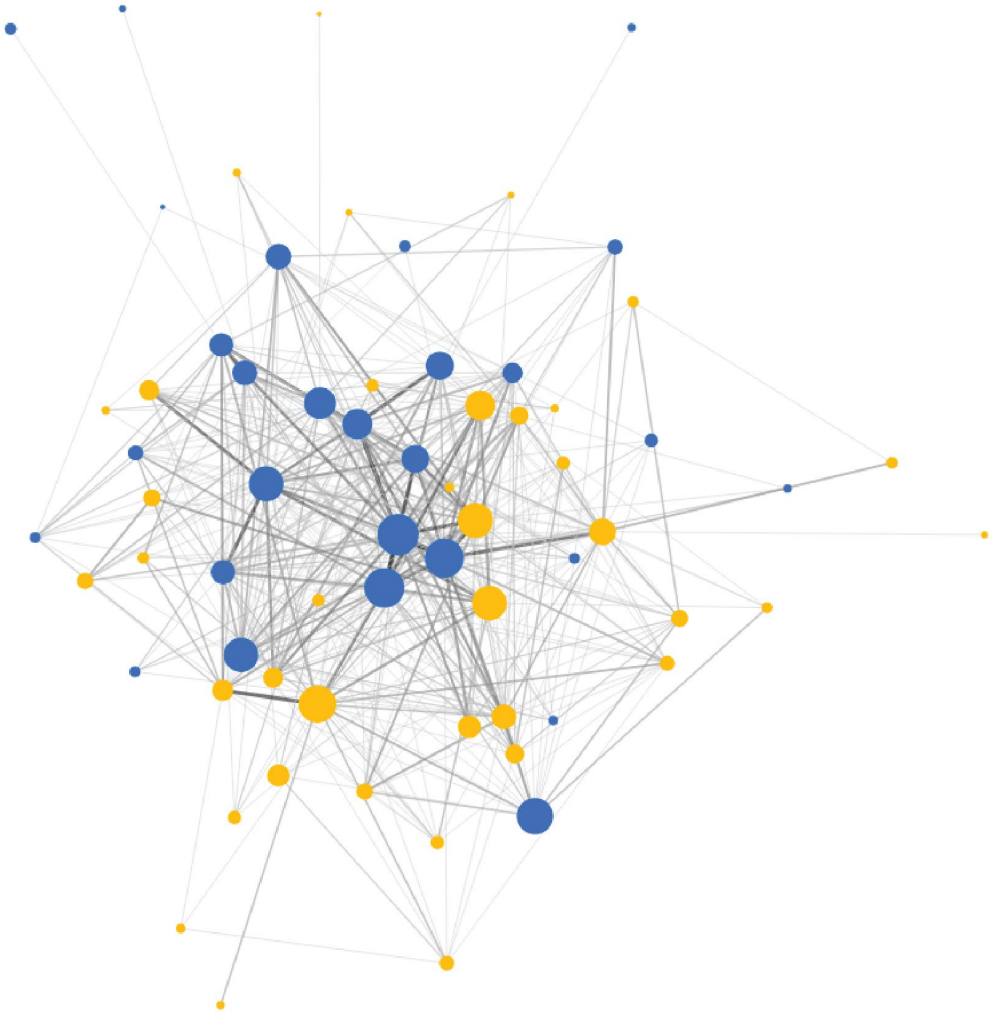

Figure 4.6: Network graph showing the number of pairwise co-occurrences of different code combinations (yellow is built environment factors, while blue is interaction factors).

4.3.1 *Low Visibility Crossings*

The co-occurrence matrix showed that crossings with little overview were frequently mentioned in combination with high speed and cars. Delving into quotes demonstrated that the combination of factors likely increased parents' perceived risk.

Figure 4.7 highlights the connections between crossings with little overview, high speeds, and cars. The network shows that all three factors were frequently mentioned together. However, the frequency of co-occurrence does not necessarily mean that the factors mentioned influenced each other. Only when looking at the context in the interviews is it possible to see whether the combination of cars, little visibility, and high speed also interacted with and increased the perceived risk of parents.

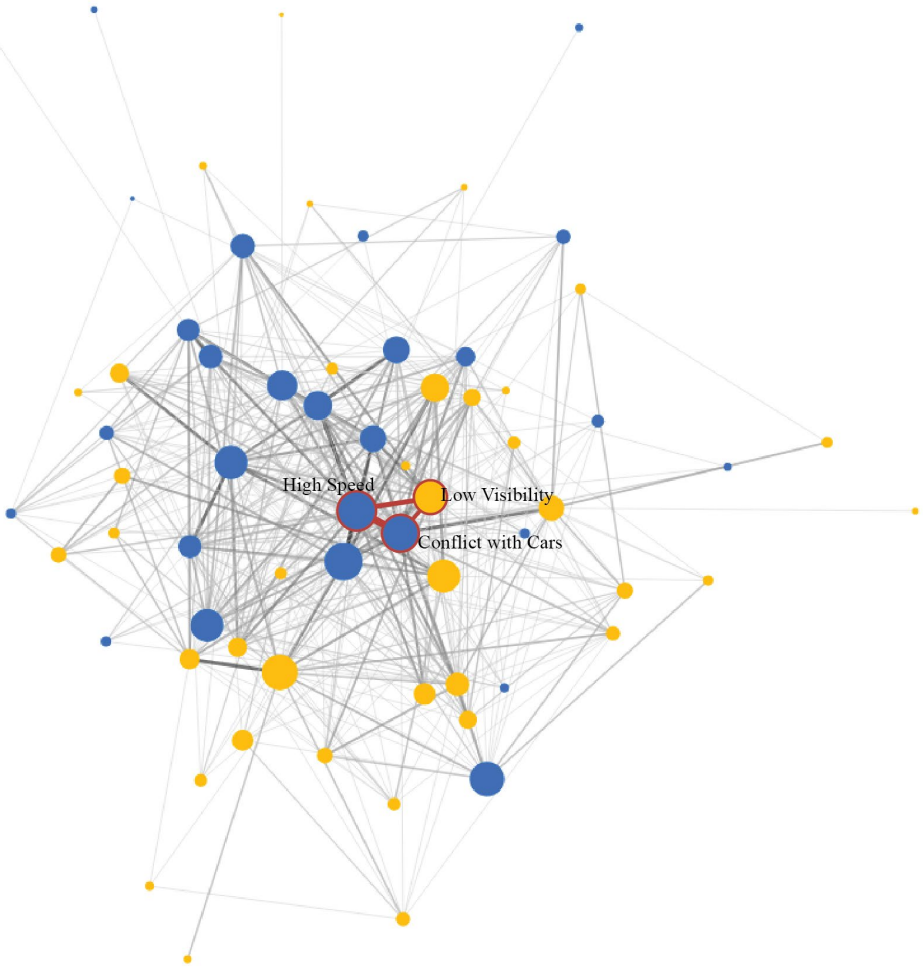

Figure 4.7: Network of co-occurrences, highlighting crossings low visibility, conflict with cars, and high speed (yellow is built environment factors, blue is interaction factors).

In interviews, the lack of visibility at a crossing was often mentioned in the context of not being able to spot a car in time. Thus, the low visibility was a challenge because of other events which happened at the same place. For example, Participant 12 explained: *"There's one intersection. This intersection where you can't see the other traffic coming this way until like very late. So, it's hard to like, because also you're actually going downhill right here. So, you come into this*

kind of quick and then sometimes it'll be a car coming in all of a sudden. And they like slam on the brakes." The intersection was highlighted because it was hard to see traffic coming, but the exacerbating factor for Participant 12 was that cars came in fast (see Figure 4.8). This forced cars to react quickly. Participant 3 also mentioned: *"You know they (cars) want to go as fast as they can. And so, they drive at least 50 km/h, but it's like a hill. It's on top of the hill. So, you see them coming very late. You can hear them, but you cannot see them coming."* Here again, Participant 3 discussed the issues of cars going very fast, but contextualized it by the crossing being in a position where you could only see the cars very late. Both quotes showed that the combination of factors introduced an element of uncertainty which created the unsafe situation perceived.

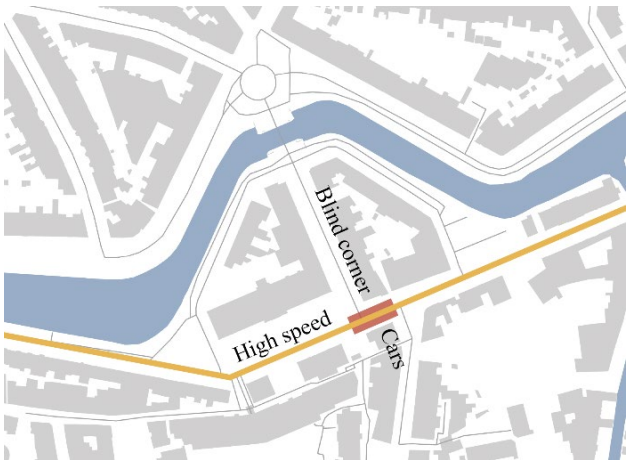

Figure 4.8: An example of how low visibility, cars, and high speed were mentioned together in one crossing (Participant 12).

Overall, both quotes highlighted a place where the combination of low visibility, presence of cars, and high speed created a more uncertain situation than any of the factors would in isolation. A low visibility crossing always carries a risk as one cannot see what comes ahead. However, if one adds higher speed this leaves less time to react and can lead to worse injuries in the case of an accident. Moreover, cars might have less overview than other modes. Thus, when retracing the situation, it was the combination of factors that exacerbated the danger experienced.

4.3.2 Narrow Bike Paths

In the co-occurrence matrix narrow bike paths and raised curbs were frequently mentioned together, interview quotes demonstrated that the combination likely exasperated parents' concern.

Figure 4.9 highlights the link between raised bike paths and narrow bike lanes. The network shows that both terms were frequently mentioned together.

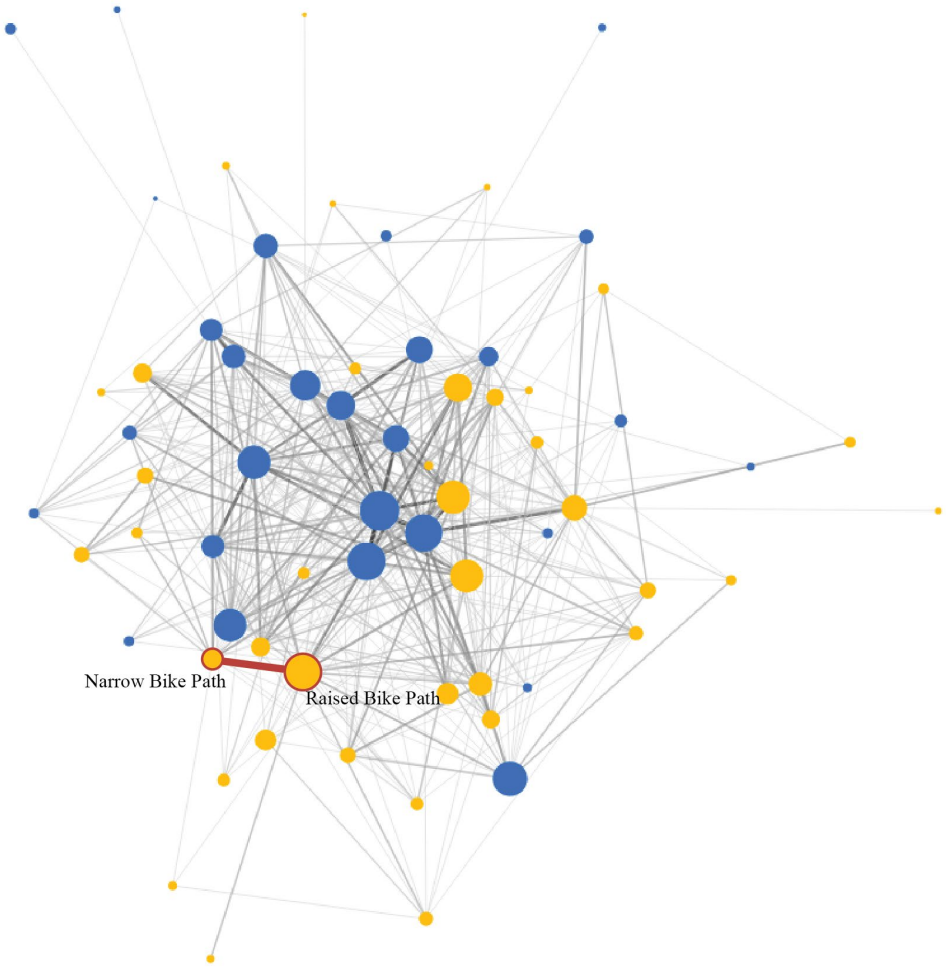

Figure 4.9: Network of co-occurrences, highlighting raised curbs and narrow bike paths (yellow is built environment factors, blue is interaction factors).

The context of interviews suggested that narrow bike paths were a bigger issue if a raised curb prevented parents from avoiding on-coming traffic. Participant 5 explained: *"And basically, that's also because the bicycle path isn't big enough, but also on your side, there's no room for error. So, there is this curb. And if you get close to the curb, then your pedal can actually kick the, kick the curb. And then you… So, you have little margin with respect to the curb."* From this it appears that while narrow bike paths were an issue to parents, the issue was amplified if there were raised sides, since it created less flexibility to veer to the side or avoid others on the bike path (see Figure 4.10).

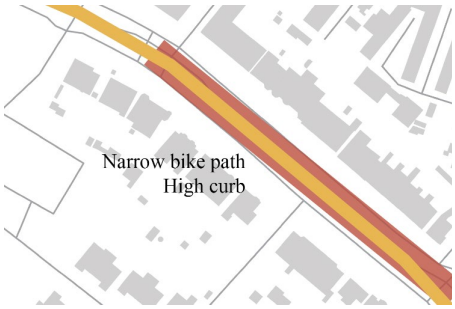

Figure 4.10: Example of a bike path marked as narrow with high curbs (Participant 5).

4.3.3 *Fat Bikes*

When considering co-occurrence fat bikes showed up often in combination with youth group and illegal behavior. Interviews showed that the combination likely influenced parents' concern.

Figure 4.11 shows the link between fat bikes, youth groups, and illegal behavior. However, the diagram does not illustrate if the connection also impacted parents' perceived traffic safety.

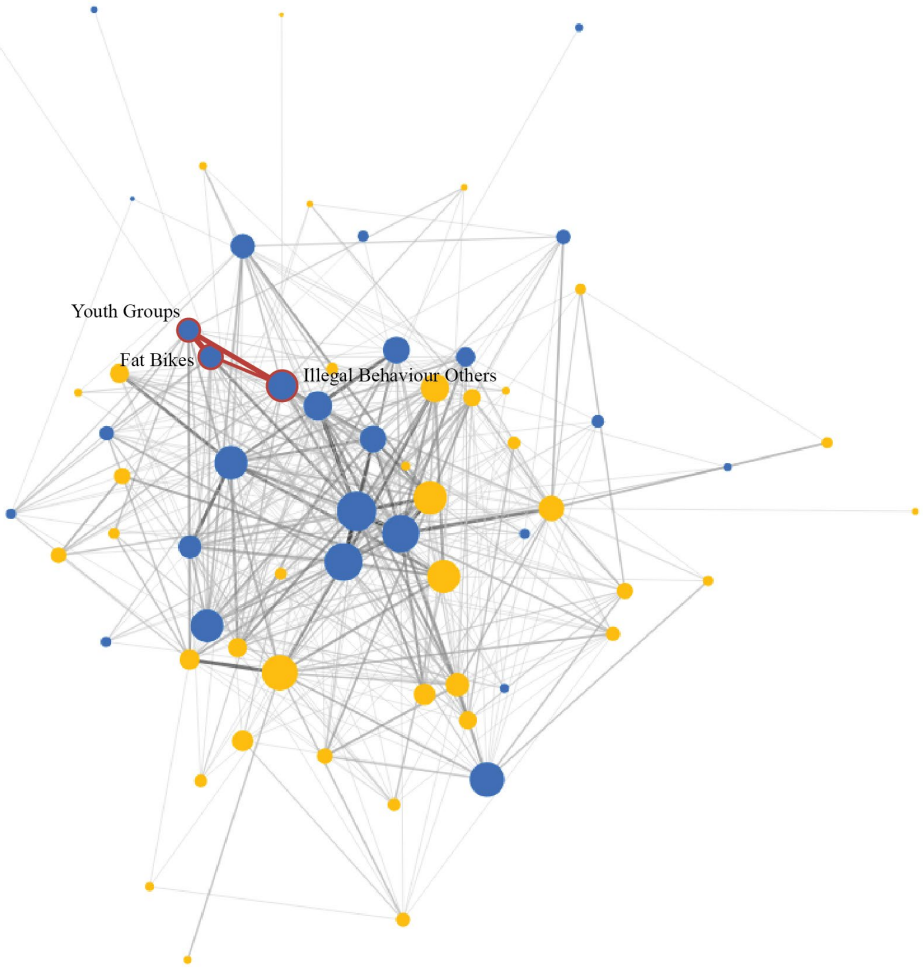

Figure 4.11: Network of co-occurrences, highlighting youth groups, fat bikes, and illegal behavior by others (yellow is built environment factors, blue is interaction factors).

Most interviews mentioned challenges with fat bikes, but rarely because of the bike itself. The responses varied but showed that the discomfort usually came from the bikes being driven by teenagers which frequently disregarded traffic rules. Participant 5 explained their problematic interactions with fat bikes and other modes: *"There's three high schools on that bicycle path, including a big share of mopeds, scooters, fat bikes, whatever you can think of. Preferably people hanging on the back of another fat bike. So, they form sort of these queues being dragged along. Not necessarily paying attention to anything else on the bicycle path …"* Participant 5 emphasized that they found the disregard for other road users in their behavior problematic. Participant 10 also differentiated between different users: *"They (fat bikes) go much more than*

25, and these kids are just way too young. If we're talking about chaotic in traffic and having the time to automate everything you need to know and act in traffic, these young kids don't have that. And so, they're just, they're just a danger on the road. Only them, actually, because there are also other people that move quite fast with an electric bike, but they are different people, so they're not these young kids, they're often these middle-aged men, actually." Figure 4.12 shows the location mentioned by Participant 10. Several parents specifically delineated between fast electric bikes and fat bikes, though the speed of the two was similar. Thus, the fat bike was specifically an issue, because of the type of user group associated with it.

Figure 4.12: Example of an area were fat bikes, youth groups, and illegal behavior were mentioned together (Participant 10).

Consequently, the quotes highlighted that in this case fat bikes in themselves were not an issue. It was the combination of factors which created more uncertainty for parents along their travel route, since youth groups paid less attention to their surroundings and illegal behavior created unexpected situations for parents.

4.3.4 Buses

Lastly, the co-occurrence matrix showed that buses and accidents frequently appeared together, while interviews reflected that this combination sometimes formed a detrimental factor for many parents.

Figure 4.13 shows the link between buses and accidents in the network graph. Buses were often mentioned as problematic or concerning, though not by all parents.

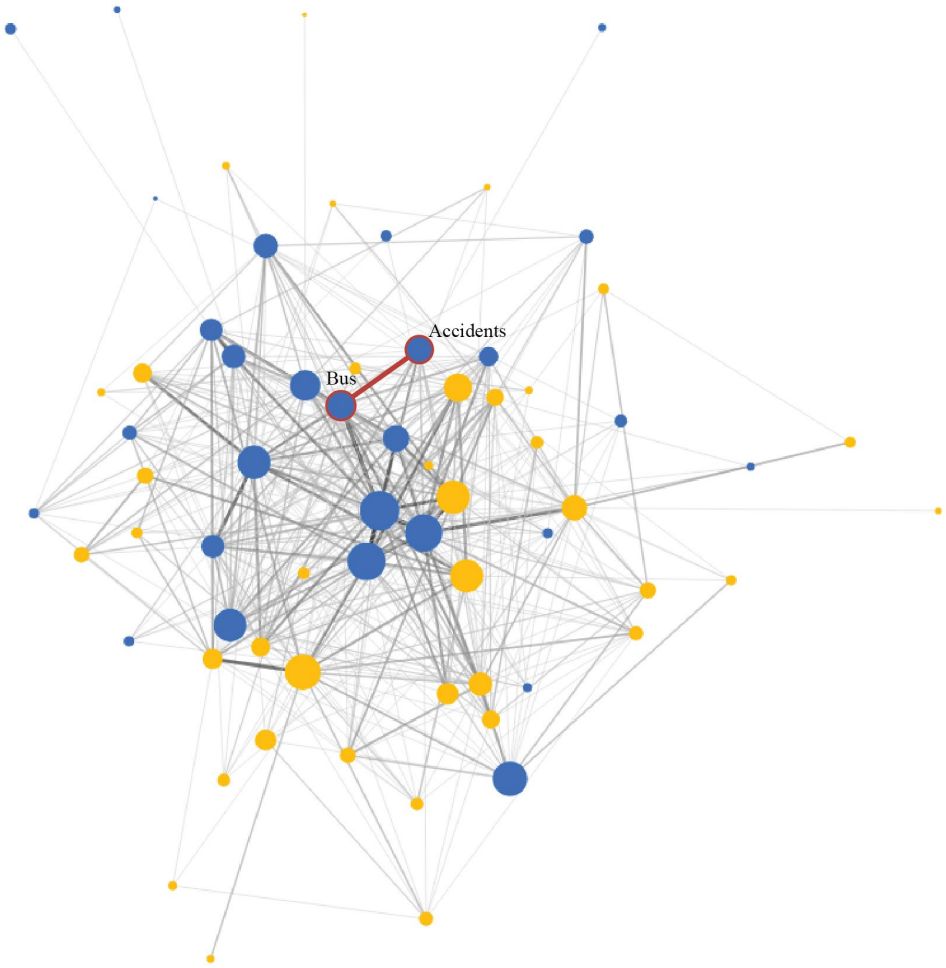

Figure 4.13: Network of co-occurrences, highlighting buses and accidents (yellow is built environment factors, blue is interaction factors).

Quotes from interviews indicated that buses were often a focus point for parents which had e.g. experienced accidents which involved children and buses: *"We don't go into town because, yeah, it's too dangerous. Yeah, I think like four years ago one of the children from school was hit by a bus. And they died. So, the awareness is really high."* (Participant 7). Similarly, Participant 17 explained: *"My partner tends to avoid that area, especially with the children. Because close by the station, not last year, but the year before, a little child was killed by a bus there."* Figure 4.14 shows a location where buses and accidents were an issue, mentioned by Participant 7. Hence, it was not only bus itself that posed the threat, but the association with fatal accidents which influenced parents' risk perception.

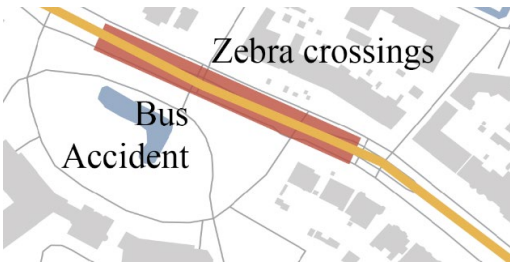

Figure 4.14: Example of an area where buses and accidents were mentioned together (Participant 7).

Accidents, especially severe accidents, seemed to be a central concern to parents' perception in most combinations. The association with accidents moved buses from a more neutral factor to a deciding factor in travel choice for some parents. Therefore, again the combination of factors increased the risk perceived in a specific location, where either factor did not carry the same weight in isolation.

4.3.5 Summary

The examples identified in this section showed that parents' risk perception was also formed by the interactions between the various factors they mentioned. Low visibility crossings were riskier in combination with fast moving cars. Narrow bike paths posed a greater risk if raised sides prevented maneuvering. Fat bikes were problematic due to their association with youth groups and illegal behavior. Lastly, buses were seen as riskier by parents which had experienced fatal accidents. The number of interactions is likely as plentiful as there are factors. Thus, it is impossible to cover and discuss all the interactions in this research project. However, this does illustrate that while this research provides an overview of many factors which influenced parents' safety, this list is only half of the picture. Parents' perceived traffic risk is more than simply the sum of its parts and would require a more detailed network diagram for an in-depth understanding.

5 Discussion

The goal of this research was to identify what factors informed parents' perceived traffic safety and how. Overall, parents' perceived traffic safety was influenced by many different factors as seen in Table 4.3 and Table 4.4. Including, but not limited to, speed, volume, illegal/dangerous behavior, crossing design, bike path design, and construction. However, this research moved beyond simply collecting a list of factors, and used interviews to understand the context and impact parents attributed to the different factors. This allowed the current research to add to past literature and provide more fundamental insight into how parents' perceived safety was formed in a bike-oriented context. This research highlighted that the combination of factors in a specific location amplified the impact of the specific factors, and that children's biking skills and how parents approached risk mitigated the risk experienced by parents. The following section builds on the results, to highlight how they can inform the current understanding of parents' perceived traffic risk and be used to improve traffic planning and design processes.

Initially, the results are compared to past research. Second, the key finding resulting from this research is presented. Then the main implications for how factors form parents' perceived traffic safety are discussed. Accordingly, this research proposes a simple model about the formation of parents' perceived traffic safety. Building on the model implications for design/planning are highlighted. Lastly, limitations and future research needed are considered.

5.1 Reflection on Results

Overall, the results of this research largely overlapped with previous literature. Though the use of interviews within this research provided a more in-depth understanding of the factors parents mention. The bike-oriented context added additional detail to the factors. The focus on individual experiences shifted factors found from neighborhood level to individual behavior, while the timing of the interviews prevented some factors in literature from being mentioned in interviews.

5.1.1 Built Environment Factors

The built environment factors found in literature and in the results largely overlapped (as seen in Table 4.1 and Table 4.3) with some important deviation. These deviations can likely be attributed to the use of interviews, the bike-oriented context, and the study running in the summer.

Both the current study and past research confirmed the importance of having designated and well-maintained active mobility infrastructure (AlQuhtani, 2025; Amiour et al., 2022; Aranda-Balboa et al., 2021; Herazo-Beltrán et al., 2024; Katsavounidou et al., 2024; Kotoula et al., 2021; Kweon et al., 2021; Masoumi et al., 2020; Siiba, 2021). Both also highlighted that infrastructure which had a barrier to other traffic felt safer (Kweon et al., 2021). Moreover, both

cited that parents' required crossings they consider secure to feel safe (Amiour et al., 2022; Chinkonda et al., 2024; Schicketanz et al., 2024; Swain et al., 2024).

However, the bike-oriented context of this research informed a few differences between the current study and the more car-centric cultures in past literature. In the literature parents perceived isolated biking paths as less safe, because they were empty (Amiour et al., 2022; Vasey et al., 2022). In this research, isolated bike paths were considered safe, because they ran separately from the car infrastructure. In the Netherlands a vibrant biking community likely ensures that biking paths in general are well frequented, negating the risk of isolation. This research also introduced more detailed factors related to the difference between the types of bike path, rather than mostly focusing on the presence of bike paths. The bike-oriented cultural context of this study probably gave parents the experience necessary to differentiate between different designs and their impact. Bike parking, while a common theme in literature, was not brought up in this study (Herazo-Beltrán et al., 2024). This might be because the bike centric culture in the Netherlands ensures the presence of bike parking at most central locations, preventing this from becoming an issue.

The timing of the study likely explains why lack of streetlights was a concern to parents in the literature, but not mentioned in this study (Katsavounidou et al., 2024). Parents were asked to map their average route to/and from school in the summer, hence they generally biked during daylight hours. Consequently, streetlights were not necessary, but the responses might have differed if parents were interviewed in the winter.

Lastly, the use of interviews in this study probably allowed parents to highlight that the role of crossing design was more nuanced than assumed in past research. The literature showed a positive association between secured crossings and perceived safety, while this study reflected a more ambiguous relationship (Amiour et al., 2022; Chinkonda et al., 2024; Schicketanz et al., 2024; Swain et al., 2024). The interviews allowed parents to add more context to their original association, which gave them the opportunity to point out how safe crossings to them depended on how people used them.

5.1.2 Interaction Factors

The interaction factors found in literature and this research largely overlapped (see Table 4.1 and Table 4.4) with some differences. These differences are probably explained by the focus on an individual level and the bike-oriented context of this study.

Both the current study and past literature found that traffic density and speed greatly influences parents perceived traffic safety (Aliyas et al., 2022; AlQuhtani, 2025; Amiour et al., 2022; Aranda-Balboa et al., 2021; Herazo-Beltrán et al., 2024; Hermida et al., 2025; Masoumi et al., 2020; Schicketanz et al., 2024; Vasey et al., 2022; Wangzom et al., 2023). Moreover, illegal behavior by children and other actors was also a major concern in both the current and past

studies, because the unexpected behavior could put the children and risk (Cadima & Pinho, 2024; Chinkonda et al., 2024; Katsavounidou et al., 2024).

However, this study focused on parents' individual perception, thus the neighborhood level factors frequently mentioned in past research were rarely brought up. The analyzed literature linked neighborhood safety to the perceived safety of parents (Ammar & Derbel, 2024; Kweon et al., 2023; Zougheibe et al., 2021). Nonetheless, this concept was barely mentioned in the current study. The reason for this might be two-fold. The data collection of this research was focused on the routes themselves and did not direct parents' attention to the overarching neighborhood environment. Also, the sample of people interviewed in this study might live in areas which have been less exposed to crime. Both could inform why neighborhood cohesion or crime would not be on parents' mind in this study.

While the literature highlighted that trusted travel companions were important to parents' perceived safety, this was not mentioned in this research (Schicketanz et al., 2024; Vasey et al., 2022). This could be attributed to the fact that all children in this study were brough to school by their own parents. Consequently, parents likely never made an evaluation of who they would trust to bring their children to school.

Lastly, the bike-oriented context of this research added more detailed interaction factors not found in literature. Primarily this research introduced a longer list of road actors that concerned parents (e.g. electric bikes, buses). Moreover, parents explicitly referred to accidents between biking children and other travel modes as a detrimental factor to their perceived traffic safety, which was only briefly brought up in the Dutch literature (Macedo et al., 2023). Other road actors anticipating and adjusting their actions to account for children's behavior in traffic, was a major positive factor supporting parents' perception of traffic safety only mentioned in this study. All three of these factors were likely added due to the bike culture participants grew up in, which gave them extensive knowledge of the interactions between cyclists and other modes, allowing them to raise detailed concerns surrounding these.

5.1.3 Interplay Between Factors

This research also found that various factors interacted to inform parents' perceives traffic safety, something which was not commonly considered in the global nor Dutch literature. This difference might be attributed to the use of interviews. Not all, but many past studies predominantly relied on surveys to identify factors (see Appendix B and Appendix D). Surveys allow little room for parents to introduce nuance to their responses. Hence, when focusing on surveys it is harder to identify the background mechanism which inform certain responses. By using interviews with mental maps, this research allowed for more in-depth responses which also highlighted the context of choices.

5.2 Key Finding: Minimize Unpredictability

Overall, when considering the various quotes in the results it seems that the underlying goal for parents was to minimize the unpredictability along their routes. With several factors, parents mentioned challenges because something unexpected happened. Moreover, the explanation of the interplay between factors also feeds into this underlying notion. Overall, parents try to find routes where the expected behavior at a location overlaps with what happens at the location, and routes with infrastructure that minimizes the chance and consequences of potential mistakes.

From the results it seems that parents try to find a route where the behavior they expect at a location overlaps with what happens at the location, if these do not align parents feel unsure. For example, parents indicated that they need to feel reassured that cars and bikes will actually stop for crossings, or that cars actually drive the speed limit in a school zone. Similarly, they avoid fat bikes because they worry that they might break traffic regulations.

Parents also look for infrastructures which minimize the chance and consequences of mistakes, to feel safe. For example, barriers at the side of the bike path prevented kids from veering into traffic. No cross-traffic over the bike paths reduced the number of road actors to consider at a specific location. An isolated bike path took other road actors out of the equation altogether.

From the results one can see that the built environment seems to play a major role in setting expectations of a space by introducing bike paths and secure crossings, but the behavior within the space is central in informing parents' experiences. Hence, to allow parents to minimize unpredictability along their route and increase their perceived safety the behavior in a space should match the infrastructure. Thus, built environment and interaction factors need to align. This conclusion indicates that providing biking infrastructure is only part of the challenge and could explain why improving parents' perceived traffic safety can be challenging even in a bike-oriented context.

5.3 Implications for How Factors Influence Parents' Perceived Traffic Safety

This research also provides other interesting insights which inform the current understanding of how route factors influence parents' perceived traffic safety. The following section highlights three implications from the results which inform the role of the factors found. Namely, factors vary in importance, factors influence each other, and built environment and interactions factors need to be considered in combination.

5.3.1 Variation in Importance

As seen in the results, while many factors were mentioned by parents, not all factors carried the same importance. The variation was both in how many parents discussed a given factor and how much a given factor influenced their behavior. Some factors were brought up by many parents, e.g. conflict with bikes and cars, and hence was an issue many parents experienced.

Other factors, such as accidents, were only mentioned by a handful of parents, but for them it greatly impacted their perceived traffic safety and often led to a route change. This demonstrates that not all factors influence parents' safety perception the same way. It also reflects that simply considering how many parents mentioned a factor might not provide an accurate image of its importance to perceived traffic safety, since the impact of a factor might be better understood by whether or not it caused parents to change their route or behavior. This implication is especially interesting when considering that many past studies used survey data which might not be unable to account for this distinction (see Appendix B and Appendix D).

5.3.2 Interplay Changes Perceived Safety

Interviews also showed that various factors interacted with each other to increase or decrease parents' traffic safety perception. As seen in Section 4.3, parents continuously talked about the interplay between different factors when discussing traffic safety. For example, buses were more concerning when associated with traffic accidents. Thus, simply listing all factors mentioned in one location likely would not provide an adequate understanding of the traffic risk parents experience.

5.3.3 Interaction vs Built Environment

This research also indicated that while built environment factors were frequently mentioned in interviews, the risk associated with them was often rather attributed to behaviors around the infrastructure. For example, crossings were less safe if cars did not stop. This implies that interaction factors might play a role in forming the potential impact of built environment factors. Built environment factors still play a role in perceived safety. Traffic light crossings were considered safer by parents than zebra crossings, for example. However, the reason many of these places felt unsafe was linked back to the behavior of others. Considering both interaction and built environment factors is therefore important when considering parents' perceived safety

5.4 Model of Parents' Perceived Traffic Safety

Moving beyond the understanding of the factors, this research used the overarching dimensions of the results to propose a preliminary model outlining how the different dimensions inform parents' perceived traffic safety. The proposed model combines the interaction of factors found on the road, children's characteristics, and parents' approach to risk which all mutually influence each other (Figure 5.1). These three dimensions are chosen since they were frequently mentioned by parents, as elements which influenced their overall traffic safety perception (see Section 4.2).

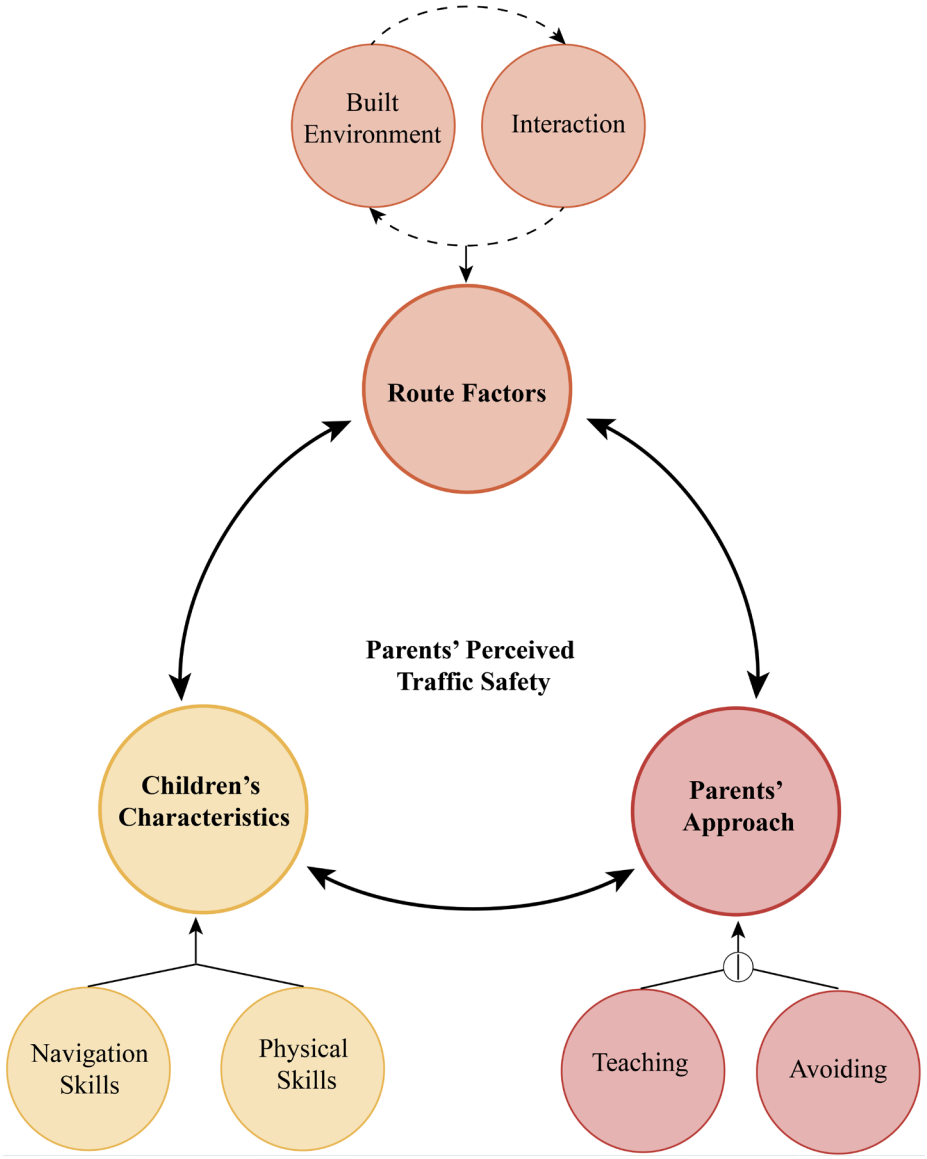

Figure 5.1: Visualization of model proposing how the different overarching dimensions potentially work together to form parents' perceived traffic safety.

In the model, route factors are formed by the combination of various interaction and built environment factors found by parents on their school route. The impact of route factors on parents' perceived safety is defined both by the type of factors as well as the interplay between factors in any specific location (see Section 4.3).

Children's characteristics, in the model, refers to the biking and navigation skills of the child. To parents, a child which can bike well is less likely to make mistakes, while a child that can navigate traffic well has more capacity to handle uncertainty and new situations (see Section 4.2.4.1).

Parents' approach to risk represents their tendency to either avoid or teach different challenges along their route. Parents which are more avoidant will look for routes where the risk and uncertainty is quite low, while a parent focused on teaching might be willing to accept more risk/uncertainty along the route (Section 4.2.4.2).

Overall, the model proposes that all three dimensions need to somewhat align to reduce parents risk perception and encourage more AST. For example, in an ideal scenario parents choose to teach, which means they would accept more risk. This choice is facilitated by having a child which can read traffic relatively well and has grown up biking. Lastly, the route should also have infrastructure which minimizes risk, and where the behavior aligns with the expectation set by the built environment. Furthermore, the model reflects the potential for compromise across the three factors. If the children are very good bikers and navigate traffic well, parents might be willing to accept more risk along the route itself, since they feel confident that their child will be fine. Similarly, if the child struggles to bike in a straight line, even a safe route might be too risky for parents, because they cannot be sure that their child will bike as expected. Lastly, parents which themselves avoid risks can have both highly skilled children and a safe route, and still opt out of biking, since safety is never guaranteed. Thus, the model proposes that parents' perceived traffic safety is not only dependent on factors along the route, but also children's skills and parents' approach to risk.

5.5 Insights for Traffic Design and Planning

While not a core goal of this research, the above-mentioned insights do have some implications for how one could plan traffic to improve parents' perceived safety. Specifically, one should design for the specific context, the focus should shift from infrastructure to behavior, planning should accommodate younger children, there should be a focus on children's skills, and language could reframe from risk to challenging.

5.5.1 Understand the Context

This research indicates that traffic planners should look beyond the specific infrastructure they are implementing, to understand how it will be positioned within the factors that already exist in a location and the local perception. Any new traffic design needs to fit into this already existing network of factors. Understanding the potential synergies between current factors and the new design would enable a better comprehension of the implications of the new additions. If parents in a given area know that zebra crossings are ignored, a zebra crossing will not be effective. Acknowledging this context can both boost the usefulness of new infrastructure and prevent unwanted consequences.

5.5.2 Consider Behavior and Infrastructure

While built environment factors matter in parents design choices, this research indicates that safety perception might depend more on behavior, and how others interact with the infrastructure and each other, than the infrastructure itself. Hence, rather than simply targeting infrastructure, the design process should introduce a steady focus on behavior as well. While a traffic light crossing might be perceived as safer than a zebra crossing, this is only the case if other actors do not stop at the zebra crossing. Thus, when implementing new infrastructure,

design should also focus on how to guide the behavior to follow the expectations set by the infrastructure.

5.5.3 Plan for the Youngest Child

As a side note, this research showed that parents with multiple kids usually travel in a group, and older children tag along with their parents. In interviews parents indicated that they make travel decisions with their younger children in mind. Therefore, design interventions should focus on accommodating the needs of the younger children.

5.5.4 Build Children's Skills

Overall, the proposed model indicates that interventions which target children's biking and navigation skills might be an effective approach to reducing risk perception. Parents mentioned that trusting children's biking skills makes them feel safer when biking. Moreover, participants indicated that the bike exam in the Netherlands is a good indication to parents of children's skills. Hence, interventions could focus on moving the exam earlier or integrating biking skills into the curriculum.

5.5.5 Reframe from Risks to Challenges

Another adjacent proposal would be to change communication about traffic safety with parents from dangerous or risky, to hard and easier to teach. Some parents in interviews already indicated that they avoid framing traffic as dangerous or risky. They would rather consider traffic as easier or harder to teach to their children. This likely also speaks to how they choose to experience traffic. A consideration for a higher-level intervention could be to reframe how traffic is discussed, especially with parents in regard to children, to prevent avoidant behavior. Reframing traffic as hard and easy to teach would also acknowledge that minor accidents and mistakes are simply part of growing up for the children, and do not necessarily mean that the route itself is dangerous or risky to bike.

5.6 Limitations

This research had a variety of limitations. Primarily, it had a small and spatially diverse sample, it was not limited to one travel mode, there was no differentiation between promoting AST and independent mobility, no focus on city specific contexts, and the link between perceived risk and mobility choice was simplified.

This research project only interviewed 18 participants across seven cities. While the sample was spatially diverse, no explicit effort was made to ensure socio-economic and cultural diversity within the sample. The limited sample reduced the possibility to use the mental maps for more quantitative insight. Using the maps explicitly would compromise participants' anonymity. Also, the limited sample meant that this research could only make preliminary

conclusions about the type of factors and how they influenced traffic safety. Hence, the conclusions should be tested against a larger sample of parents.

Similarly, this research addressed parents with kids in the right age group, but did not require a specific travel mode. The modes used varied from bringing kids in cargo bikes, walking, kids biking themselves, and some used the car. Hence, this research was able to show a broad set of factors which impacted parents' perceived traffic safety. However, the research could not distinguish between factors which prevented parents from allowing their children to bike altogether, and which factors only changed the active mobility experience.

From this follows that this research did not distinguish between factors which relate to children traveling alone (independent mobility) or children travelling on their own bike with parents (AST). This means that while this research outlined a broad set of factors which impacted parents' perceived traffic safety, it was not always able to distinguish which factors prevented AST, and which prevented independent mobility.

Due to the scope of this study, it assumed a consistent social biking context across all cities. Though, in interviews parents differentiated between cities. Consequently, this assumption was likely too general, and cities probably experience significant differences in factors which influence traffic safety. However, this research did not have enough participants from the different cities to see if the variation truly stemmed from the city context or from personal differences.

Lastly, by assuming that factors which influence parents' perceived safety will also directly impact AST the research simplified a very complex choice process. The PASTA model and other behavioral models showed that mode and route choice is a complex interplay between many factors. This research delved into parents' perception of traffic safety, which in past research was linked to mobility choice. However, the impact of perception is moderated by a multitude of other dimensions. Consequently, while understanding how parents' perceived traffic safety is formed is important, mobility choice is a more complex interaction, thus making the link to AST more involved.

5.7 Future Research

This research was exploratory and therefore provided a summary of different factors which influenced parents' traffic perception and presented several new ideas about the formation of parents' perceived traffic safety to consider. Future research should capitalize on the various ideas highlighted to confirm and understand their importance.

Due to the qualitative nature of the research, it was unable to comment on the relative importance of different factors to parents' perceived traffic risk. However, when designing or developing an area it is essential to know what interventions would have the most impact, due to limited resources. Thus, future research should consider using quantitative research methods

to understand which of the factors mentioned are more or less important to parents' perceived traffic safety.

The responses in this research indicated that there were interactions between different route factors which reinforced parents' perceived traffic risk. However, for traffic design to maximize the impact on parents' perceived safety it is important to understand all the interactions. Otherwise, planners risk setting up interventions which only cater to surface level factors and do not address the underlying concerns. Consequently, future research should focus on forming a complete network analysis of the different factors influencing parents' perceived traffic safety and how they reinforce each other.

Another angle which could be interesting to pursue is understanding the impact of local variation. Though not a focus point of this study it seems that parents trust in infrastructure elements differs between cities. Consequently, local context could play a role in parents' perceived traffic safety. Future research should consider explicitly comparing different local contexts to each other, to see if there are significant variations.

Moreover, it seems that parents' personal characteristics and children's characteristics play a role in the impact of other factors. Future research should dive deeper into this relationship and confirm to what extent these elements do influence perceived traffic safety. It could also be interesting to consider whether the variations in parents' and children's characteristics could be used to understand overarching groupings with specific influence on parents' perceived traffic safety.

Lastly, this research used mental mapping as a way of engaging the participants and giving a common reference point in interviews. However, due to the limited and spatially diverse sample, this research was unable to use mental maps in a quantitative manner. Further research should build on the current methodology with a larger sample to assess the feasibility of using mental maps as a quantitative data collection method.

6 Conclusion

Overall, this research aimed to identify what factors formed parents' perceived safety in a bike-oriented context like the Netherlands. The research focused particularly on parents' experiences along the routes to school. The overreaching goal was to provide a better understanding of parents' perceived traffic risk, to eventually inform current design/planning approaches to ultimately promote more AST amongst children.

Initially this research showed that a multitude of both built environment factors (physical infrastructure) and interaction factors (interactions with other road users) informed parents' perceived traffic safety along their commutes with their children. These factors included, but were not limited to, complex crossings, high speed, high traffic volume, type of bike path, type of crossing, and accidents along the route. The research also highlighted that children's characteristics (biking skills and navigation skills) and parents' approach to risk (teaching or avoiding) mitigated parents' perception of traffic safety.

Notably, this research demonstrated that the interplay of factors in one location was important to parents' overall perceived traffic risk along the route. Often a single factor (e.g. cars present) was not the main concern, but the fact that it co-occurred with other factors (e.g. high speed and low visibility crossing).

The results found in this research largely overlapped with those described in the literature, with some important new insights. These can predominantly be attributed to the use of interviews, focus on individual experiences, and the bike-oriented context of this study. They include additional details on type of biking infrastructure needed, as well as the reason specific factors felt unsafe/safe.

Most importantly, the results of this research indicated that parents underlying goal was to minimize uncertainty along their route to improve their risk perception. Hence, infrastructure should minimize the potential for mistakes, while the behavior in and expectations of a space should align.

Thus, traffic planning should focus on aligning the behavior with the built environment to create an environment where behavior matches the expectations infrastructure set. Moreover, any urban planner which aims to improve traffic safety should actively understand the local context and network of factors they are designing for.

Considering the small sample and underlying assumptions of this research, future research should build on the current results to confirm the different new insights provided.

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7 References

Aarts, M.-J., Mathijssen, J. J. P., Van Oers, J. A. M., & Schuit, A. J. (2013). Associations Between Environmental Characteristics and Active Commuting to School Among Children: A Cross-sectional Study. *International Journal of Behavioral Medicine*, *20*(4), 538–555. https://doi.org/10.1007/s12529-012-9271-0

Abraham, C., & Sheeran, P. (2009). The Health Belief Model. In M. Conner (Ed.), *Predicting health behaviour: Research and practice with social cognition models* (2. ed., repr). Open Univ. Press. https://books.google.nl/books?hl=en&lr=&id=YjvuX4Q9s_wC&oi=fnd&pg=PA28&ots=QPNMH4Lo2m&sig=9B4tTE5y9yFmJ7y7eOTWpQV28I8&redir_esc=y#v=onepage&q&f=false

Adeoye-Olatunde, O. A., & Olenik, N. L. (2021). Research and scholarly methods: Semi-structured interviews. *JACCP: JOURNAL OF THE AMERICAN COLLEGE OF CLINICAL PHARMACY*, *4*(10), 1358–1367. https://doi.org/10.1002/jac5.1441

Algemeen. (2022, July 5). Fietspaden in Utrecht steeds drukker: 'Let op elkaar en geef elkaar de ruimte' (Increasingly busy bike paths in Utrecht 'Give each other room'). *DUIC*. https://www.duic.nl/algemeen/fietspaden-in-utrecht-steeds-drukker-let-op-elkaar-en-geef-elkaar-de-ruimte/

Aliyas, Z., Lak, A., & Cloutier, M.-S. (2022). Emotional perceptions and barriers to Children's active school travel in low and high socio-economic neighbourhoods in Iran. *Journal of Transport & Health*, *26*, 101483. https://doi.org/10.1016/j.jth.2022.101483

AlQuhtani, S. (2025). Perceived parental barriers to children's walking to school in a sprawled city: A case study for Najran City, Saudi Arabia. *Journal of Transport & Health*, *41*, 102013. https://doi.org/10.1016/j.jth.2025.102013

Amiour, Y., Waygood, E. O. D., & Van Den Berg, P. E. W. (2022). Objective and Perceived Traffic Safety for Children: A Systematic Literature Review of Traffic and Built Environment Characteristics Related to Safe Travel. *International Journal of Environmental Research and Public Health*, *19*(5), 2641. https://doi.org/10.3390/ijerph19052641

Ammar, Y., & Derbel, A. (2024). Quantitative analysis of the main causes of road insecurity around schools in the city of Sousse. *2024 IEEE 15th International Colloquium on Logistics and Supply Chain Management (LOGISTIQUA)*, 1–6. https://doi.org/10.1109/LOGISTIQUA61063.2024.10571434

Amsterdam Bike City. (2024, April 8). *Proef: Snelle fietsers mogen naar de rijbaan (Trial: Fast bikes allowed on the road)*. Amsterdam Bike City. https://bikecity.amsterdam.nl/proef-snelle-fietsers-mogen-naar-de-rijbaan/#:~:text=Op%20het%20fietspad%20geldt%20een,snelheid%20van%2030%20km%2Fuur.

Aranda-Balboa, M. J., Chillón, P., Saucedo-Araujo, R. G., Molina-García, J., & Huertas-Delgado, F. J. (2021). Children and Parental Barriers to Active Commuting to School: A Comparison Study. *International Journal of Environmental Research and Public Health*, *18*(5), 2504. https://doi.org/10.3390/ijerph18052504

Bremmer, D. (2025, July 10). Kabinet onderzoekt maximumsnelheid voor de fiets om aantal fietsongelukken te verminderen (Cabinet considers maximum speed for bikers to reduce accidents). *AD*. https://www.ad.nl/binnenland/kabinet-onderzoekt-maximumsnelheid-voor-de-fiets-om-aantal-fietsongelukken-te-verminderen~a336d6ed/?referrer=https%3A%2F%2Fwww.google.com%2F

Brennan-Horley, C. (2010). Mental mapping the 'creative city'. *Journal of Maps*, *6*(1), 250–259. https://doi.org/10.4113/jom.2010.1082

Buiter, H. (2015). How Utrecht became a biking city (Hoe Utrecht fietsstad werd). *Oud Utrecht*. https://oud-utrecht.nl/images/pdf-bestanden/Bijlagen/Utrecht%20fietsstad%20TSOU-2015-05.pdf

Cadima, C., & Pinho, P. (2024). Walkability and Parental Safety Perceptions as Determinants of Children's School Commutes: A Systematic Review. *Urban Planning*, *9*, 8790. https://doi.org/10.17645/up.8790

Chinkonda, B., Piragauta, A., Mazingi, D., Chokotho, L., Nzanga, M., Manyozo, S., Puvanachandra, P., & Peden, M. (2024). Parents' and Teachers' Perceptions of Risks Associated with Children's Walks to School in Blantyre, Malawi. *International Journal of Environmental Research and Public Health*, *21*(11), 1479. https://doi.org/10.3390/ijerph21111479

Cluster Stedelijke Ontwikkeling. (2020). *Ruimte voor een groen, vitaal Leiden*. https://gemeente.leiden.nl/wp-content/uploads/2024/02/agenda-autoluwe-binnenstad.pdf

Fereday, J., & Muir-Cochrane, E. (2006). Demonstrating Rigor Using Thematic Analysis: A Hybrid Approach of Inductive and Deductive Coding and Theme Development. *International Journal of Qualitative Methods*, *5*(1), 80–92. https://doi.org/10.1177/160940690600500107

Gemeente Amsterdam. (n.d.). Amsterdam Safe and Livable (Amsterdam veilig en leefbaar). *Gemeente Amsterdam, Verkeer En Openbare Ruimte*. https://assets.amsterdam.nl/publish/pages/1042158/beleidsnota_30km_in_de_stad.pdf

Gemeente Leiden. (n.d.). *Carfree Innercity (Autoluwe Binnenstad)*. https://gemeente.leiden.nl/projecten/autoluwe-binnenstad/

Götschi, T., De Nazelle, A., Brand, C., & Gerike, R. (2017). Towards a Comprehensive Conceptual Framework of Active Travel Behavior: A Review and Synthesis of Published Frameworks. *Current Environmental Health Reports*, *4*(3), 286–295. https://doi.org/10.1007/s40572-017-0149-9

Helbich, M., Emmichoven, M. J. Z. V., Dijst, M. J., Kwan, M.-P., Pierik, F. H., & Vries, S. I. D. (2016). Natural and built environmental exposures on children's active school travel: A Dutch global positioning system-based cross-sectional study. *Health & Place*, *39*, 101–109. https://doi.org/10.1016/j.healthplace.2016.03.003

Herazo-Beltrán, Y., Sánchez-Guette, L., González, S. A., Pahuana-Escobar, M., Berdejo-Sandoval, V., Álvarez-González, J., & Mestre-Morón, B. (2024). Environmental and social barriers to active school transport in the Colombian Caribbean region. *Revista de La Facultad de Medicina*, *72*(1), e104638. https://doi.org/10.15446/revfacmed.v72n1.104638

Hermida, C., Chillón, P., Andrade, J., Barranco-Ruiz, Y., Campos-Garzón, P., Palma-Leal, X., Quezada, A., Villa-González, E., Orellana, D., & Huertas-Delgado, J. (2025). Parents' perceived barriers to active commuting to school. Comparative study between Spanish and Ecuadorian cities. *International Journal of Environmental Health Research*, *35*(2), 398–409. https://doi.org/10.1080/09603123.2024.2358478

Jain, N. (2021). Survey Versus Interviews: Comparing Data Collection Tools for Exploratory Research. *The Qualitative Report*. https://doi.org/10.46743/2160-3715/2021.4492

Katsavounidou, G., Voutsa, E., & Sepetzi, S. (2024). Active but not Independent: Children's School Travel Patterns in a Compact-City Environment in Greece. *Urban Planning*, *9*, 8682. https://doi.org/10.17645/up.8682

Kotoula, K. M., Botzoris, G., Aifantopoulou, G., & Profillidis, V. (2021). Exploring the Factors Influencing Parental Choices on School Trips. *Periodica Polytechnica Transportation Engineering*, *49*(4), 369–381. https://doi.org/10.3311/PPtr.15890

Kweon, B.-S., Rosenblatt-Naderi, J., Ellis, C. D., Shin, W.-H., & Danies, B. H. (2021). The Effects of Pedestrian Environments on Walking Behaviors and Perception of Pedestrian Safety. *Sustainability*, *13*(16), 8728. https://doi.org/10.3390/su13168728

Kweon, B.-S., Shin, W.-H., & Ellis, C. D. (2023). School Walk Zone: Identifying Environments That Foster Walking and Biking to School. *Sustainability*, *15*(4), 2912. https://doi.org/10.3390/su15042912

Lam, L. T. (2001). Parental risk perceptions of childhood pedestrian road safety. *Journal of Safety Research*, *32*(4), 465–478. https://doi.org/10.1016/S0022-4375(01)00061-5

Legard, R., Keegan, J., & Ward, K. (2003). In-depth interviews. In *Qualitative research practice: A guide for social science students and researchers* (1st edn, pp. 138–169). SAGE Publications Ltd.

Macedo, F. E., Raaphorst, K. M. C., Bevelander, K. E., & Van Der Krabben, E. (2023). The influence of the built environment on active school travel in the Netherlands: A mode choice analysis. *Multimodal Transportation*, *2*(4), 100103. https://doi.org/10.1016/j.multra.2023.100103

Masoumi, H., Rooijen, M. V., & Sierpiński, G. (2020). Children's Independent Mobility to School in Seven European Countries: A Multinomial Logit Model. *International Journal of Environmental Research and Public Health*, *17*(23), 9149. https://doi.org/10.3390/ijerph17239149

Mercê, C., Branco, M., Catela, D., Lopes, F., Rodrigues, L. P., & Cordovil, R. (2021). Learning to Cycle: Are Physical Activity and Birth Order Related to the Age of Learning How to Ride a Bicycle? *Children*, *8*(6), 487. https://doi.org/10.3390/children8060487

Mitra, R., & Manaugh, K. (2020). A social-ecological conceptualization of children's mobility. In *Transportation and Children's Well-Being* (pp. 81–100). Elsevier. https://doi.org/10.1016/B978-0-12-814694-1.00005-1

Molina-García, J., García-Massó, X., Menescardi, C., Estevan, I., & Queralt, A. (2025). Parental neighbourhood perceptions and active commuting to school in children according to their sex using a self-organised map approach: A cross-sectional study. *BMC Public Health*, *25*(1), 1089. https://doi.org/10.1186/s12889-025-22309-y

Naber, C. (2021, June 7). Busdrama Leiden: 'Moeder gilde naar dochter, achterop haar fiets zat nog een kind' (Leiden bus tragedy: 'Mother screamed at daughter, another child was sitting on the back of her bike'). *PZC Nieuws*. https://www.pzc.nl/binnenland/busdrama-leiden-moeder-gilde-naar-dochter-achterop-haar-fiets-zat-nog-een-kind~aa556385/?referrer=https%3A%2F%2Fwww.google.com%2F

Nevelsteen, K., Steenberghen, T., Van Rompaey, A., & Uyttersprot, L. (2012). Controlling factors of the parental safety perception on children's travel mode choice. *Accident Analysis & Prevention*, *45*, 39–49. https://doi.org/10.1016/j.aap.2011.11.007

Nightingale, A. (2009). A guide to systematic literature reviews. *Surgery (Oxford)*, *27*(9), 381–384. https://doi.org/10.1016/j.mpsur.2009.07.005

Nyström, M., Henriksson, M., Lindqvist, A.-K., & Rutberg, S. (2023). Making the right decision for our children's future: Parents' perceptions of active school travel in disadvantaged neighborhoods. *Journal of Transport & Health*, *30*, 101617. https://doi.org/10.1016/j.jth.2023.101617

Prasad, D. B. (2008). *Content analysis: A method of Social Science Research, In D.K. Lal Das (ed) Research Methods for Social Work, (pp.174-193), New Delhi: Rawat Publications, 2008.* Unpublished. https://doi.org/10.13140/RG.2.1.1748.1448

Provincie Utrecht. (n.d.). *Fiets 2019-2023 (Bike 2019-2023)* (p. 60). Provincie Utrecht. Retrieved 22 July 2025, from https://www.provincie-utrecht.nl/sites/default/files/2020-03/uitvoeringsprogramma_fiets_2019-2023.pdf

Redactie. (2023, March 24). Meisje (7) overleden bij ernstig ongeluk met stadsbus in Utrecht, jongetje (5) zwaargewond (Girl (7) died in serious accident with city bus in Utrecht, boy (5) criticly injured). *RTV Utrecht*. https://www.rtvutrecht.nl/nieuws/3558267/meisje-7-overleden-bij-ernstig-ongeluk-met-stadsbus-in-utrecht-jongetje-5-zwaargewond

Redactie. (2025, June 28). Kind op fiets gewond na aanrijding met Utrechtse stadsbus, politie zoekt getuigen (Child on bicycle injured after collision with Utrecht city bus, police looking for witnesses). *RTV Utrecht*. https://www.rtvutrecht.nl/nieuws/3913125/kind-op-fiets-gewond-na-aanrijding-met-utrechtse-stadsbus-politie-zoekt-getuigen

Rijksinstituut voor Volksgezondheid en Milieu Ministerie van Volksgezondheid, Welzijn en Sport. (n.d.). *Numbers and Facts sport and Movement (Cijfers en Feiten sport en Bewegen)*. https://www.loketgezondleven.nl/gezondheidsthema/sport-en-bewegen/cijfers-en-feiten-sport-en-bewegen

Rothman, L., Buliung, R., To, T., Macarthur, C., Macpherson, A., & Howard, A. (2015). Associations between parents' perception of traffic danger, the built environment and walking to school. *Journal of Transport & Health*, *2*(3), 327–335. https://doi.org/10.1016/j.jth.2015.05.004

Schicketanz, J., Kabisch, S., Bagoly-Simó, P., & Lakes, T. (2024). Factors that are perceived as supporting or hindering active school travel (AST): Go-along interviews with primary school children and their parents. *Children's Geographies*, *22*(2), 217–233. https://doi.org/10.1080/14733285.2023.2269104

Siiba, A. (2021). Influence of parental attitude and perception of built environment attributes on children's active travel to school in Ghana. *Case Studies on Transport Policy*, *9*(2), 805–812. https://doi.org/10.1016/j.cstp.2021.03.017

Siiba, A., Agyei, V., Iddrisu, S., Adjei, S. A., & Ibrahim, H. (2025). Distance and perception of safety of the built environment are predominant factors influencing walking and bicycling to school: A systematic review. *Transportation Research Part F: Traffic Psychology and Behaviour*, *109*, 1137–1149. https://doi.org/10.1016/j.trf.2025.01.029

Swain, R., Oswin, P., Truelove, V., & Larue, G. S. (2024). Children's and parents' perceptions on safe routes to schools: A mixed-methods study investigating factors influencing active school travel. *Journal of Urban Design*, *29*(2), 208–230. https://doi.org/10.1080/13574809.2023.2223517

Syvak, A. (n.d.). *Teenage boy high school student cartoon character carrying backpack going to study isolated on white* [Vector Image]. Adobe Stock. https://stock.adobe.com/search/images?k=Teenage+boy+high+school+student+cartoon+character+carrying+backpack+going+to+study+isolated+on+white&search_type=usertyped&asset_id=1136974567

Syvak, P. (n.d.). *Children Enjoying Outdoor Activities On Bicycles And Balance Bikes. Kids Engaging In Fun Exercise, Riding Bikes* [Vector Image]. Adobe Stock. https://stock.adobe.com/images/children-enjoying-outdoor-activities-on-bicycles-and-balance-bikes-kids-engaging-in-fun-exercise-riding-bikes/893659101

te Brömmelstroet, M. (2014, November 20). *De choreografie van een kruispunt: Naar een gebruiksgeorienteerde ontwerplogica voor kruispunten (The choreography of an intersection: Towards a logical user-oriented design for intersections)*. Colloquium Vervoersplanologisch Speurwerk, Groningen. https://www.cvs-congres.nl/e2/site/cvs/custom/site/upload/file/paper_search/2014/cvs14_034.pdf

te Brömmelstroet, M., Boterman, W., & Kuipers, G. (2020). 12. How culture shapes–and is shaped by–mobility: Cycling transitions in The Netherlands. In C. Curtis (Ed.), *Handbook of sustainable transport*. Edward Elgar Publishing Limited. https://books.google.nl/books?hl=en&lr=&id=Ai0NEAAAQBAJ&oi=fnd&pg=PA109&dq=netherlands+biking+culture&ots=3c58hOun_m&sig=8XKlXVpU4ips3rJgsT6zyTDzF_w#v=onepage&q&f=false

Torres, M. A., Oh, H. W., & Lee, J. (2022). The Built Environment and Children's Active Commuting to School: A Case Study of San Pedro De Macoris, the Dominican Republic. *Land*, *11*(9), 1454. https://doi.org/10.3390/land11091454

Van Den Berg, P., Waygood, E. O. D., Van De Craats, I., & Kemperman, A. (2020). Factors affecting parental safety perception, satisfaction with school travel and mood in primary school children in the Netherlands. *Journal of Transport & Health*, *16*, 100837. https://doi.org/10.1016/j.jth.2020.100837

Van Kann, D. H. H., Kremers, S. P. J., De Vries, S. I., De Vries, N. K., & Jansen, M. W. J. (2016). Parental Active Transportation Routines (PATRns) as a Moderator of the Association Between Neighborhood Characteristics and Parental Influences and Active School Transportation. *Environment and Behavior*, *48*(7), 946–965. https://doi.org/10.1177/0013916515574548

Vasey, T. V., Carroll, S. J., Daniel, M., & Cargo, M. (2022). Changing Primary School Children's Engagement in Active School Travel Using Safe Routes to School Interventions: A Rapid Realist Review. *International Journal of Environmental Research and Public Health*, *19*(16), 9976. https://doi.org/10.3390/ijerph19169976

Von Stülpnagel, R., Riach, N., Hologa, R., Kees, J., & Gössling, S. (2024). School route safety perceptions of primary school children and their parents: Effects of transportation mode and infrastructure. *International Journal of Sustainable Transportation*, *18*(6), 465–477. https://doi.org/10.1080/15568318.2024.2350992

Wangzom, D., White, M., & Paay, J. (2023). Perceived Safety Influencing Active Travel to School—A Built Environment Perspective. *International Journal of Environmental Research and Public Health*, *20*(2), 1026. https://doi.org/10.3390/ijerph20021026

Zougheibe, R., Jepson, B., Norman, R., Gudes, O., & Dewan, A. (2021). Is there a correlation between children's outdoor active mobility behaviour and neighbourhood safety? A systematic review of the evidence. *BMJ Open*, *11*(7), e047062. https://doi.org/10.1136/bmjopen-2020-047062

Appendix A Systematic Literature Review Global: Selection

	SCOPUS	PubMED
Search term	PUBYEAR AFT 2020 TITLE-ABS-KEY ((Bike OR "Active Mobility" OR Walking OR "School Travel" OR "Active School Travel" OR "Active Commute" OR Pedestrian* OR Cyclist*) AND (Accident* OR Risk* OR Safet* OR Hazard* OR Danger* OR Unsafe* OR Securit*) AND (School* OR Kindergarten) AND(Perception* OR Perceive*) AND (Parent* OR Father* OR Mother* OR Guardian* OR Child*))	(((Bike[Title/Abstract] OR "Active Mobility"[Title/Abstract] OR Walking[Title/Abstract] OR "School Travel"[Title/Abstract] OR "Active School Travel"[Title/Abstract] OR "Active Commute"[Title/Abstract] OR Pedestrian*[Title/Abstract] OR Cyclist*[Title/Abstract]) AND (Accident*[Title/Abstract] OR Risk*[Title/Abstract] OR Safet*[Title/Abstract] OR Hazard*[Title/Abstract] OR Danger*[Title/Abstract] OR Unsafe*[Title/Abstract] OR Securit*[Title/Abstract]) AND (School*[Title/Abstract] OR Kindergarten[Title/Abstract]) AND (Perception*[Title/Abstract] OR Perceive*[Title/Abstract]) AND (Parent*[Title/Abstract] OR Father*[Title/Abstract] OR Mother*[Title/Abstract] OR Guardian*[Title/Abstract] OR Child*[Title/Abstract]))) AND ("2020/01/01"[Date - Publication] : "3000"[Date - Publication])
Number Articles	99	37
Exclude title	30	15
Exclude abstract	45	15
Unavailable	1	-
After Filtering	23 (5 overlaps)	7 (5 overlaps)

Appendix B Systematic Literature Review Global: Final List

Authors	Title	Data Collection Method	DOI
Masoumi, H., Rooijen M. V., & Sierpiński, G.	Children's Independent Mobility to School in Seven European Countries: A Multinomial Logit Model.	Survey Questionnaire	10.3390/ijerph17239149
Vasey, T. V., Carroll, S. J., Daniel, M., & Cargo, M.	Primary School Children's Engagement in Active School Travel Using Safe Routes to School Interventions: A Rapid Realist Review.	Rapid Realist Review	10.3390/ijerph19169976
Aranda-Balboa, M. J., Chillón, P., Saucedo-Araujo, R. G., Molina-García, J., & Huertas-Delgado, F. J.	Children and parental barriers to active commuting to school: a comparison study	Cross-sectional Survey Questionnaire	10.3390/ijerph18052504
Cadima, C., & Pinho, P.	Walkability and Parental Safety Perceptions as Determinants of Children's School Commutes: A Systematic Review.	Systematic Literature Review Interviews	10.17645/up.8790
Chinkonda, B., Piragauta, A., Mazingi, D., Chokotho, L., Nzanga, M., Manyozo, S., ... & Peden, M.	Parents' and Teachers' Perceptions of Risks Associated with Children's Walks to School in Blantyre, Malawi	Focus Groups	10.3390/ijerph21111479
Herazo-Beltrán, Y., Sánchez-Guette, L., González, S. A., Pahuana-Escobar, M., Berdejo-Sandoval, V., Álvarez-González, J., & Mestre-Morón, B.	Environmental and social barriers to active school transport in the Colombian Caribbean region	Cross-sectional Survey Questionnaire	10.15446/revfacmed. v72n1.104638
Hermida, C., Chillón, P., Andrade, J., Barranco-Ruiz, Y., Campos-Garzón, P., Palma-Leal, X., ... & Huertas-Delgado, J.	Parents' perceived barriers to active commuting to school.	Survey Questionnaire	10.1080/09603123. 2024.2358478
Katsavounidou, G., Voutsa, E., & Sepetzi, S.	Active but not Independent: Children's School Travel Patterns in a Compact-City	Survey Questionnaire	0.17645/up.8682
Kotoula, K. M., Botzoris, G., Aifantopoulou, G., & Profillidis, V.	Exploring the factors influencing parental choices on school trips	Survey Questionnaire	10.3311/PPtr.15890
Kweon, B. S., Rosenblatt-Naderi, J., Ellis, C. D., Shin, W. H., & Danies, B. H.	The effects of pedestrian environments on walking behaviors and perception of pedestrian safety.	Experimental Design - virtual walking environments which were rated	10.3390/su13168728

Kweon, B. S., Shin, W. H., & Ellis, C. D.	School Walk Zone: identifying environments that foster walking and biking to school	Survey Questionnaire Geographic data to estimate walkability	10.3390/su15042912
Schicketanz, J., Kabisch, S., Bagoly-Simó, P., & Lakes, T.	Factors that are perceived as supporting or hindering active school travel (AST): go-along interviews with primary school children and their parents.	Walk-along Interviews	10.1080/14733285.2023.2269104
Siiba, A.	Influence of parental attitude and perception of built environment attributes on children's active travel to school in Ghana.	Survey Questionnaire	10.1016/j.cstp.2021.03.017
Swain, R., Oswin, P., Truelove, V., & Larue, G. S.	Children's and parents' perceptions on safe routes to schools: a mixed-methods study investigating factors influencing active school travel.	Survey Questionnaire	10.1080/13574809.2023.2223517
Torres, M. A., Oh, H. W., & Lee, J.	The built environment and children's active commuting to school: A case study of San Pedro De Macoris, the Dominican Republic.	Survey Questionnaire Site Audits	10.3390/land11091454
von Stülpnagel, R., Riach, N., Hologa, R., Kees, J., & Gössling, S.	School route safety perceptions of primary school children and their parents: Effects of transportation mode and infrastructure.	Survey Questionnaire with maps	10.1080/15568318.2024.2350992
Aliyas, Z., Lak, A., & Cloutier, MS.	Emotional perceptions and barriers to Children's active school travel in low and high socio-economic neighbourhoods in Iran	Survey Questionnaire	10.1016/j.jth.2022.101483
AlQuhtani, S.,	Perceived parental barriers to children's walking to school in a sprawled city: A case study for Najran City, Saudi Arabia	Survey Questionnaire	10.1016/j.jth.2025.102013
Ammar, Y., & Derbel, A.,	Quantitative analysis of the main causes of road insecurity around schools in the city of Sousse	Survey Questionnaire	10.1109/LOGISTIQUA61063.2024.10571434

Molina-García, J., García-Massó, X., Menescardi, C., Estevan, I., & Queralt, A.	Parental neighbourhood perceptions and active commuting to school in children according to their sex using a self-organised map approach: a cross-sectional study	Self-reported Questionnaire Self-organized Map Analysis	10.1186/s12889-025-22309-y
Nyström, M., Henriksson, M., Lindqvist, AK., & Rutberg, S.	Making the right decision for our children's future: Parents' perceptions of active school travel in disadvantaged neighborhoods	Semi-structured Interviews	10.1016/j.jth.2023.101617
Siiba, A., Agyei, V., Iddrisu, S., Adjei, S. A., & Ibrahim, H.	Distance and perception of safety of the built environment are predominant factors influencing walking and bicycling to school: A systematic review	Systematic Literature Review	10.1016/j.trf.2025.01.029
Wangzom, D., White, M., & Paay, J.	Perceived Safety Influencing Active Travel to School—A Built Environment Perspective	Systematic Literature Review	10.3390/ijerph20021026
Zougheibe, R., Jepson, B., Norman, R., Gudes, O., & Dewan, A.	Is there a correlation between children's outdoor active mobility behaviour and neighbourhood safety? A systematic review of the evidence	Systematic Literature Review	10.1136/bmjopen-2020-047062
Amiour, Y., Waygood, E. O. D., & van den Berg, P. E. W.	Objective and Perceived Traffic Safety for Children: A Systematic Literature Review of Traffic and Built Environment Characteristics Related to Safe Travel	Systematic Literature Review	10.3390/ijerph19052641

Appendix C Systematic Literature Review Netherlands: Selection

	SCOPUS	PubMED
Search term	TITLE-ABS-KEY ((Bike OR "Active Mobility" OR Walking OR "School Travel" OR "Active School Travel" OR "Active Commute" OR Pedestrian* OR Cyclist* OR "Active Commute") AND (Accident* OR Risk* OR Safet* OR Hazard* OR Danger* OR Unsafe* OR Securit*) AND (Parent* OR Child* OR Father* OR Mother* OR Guardian*) AND (Netherland* OR Dutch OR Holland OR Randstad))	(((Bike[Title/Abstract] OR "Active Mobility"[Title/Abstract] OR Walking[Title/Abstract] OR "School Travel"[Title/Abstract] OR "Active School Travel"[Title/Abstract] OR "Active Commute"[Title/Abstract] OR Pedestrian*[Title/Abstract] OR Cyclist*[Title/Abstract]) AND (Accident*[Title/Abstract] OR Risk*[Title/Abstract] OR Safet*[Title/Abstract] OR Hazard*[Title/Abstract] OR Danger*[Title/Abstract] OR Unsafe*[Title/Abstract] OR Securit*[Title/Abstract]) AND (Netherland*[Title/Abstract] OR Dutch*[Title/Abstract] OR Holland*[Title/Abstract]) AND (Parent*[Title/Abstract] OR Father*[Title/Abstract] OR Mother*[Title/Abstract] OR Guardian*[Title/Abstract] OR Child*[Title/Abstract]))) AND ("0000"[Date - Publication] : "3000"[Date - Publication])
Number Articles	96 (24 overlap)	27 (24 overlap)
Exclude w/title	58	All not duplicate articles excluded here
Exclude w/abstract	33	-
After Filtering	5	-

Appendix D Systematic Literature Review Netherlands: Final List

Author	Title	Data Collection Method	DOI
Aarts, MJ., Mathijssen, J. J. P., Van Oers, J. A. M., & Schuit, A. J.	Associations between environmental characteristics and active commuting to school among children: A cross-sectional study	Cross-sectional Survey Questionnaire	10.1007/s12529-012-9271-0
van den Berg, P., Waygood, E. O. D., van de Craats, I., & Kemperman, A.	Factors affecting parental safety perception, satisfaction with school travel and mood in primary school children in the Netherlands	Survey Questionnaire	10.1016/j.jth.2020.100837
Macedo, F. E., Raaphorst, K. M. C., Bevelander, K. E., van der Krabben, E.	The influence of the built environment on active school travel in the Netherlands: A mode choice analysis	Survey Questionnaire Geographic Data	10.1016/j.multra.2023.100103
Van Kann, D.H.H., Kremers, S.P.J., de Vries, S.I., de Vries, N.K., & Jansen, M.W.J.	Parental Active Transportation Routines (PATRns) as a Moderator of the Association Between Neighborhood Characteristics and Parental Influences and Active School Transportation	Survey Questionnaire	10.1177/001391651 5574548
Helbich, M., Zeylmans van Emmichoven, M. J., Dijst, M. J., Kwan, MP., Pierik, F. H., & de Vries, S. I.	Natural and built environmental exposures on children's active school travel: A Dutch global positioning system-based cross-sectional study	GPS Tracked Routes	10.1016/j.healthplace.2016.03.003

Appendix E Semi-structured Interviews: 7s CARS-SID

Seven Steps to Conducting, Analyzing, and Reporting Semi-structured Interview Data Based on the table pp. 1359-1360 (Adeoye-Olatunde & Olenik, 2021)

Step Number	Details	Comment for Research
1. Assess if Semi-Structured Interviews are appropriate	-	Study is explorative and thus benefits from a more open-ended approach to knowledge acquisition.
2. Sampling technique and Recruiting participants	2a. How to sample? 2b. How to recruit?	Sample is parents in Dutch urban areas for similar experiences. Parents should have children which are in an age group where they still travel with their parents. Recruitment happens through parents WhatsApp groups, school newsletters and snowballing from previously interviewed parents.
3. Data collection design	3a. An interview Guide 3b. Collect demographic information	Set up questions based on literature reviews to have well-grounded research. Standard demographic questions about mostly the children were added in beginning.
4. Conduct interview, transcribe and store data	4a. Preparation and training 4b. Interview and recording consideration 4c. Transcription and checking 4d. Securely storing and transmitting the data	Storage and transcription processes were ensured to be safe through the ethical approval process and data management plan. The interview was tried with several non-participants to ensure flow and time management.
5. Data analysis	5a. Coding and theme identification 5b. Establishing rigor	The codes were applied iteratively but based on predefined codes from literature.
6. Drawing conclusion	-	Analysis was conducted through Atlas.ti to draw well-grounded conclusions.
7. Reporting results	7a. Reporting Guidelines 7b. Data display	Results were reported through a combination of quotes, frequency and network analysis of codes.

Appendix F All Codes

Color codes

Accidents: Purple, Interaction: Blue, Built Environment: Yellow, Childs Feature: Red, Parents' Typology: Pink, Other: White

This table shows all the codes used/developed in the coding process.

Code	
● **Accident occurred**	
● **Bad maintenance**	
	● Cracks or holes in the road
	● Unclear/changing guiding-lines for bike path
● **Behavior which breaks traffic rules**	
	● Cut turn entering road
	● Dangerous/illegal behavior by kids
	● Dangerous/illegal behavior by other road users
	● Unclear right of way
○ **Complex crossing**	
	● Large flow of traffic
	● Little overview/low visibility
	● Many crossings along route
	● Many lanes at crossing
● **Conflict with other modes**	
	● Bikes
	● Bus
	● Cars
	● Delivery drivers
	● Electric bikes
	● Electric vehicles
	● Fat bikes
	● Large vehicles
	● Many different modes congregate
	● Motorcycle
	● Pedestrian
	● Scooters
	● Train
● **Construction**	
	● Both directions in same lane
	● New road actors
	● No path available
	● Rerouting of path
● **Crime in neighborhood**	
● **Design bike/walk path**	
	● Cross traffic on bike lane
	● Green strip/physical barrier to car lane
	● High curb/raised bike path
	● Narrow bike path
	● No cross-traffic bike lane

	● Parked cars on side of bike lane
	● Two-way traffic on bike lane
● **High volume**	
● **Kids feature**	
	● Children's knowledge of area/route
	● Children's skill to biking
	● Childs innate tendency (daydreaming/focus)
	● Communication with child
	● Trust in kids
● **Material used**	
	● Asphalt
	● Cobblestone
	● Dirt path
	● High ledge
	● Tracks on road
● **Other factors**	
	● Dark
	● Distance
	● Habit
	● Interesting
	● Sound
	● Time
	● Weather
● **Others along route**	
	● Stranger danger
	● Youth groups
● **Parents typology**	
	● Avoid major risks
	● Teach situation
○ **Positive factors**	
	● Ability to keep right turn
	● Calm/slow traffic
	● High neighborhood cohesion
	● Others think along
	● Travel same direction as traffic
	● Secure/safe crossing
	● Wide bike paths
● **Road features**	
	● Lack of parking for car
	● Merge onto car road
	● Narrow road
	● Little bike parking
	● One way traffic
	● Traffic signs
	● Speed managing features
	● Travel against traffic
● **Speed related issues**	
	● High speed
	● Variation in speed

● **Travel by car**	
● **Type bike path**	
	● Bike first street
	● Bike path alone without car street
	● Integrated bike path (drawn on road)
	● No bike/walk path
	● Separated/raised bike path
● **Unpredictable situation (generally)**	
● **Unsafe crossing**	
	● Crossing for pedestrians only
	● Traffic light takes long
	● w/ Crossing guard
	● w/ Outlines of crossing
	● w/ Traffic light
	● w/ Zebra crossing

Appendix G Frequency and Number of Interviews Mentioning Code

Color categories: Accidents: Purple, Interaction: Blue, Built Environment: Yellow, Childs Feature: Red, Parents' Typology: Pink, Other: White

The table shows all the codes possible, how many times they were mentioned in total, and the number of interviews the code was mentioned in.

Code		Frequency Total	Number of Interviews
● **Accident occurred**		35	12
● **Bad maintenance**		4	2
	● Cracks or holes in the road	4	2
	● Unclear/changing guiding-lines for bike path	0	0
● **Behavior which breaks traffic rules**		76	15
	● Cut turn entering road	3	2
	● Dangerous/illegal behavior by kids	5	3
	● Dangerous/illegal behavior by other road users	44	13
	● Unclear right of way	29	6
○ **Complex crossing**		117	18
	● Large flow of traffic	53	16
	● Little overview/low visibility	54	15
	● Many crossings along route	8	4
	● Many lanes at crossing	18	7
● **Conflict with other modes**		200	18
	● Bikes	34	13
	● Bus	40	13
	● Cars	66	18
	● Delivery drivers	4	3
	● Electric bikes	5	3
	● Electric vehicles	2	1
	● Fat bikes	27	10
	● Large vehicles	18	7
	● Many different modes congregate	26	11
	● Motorcycle	1	1
	● Pedestrian	10	4
	● Scooters	5	3
	● Train	3	1
● **Construction**		10	6
	● Both directions in same lane	0	0
	● New road actors	3	3
	● No path available	3	2
	● Rerouting of path	7	4
● **Crime in neighborhood**		6	2
● **Design bike/walk path**		58	12
	● Cross traffic on bike lane	10	5

	● Green strip/physical barrier to car lane	10	5
	● High curb/raised bike path	4	4
	● Narrow bike path	20	7
	● No cross-traffic bike lane	3	1
	● Parked cars on side of bike lane	15	6
	● Two-way traffic on bike lane	6	4
● **High volume**		69	17
● **Kids feature**		76	17
	● Children's knowledge of area/route	16	7
	● Children's skill to biking	39	14
	● Childs innate tendency (daydreaming/focus)	12	9
	● Communication with child	12	8
	● Trust in kids	12	7
● **Material used**		21	6
	● Asphalt	8	4
	● Cobblestone	12	6
	● Dirt path	0	0
	● High ledge	2	2
	● Tracks on road	0	0
● **Other factors**		62	15
	● Dark	5	3
	● Distance	4	4
	● Habit	1	1
	● Interesting	38	14
	● Sound	8	2
	● Time	2	2
	● Weather	4	2
● **Others along route**		25	11
	● Stranger danger	0	0
	● Youth groups	25	11
● **Parents' typology**		73	17
	● Avoid major risks	44	13
	● Teach situation	34	15
○ **Positive factors**		135	18
	● Ability to keep right turn	6	3
	● Calm/slow traffic	58	17
	● High neighborhood cohesion	2	1
	● Others think along	8	5
	● Travel same direction as traffic	6	2
	● Secure/safe crossing	53	15
	● Wide bike paths	7	5
● **Road features**		54	13
	● Lack of parking for car	1	1
	● Merge onto car road	3	1

	• Narrow road	32	11
	• Little bike parking	2	1
	• One way traffic	13	6
	• Traffic signs	1	1
	• Speed managing features	5	1
	• Travel against traffic	6	3
• **Speed related issues**		83	17
	• High speed	74	17
	• Variation in speed	10	4
• **Travel by car**		1	1
• **Type bike path**		145	18
	• Bike first street	16	6
	• Bike path alone without car street	22	9
	• Integrated bike path (drawn on road)	23	11
	• No bike/walk path	27	9
	• Separated/raised bike path	61	15
• **Unpredictable situation (generally)**		52	16
• **Unsafe crossing**		87	17
	• Crossing for pedestrians only	13	8
	• Traffic light takes long	8	3
	• w/ Crossing guard	2	1
	• w/ Outlines of crossing	39	14
	• w/ Traffic light	18	4
	• w/ Zebra crossing	12	5

Appendix H Co-Occurrence Matrix

The co-occurrence matrix shows how often two codes were mentioned together in one location or phrase in the interviews/mental maps.

The following table shows some of the main co-occurrences also used within this thesis.

Code Label	Accident Occurred	Dangerous/Illegal Behavior by Other Road Users	Complex Crossing: Large Flow of Traffic	Complex Crossing: Little Overview/Low Visibility	Complex Crossing: Many Lanes at Crossing	Conflict With Other Modes: Bikes	Conflict With Other Modes: Bus	Conflict With Other Modes: Cars	Conflict With Other Modes: Fat Bikes	Conflict With Other Modes: Large Vehicles	Conflict With Other Modes: Many Different	Design Bike/Walk Path: Narrow Bike Path	High Volume	Others Along Route: Youth Groups	Positive Factors: Secure/Safe Crossing	Road Features: Narrow Road	Speed Related Issues: High Speed	Type Bike Path: Integrated Bike Path (Drawn on	Type Bike Path: No Bike/Walk Path	Type Bike Path: Separated/Raised Bike	Unsafe Crossing: W/ Outlines of Crossing	Unsafe Crossing: W/ Traffic Light
Accident Occurred	0	0	3	2	1	0	9	3	0	0	1	1	1	1	1	1	6	0	2	0	0	5
Dangerous/Illegal Behavior by Other Road Users	0	0	0	4	0	9	0	4	5	1	0	1	1	8	1	0	6	1	0	0	0	3
Complex Crossing: Large Flow of Traffic	3	0	0	4	9	6	6	3	0	0	10	0	1	0	8	1	6	1	1	0	4	6
Complex Crossing: Little Overview/Low Visibility	2	4	4	0	3	8	3	14	1	0	4	1	7	1	0	0	9	2	1	1	3	1
Complex Crossing: Many Lanes at Crossing	1	0	9	3	0	2	1	1	0	0	1	0	1	0	1	0	3	0	0	0	1	1
Conflict With Other Modes: Bikes	0	9	6	8	2	0	2	7	2	2	1	1	6	3	0	1	8	0	0	1	0	1
Conflict With Other Modes: Bus	9	0	6	3	1	2	0	5	0	4	3	1	2	0	0	3	11	3	6	1	0	2
Conflict With Other Modes: Cars	3	4	3	14	1	7	5	0	1	6	1	1	9	1	0	9	18	6	5	2	6	3
Conflict With Other Modes: Fat Bikes	0	5	0	1	0	2	0	1	0	1	1	2	1	11	0	0	7	0	0	2	0	0
Conflict With Other Modes: Large Vehicles	0	1	0	0	0	2	4	6	1	0	2	0	2	0	0	2	2	2	1	1	0	0
Conflict With Other Modes: Many Different Modes Congregate	1	0	10	4	1	1	3	1	1	2	0	0	5	1	2	2	2	0	2	1	2	2
Design Bike/Walk Path: Narrow Bike Path	1	1	0	1	0	1	1	1	2	0	0	0	4	5	1	0	1	0	1	10	0	0
High Volume	1	1	1	7	1	6	2	9	1	2	5	4	0	2	5	2	15	0	3	7	8	0

Others Along Route: Youth Groups	1	8	0	1	0	3	0	1	11	0	1	5	2	0	1	0	1	0	0	4	1	0
Positive Factors: Secure/Safe Crossing	1	1	8	0	1	0	0	0	0	0	2	1	5	1	0	0	3	0	0	5	5	3
Road Features: Narrow Road	1	0	1	0	0	1	3	9	0	2	2	0	2	0	0	0	1	2	3	0	0	0
Speed Related Issues: High Speed	6	6	6	9	3	8	11	18	7	2	2	1	15	1	3	1	0	4	3	0	5	6
Type Bike Path: Integrated Bike Path (Drawn on Road)	0	1	1	2	0	0	3	6	0	2	0	0	0	0	0	2	4	0	0	0	0	0
Type Bike Path: No Bike/Walk Path	2	0	1	1	0	0	6	5	0	1	2	1	3	0	0	3	3	0	0	3	1	2
Type Bike Path: Separated/Raised Bike Path	0	0	0	1	0	1	1	2	2	1	1	10	7	4	5	0	0	0	3	0	1	0
Unsafe Crossing: W/ Outlines of Crossing	0	0	4	3	1	0	0	6	0	0	2	0	8	1	5	0	5	0	1	1	0	0
Unsafe Crossing: W/ Traffic Light	5	3	6	1	1	1	2	3	0	0	2	0	0	0	3	0	6	0	2	0	0	0

Appendix I AI Statement

During the process of creating and writing this master thesis very little AI was used.

The main use of AI was Word's own transcription software, which was used to transcribe the various interviews. After using this tool, I reviewed and edited all transcribed interviews to ensure that all content was accurate, and any mistakes made were corrected. I take full responsibility for the content of the publication.

The research also used ChatGPT occasionally in the writing for very specific phrasings to find simpler or more direct language. One example being changing 'others thinking along in traffic' to 'anticipating needs in traffic'. This was only done a handful of times. I reviewed any wording changes before adopting or rejecting. I take full responsibility for the content of the publication.