IMPROVING TRAFFIC SAFETY

A POLICY ANALYSIS OF TRAFFIC FATALITY CAUSES

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Improving Traffic Safety

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I. Preface

After extensive reading, writing, and revision, I am pleased to present my thesis, "Improving Traffic Safety: A Policy Analysis of Traffic Fatality Causes." This research represents the end of my efforts toward completing my master's in public administration at the University of Twente.

I am grateful to my first supervisor, Guus Meershoek, for our insightful discussions that shaped the content of this research. I also extend my appreciation to my second supervisor, René Torenvlied, for his guidance and support in bringing this work to completion.

Throughout these months, I have maintained an interest in traffic safety, and I am excited that this research continues to explore this crucial area. I hope that this thesis offers valuable insights into the traffic situation in 2022 and provides recommendations for enhancing traffic conditions in the future.

II. Summary

The Netherlands targets zero traffic deaths by 2050, with strategic plans addressing vulnerable road users through collaborative safety policies. This research examined demographic, policy, and behavioral factors contributing to traffic fatalities, aiming to recommend policy decisions and improve road safety. A significant rise in traffic fatalities happened in 2022, particularly among cyclists and the elderly. To find out what has been going wrong in the Netherlands, a policy analysis has been conducted.

A comparative analysis was done to examine traffic-related fatalities. The theoretical framework of this research encompasses several key concepts that provide a structured approach to understanding the complex dynamics of traffic safety: a policy analysis involves evaluating the policymaking process to address complex societal issues. It recognizes that societal problems lack straightforward solutions due to their multifaceted nature. The approach involves systematic procedures to understand and interpret these issues. Traffic safety theory, Vision Zero was examined which aims to eliminate road fatalities by emphasizing safe road designs and policy measures that prioritize safety. This policy analysis used Vision Zero as a guideline of what traffic regulation and management should look like as well as, systems theory, which views road safety as a complex system where various components interact dynamically. It highlights the interconnectedness and interdependencies within a system.

Factors such as an aging population, increased electric vehicle use, and distractions such as phone usage are demographic and behavioral factors contributing to the rise in traffic fatalities. There is a concern about the higher fatality rates among inexperienced drivers, cyclists, and older people. There is also a rise in drug- and alcohol-related accidents. Most accidents seem to happen on 50km/h roads and intersections. The reason for this is that these types of roads have more reasons to be attentive. When it comes to road design, Vision Zero and the Dutch approach (safety approach) believe that roads should influence user behavior and be clear in their use. Various studies also highlight the effectiveness of self-explaining roads, designed to naturally encourage safe driving behaviors without reliance on enforcement. Research suggests that specific road elements, such as physical separations and clear markings, influence speed choices and response times. For older drivers, intersections are particularly hazardous. Improvements such as roundabouts, reduced complexity, and better visibility can enhance safety for this demographic.

With non-regulatory initiatives and law and regulations, they often lack a universal framework and vary by target groups and methods. Often initiatives such as campaigns are too short to make it work, but no research exists on long-term campaigns and their results, probably because long-term campaigns rarely happen. Traffic enforcement faces challenges due to competing priorities and limited personnel. For road users, it is often also clear that there is a small chance of being caught, resulting in more misconduct. Ways to improve this are regular and visible checks, focus on high-accident areas, and combining enforcement with education and public awareness campaigns.

To enhance traffic safety in the Netherlands, a multifaceted strategy is essential. This includes strengthening enforcement efforts with increased police patrols and technologies such as mobile speed cameras and ensuring consistent penalties for offenses such as distracted driving and speeding. Expanding the current demerit points system to cover a broader range of violations can also be effective, particularly when combined with incentives for safe driving. Long-term educational campaigns should focus on raising awareness about safe driving practices across different demographic groups. Additionally, investing in road infrastructure that prioritizes safety, especially at intersections and high-speed zones, is crucial. Finally, adopting a comprehensive approach that integrates road design, vehicle safety features, and user behavior is vital for achieving Vision Zero's goal of eliminating traffic fatalities and severe injuries.

III. Content

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Built up area	A built-up area comprises regions featuring extensive human-made structures, encompassing residential, commercial, and industrial developments. These areas are characterized by higher population density and greater urbanization compared to areas outside the built-up area (Letselschade Advocaten, 2021).
CBR	Central Agency of Driving Permits
CBS	Central Agency for Statistics
CROW	Institute for infrastructure, public space, traffic and transport, and work and safety.
SWOV	Dutch Institute for Road Safety Research
Kennisnetwerk SPV	Knowledge network: strategic plan for traffic safety. Collaboration between CROW and SWOV.
VVN	Veilig Verkeer Nederland (Safe Traffic Netherlands). Organization for traffic safety.

1. Introduction

1.1 Problem analysis

1.1.1 Problem definition

Since 1973, there has been a decrease in traffic deaths, but this decline stagnated in the last decade. In 2022, the number of fatalities increased compared to 2021, with a significant proportion involving cyclists (39%) and car occupants (30%). A majority of fatalities (54%) occurred among people aged sixty or older (SWOV, 2023a). Alongside deaths, 6,800 people suffered serious injuries, and 110,000 sought emergency care (Aarts et al., 2022). Addressing traffic deaths is crucial for humanitarian reasons and the substantial economic impact, constituting 15 percent of the total costs of traffic accidents, around four billion euros in 2020. The Netherlands aims for zero traffic deaths by 2050 (SWOV, 2023b).

This policy analysis will assess the effectiveness of road safety policies, road design, and behavioral aspects in the Netherlands in 2022 by examining traffic data from 2022 and preceding years. The analysis will evaluate whether these factors are on track to achieve the national goal of zero traffic deaths by 2050. The findings will provide insights for policymakers to enhance road safety interventions.

1.2 Research questions

Main research question

- What are the factors, including demographic factors, policy measures, and behavioral aspects, contributing to the increase in traffic-related deaths among road users in the Netherlands in 2022?

The meaning of demographic factors, policy measures, and behavioral aspects will be discussed in the chapter about the theory (5.3 Concepts p.8).

Sub questions

1. How have regulatory policies, including the enforcement of traffic regulations by law enforcement agencies, impacted road safety outcomes in the Netherlands in 2022?
2. What was the effect of non-regulatory initiatives, such as campaigns and infrastructure design, on road safety and the occurrence of traffic-related fatalities in the Netherlands in 2022?
3. What demographic and situational factors, along with behavioral aspects such as driver behavior and adherence to traffic regulations, contributed to the rise in traffic-related deaths among road users in 2022?

1.3 Significance

Scientifically, a policy analysis on this holds relevance because instead of solely understanding which individuals are vulnerable to fatalities, investigating the underlying causes will provide insights. This knowledge will address existing gaps and guide future research. In terms of policy implications, conducting research that informs policymakers is scientifically significant. Such findings contribute to the broader societal impact of scientific research by guiding decision-making processes and influencing interventions. Moreover, replication studies also hold scientific relevance. By replicating prior research, the reliability of scientific knowledge can be ensured. This process either confirms or questions the results of previous studies, strengthening the overall scientific understanding.

From a societal standpoint, conducting research to identify the underlying reasons behind the upward trend in traffic-related deaths is important. Through a comprehensive examination of these causes, a policy analysis can facilitate the formulation of targeted interventions aimed at improving road safety and reducing fatalities. Analyzing the specific circumstances associated with these incidents will shed light on crucial aspects. This understanding will help identify vulnerable groups and tailor interventions accordingly. Furthermore, by assessing the impact of policy measures implemented in the Netherlands over the past years, policymakers can determine whether additional interventions are necessary.

3. Theoretical framework

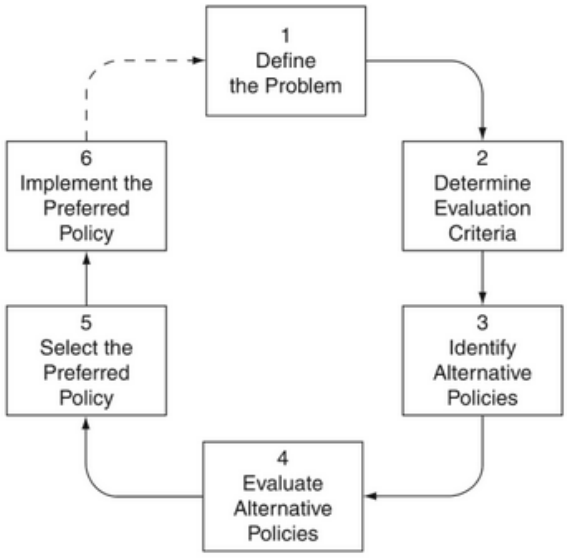
This theoretical framework aims to look closely at the key concepts. This helps the upcoming research to grasp the focus of the study and get a clear picture of all the concepts. The research questions have already set the direction by outlining the concepts that will be examined.

3.1 Policy analysis

Policy analysis entails examining issues and the policymaking process to understand and evaluate the often complex outcomes. The initial step is comprehending policy formulation, the perception of the societal problem, followed by investigation and interpretation of policy implementation. Understanding the problem is challenging due to diverse perspectives and complexities, making simple solutions elusive (Yanow, 2010). Patton et al. (2012) noted that policy problems are complex and lack clear solutions due to societal complexities. To address this, a set of systematic procedures known as policy analysis can be beneficial. Developing a standard approach is difficult because of the wide range of existing problems. A basic policy analysis model has been created for situations with limited time (figure 1). This model made by Patton et al. (2012) demonstrates the fundamentals of policy analysis, while also recognizing that problems are complex and occur within specific contexts.

Figure 1

A basic policy analysis model (Patton et al., 2012).



Pawson and Tilley (1997) exemplify the complexity and problem-solving in policy analysis, focusing on scientific realism. They view causation as underlying mechanisms generating effects within specific contexts. Understanding these mechanisms and their contexts is crucial, as context influences how mechanisms produce desired outcomes. Outcomes result from the interaction between mechanisms and contexts. Scientific realism aims to accurately represent reality, believing successful theories are approximately true. It acknowledges that people's experiences can be mistaken and that phenomena exist even if not fully understood. It promotes looking beyond surface correlations to uncover underlying causes and conditions driving changes. Scientific realism focuses on identifying and understanding the outcomes to evaluate effectiveness. The outcomes of the process are not just results but also unintended consequences and side effects. In this research, it is hard to find causation because there is no evidence that factors influence each other. By examining correlations through mechanisms and contexts, scientific realism assesses not just if a program works, but how, for whom, and in what contexts. This approach offers actionable insights for improving and tailoring programs to different situations.

Traffic safety can be seen as a social system, which can be explained in five concepts. The first one, embeddedness, policy analysis involves understanding all human interactions within a social process. People's actions are based on their assumptions of what should happen, which they derive from social rules. Actions are influenced by culture, social acceptance, and economic circumstances. Overall, social actions and interactions are deeply embedded within networks of relationships and social structures, influencing individuals' decisions and behavior. Following this, mechanisms explain what makes a program work. Mechanisms are identified by looking at what triggers people to make the decisions they do. Essentially, mechanisms provide theoretical insight into how and why variables interact, while decisions are based on the consideration of multiple such variables. Social mechanisms focus on the decisions people make. Next is the context, which refers to the environment in which actions occur. The relationship between mechanisms is influenced by the context in which they occur, making context crucial for understanding why something happens the way it does. Context includes factors such as historical, social, economic, and cultural conditions. Regularities can be seen as the outcomes, resulting from the interaction of mechanisms and contexts. These regularities are patterns or trends that emerge from social processes. Changes involve the awareness that people have about their decisions and their desire to change them, though this can be challenging due to limited resources. Additionally, unpredictability arises because people do not always have complete information about contextual conditions, which limits their actions. In summary, their approach to policy analysis emphasizes understanding the intricate relationships between embeddedness, mechanisms, context, regularities, and changes. This comprehensive view helps explain the complexity of social processes and the factors influencing human behavior (Pawson & Tilley, 1997).

3.2 Road fatalities

According to CBS, a road fatality is a road user who dies within thirty days of an incident involving traffic and a moving vehicle on a public road in the Netherlands. Some situations do not classify as traffic fatalities: accidents in non-public zones, incidents on non-public train or tram tracks, deaths after 30 days, homicides, suicides, and stillbirths (CBS, n.d.).

3.3 Traffic injury

A traffic injury means that an individual has sustained an injury due to a traffic accident, requires hospitalization, and does not succumb to the injuries within thirty days (Rijkswaterstaat, n.d.).

3.4 Traffic safety

Understanding traffic safety and key insights from relevant literature is essential for this research. Johansson (2009) views road safety as a philosophy embedded in street design. He attributes a global road safety crisis to deficiencies in road design, highlighting it because of human decisions. Lobanova & Evtiukov (2020) find that the most important source of accidents is road users. They suggest that safety measures only provide limited protection. Safety violations often occur due to a variety of factors, especially when individuals become accustomed to hazardous situations. In addition, Åberg (1998) asserts that the normalization of motor vehicle use led to increased regulation of road traffic. The author suggests that understanding drivers' behavior, especially adherence to rules, can offer insights applicable to regulating behavior in other areas. However, Åberg notes that, despite safety rules, drivers often exhibit unsafe behavior, playing a substantial role in accidents. According to Gössling (2017), lobbying plays a significant role in shaping traffic safety outcomes. As an illustration, the car industry may resist the implementation of lower speed limits. Their primary focus is making a profit rather than prioritizing safety concerns.

3.5 Traffic safety theories

In traffic safety, numerous theories exist for improvement. These theoretical frameworks serve as perspectives for studying human behavior in traffic and devising strategies to improve safety. Firstly, the Haddon matrix analyzes the entire timeline of a car accident—before, during, and after the event—to prevent injuries. It considers human behavior, vehicle features, and the environment to influence changes through laws, education, and awareness. The matrix helps understand car accidents and aids in prevention (Williams, 1999). Secondly, the Swedish 'Vision Zero' concept, aims to eradicate road fatalities by addressing effective measures (Archer & Kircher, 2015). Vision Zero criticizes that speed is prioritized over safety. It prioritizes safety over benefits, urging system designers to create safe designs and account for non-compliance with traffic laws (Shahum, 2017). Some theories explore risk-taking behaviors during accidents, focusing on risk compensation (Levym & Miller, 1999; Stetzer & Hofmann, 1996). The theory posits that when forced to drive safely, individuals may increase speed or engage in other risky behaviors if they perceive the environment as safer. The authors emphasize the challenge of studying individual behavior due to its subjective nature. Alternately, Dejoy (1989) studied optimism bias in traffic among college drivers, who trust their driving skills and take more risks. As experience grows, optimism increases, causing individuals to downplay accident risks and attribute them to human factors rather than external ones. Risk Homeostasis Theory (RHT) links accident frequency to road user behavior. Users have a preferred risk level, adjusting their actions accordingly. Influencing perceptions of acceptable risk may decrease accidents and improve road safety (Wilde, 1987). Malnaca (2008) explains that people may balance risk by increasing other risks when one is reduced, maintaining their comfort level with overall risk. Another behavioral perspective that emphasizes the apprehension of consequences is deterrence theory. This theory suggests that individuals are less inclined to commit offenses when they fear facing severe consequences (Freeman et al., 2015 & Davey & Freeman, 2011). Research has questioned whether applying this idea to stop criminal activity is successful (Freeman et al., 2015). Punishment that is immediate, severe, and certain reduces lawbreaking. Legal threats are most effective when they give the impression that potential offenders will be discovered and will suffer severe punishment (Davey & Freeman, 2011).

3.5.1 Vision Zero framework

Road fatalities bring economic costs and emotional trauma, but safety concerns challenge the concept of unrestricted mobility. Vision Zero aims to change this by promoting road designs and policies that prevent accidents caused by human error Moreover, Vision Zero emphasizes collaboration and the responsibility of policymakers, while also highlighting that road users should follow rules (Visionzeronetwork, n.d.). When non-compliance occurs due to factors such as lack of knowledge or serious injuries, designers must take steps to prevent fatalities or severe injuries. Vision Zero acknowledges that crashes are inevitable and focuses on survivable crashes (Shahum, 2017).

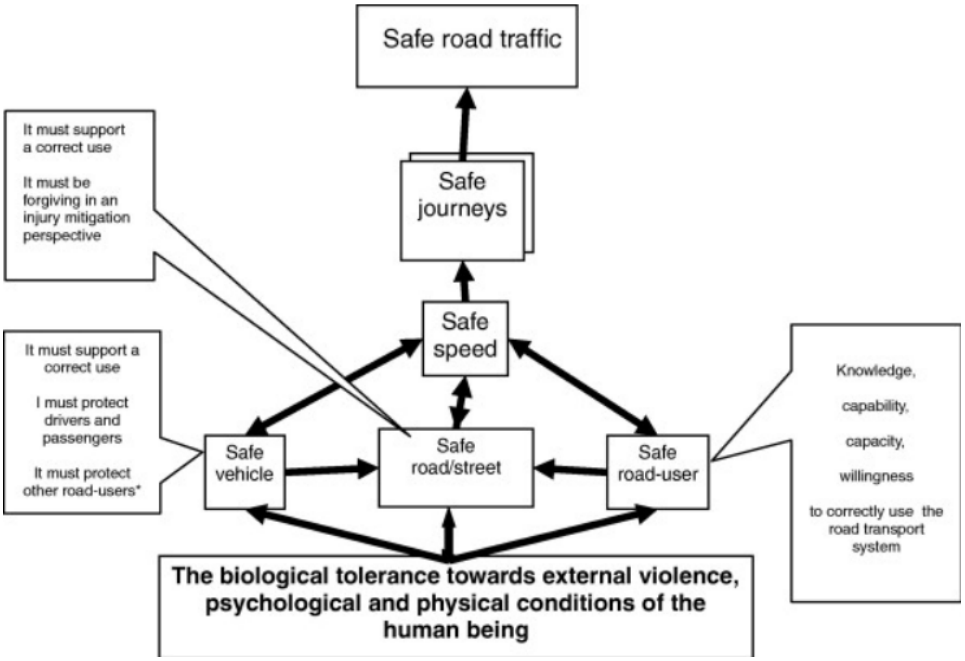
The Netherlands adopted the sustainable safety approach, in line with Vision Zero. This objective has been a longstanding priority, with the Netherlands consistently prioritizing the reduction of traffic fatalities. The Netherlands has had movements for livable and safe neighborhoods and in the 1990s, policymakers transitioned from reactive to proactive approaches, by prioritizing prevention and emphasizing anticipatory measures. From 1998 to 2007, policymakers introduced speed reduction, road categorization, and roundabout construction. Public campaigns targeted risky behaviors such as drunk driving and seat belt usage. Road design principles aimed to make roads predictable, forgiving of human error, and encourage drivers to be more aware of their responsibilities (Shahum, 2017).

3.5.2 Systems theory

A system is a collection of components that work together to accomplish tasks. System thinking considers the entire system rather than parts, recognizing the interconnectedness of its elements. Road transport is a complex system that involves various elements, such as drivers, vehicles, and infrastructure, interacting to facilitate movement. Complex systems such as road safety present challenges in identifying cause-and-effect relationships due to unpredictable behavior. Despite predetermined laws and road design, the complexity arises from the unpredictability of human behavior within this system. Similar to other complex problems, road safety involves diverse underlying causes, external factors, and resistance to simple solutions (Larsson et al., 2009). Larsson et al. (2009) employed a model depicting road transport as a system (figure 2). This model illuminates the complexity of road safety and identifies the contributing factors.

Figure 2

Systems model of road safety (Larsson et al., 2009).



Hughes et al. (2016) developed a systems theory framework that aligns with the structure of this research (figure 3). The framework encompasses components contributing to crashes, policy tools influencing these components, recent road safety strategies related to these elements and tools, and potential enhancements for these strategies. Additionally, Hughes et al. (2016) outline four critical elements of systems theory: the system's components, the interrelationships among these components, the system's purpose, and the interdependency among its components. These factors may be guided by principles and grounded in underlying theories. Despite its frequent use in literature, the term "system" often lacks coherence in theoretical application or lacks clear definition and support. Using systems theory can also be challenging due to its complexity, because of the numerous components and relationships.

Figure 3

Systems theory framework (Hughes et al., 2016).

Systems approaches use techniques to understand and improve entire systems, viewing accidents as complex interactions. They provide a comprehensive, theory-driven understanding of dynamic system behavior, proven effective in practice. However, their complexity makes them challenging to use due to numerous components and relationships (Hughes et al., 2015). Larsson (2009) notes that systems theory prioritizes controlling variability in road user performance but neglects vehicle and road component performance. Moreover, systems theory often lacks a clear definition, leading to inconsistencies and complicating its usage and comparison (Hughes et al., 2015).

Larsson (2007) suggests using systems theory for more effective road safety strategies. He notes that Vision Zero aligns with systems theory by focusing on system interactions rather than individual blame. This approach aims to create a safer transport system by controlling variability and enhancing safety measures. Applying systems theory to road transport is crucial due to its complexity, making it essential for modern safety practices and effective management (Larsson, 2007). Using systems theory enables a thorough examination of all key components involved (Hughes et al., 2015). Developing comprehensive conceptual frameworks for road safety strategies, informed by systems theory, is crucial to understand complex interactions within the transport system. Though frameworks exist for areas such as cycling, there is a gap in addressing the entire transport system (Hughes et al., 2016).

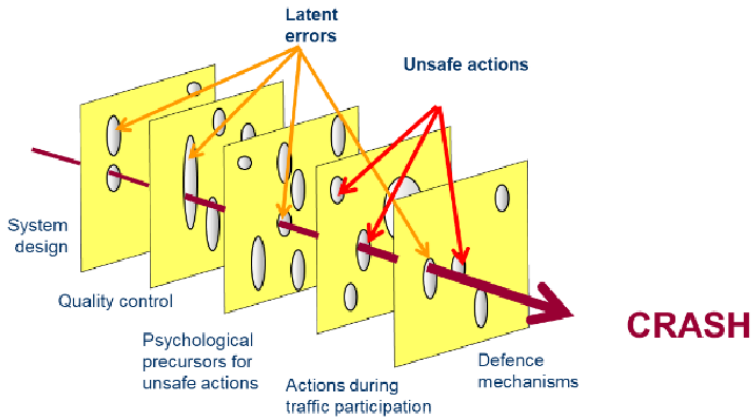
3.5.3 Other theories

Other theories, though less emphasized in this research, are still worth noting. In literature discussing systems theory, authors often compare it with other frameworks such as Haddon's matrix. While Haddon's matrix considers critical factors across all phases, it lacks in illustrating interactions, unlike systems theory. Conventional theories tend to focus on isolated components rather than examining interconnected variables. Moreover, Haddon's matrix primarily centers on the driver's role, neglecting other stakeholders and existing laws, hindering an understanding of road safety dynamics (Hughes et al., 2016). Additionally, risk compensation is a factor. People may adjust their behavior in response to perceived danger, potentially offsetting safety gains from new technology. If these interactions are not understood and managed effectively, the safety benefits of these systems could be diminished or lost entirely (Larsson, 2007). Another theory is the Safe System Approach. Countries around the world have adopted various strategies to enhance road safety, with many aligning with the overarching goal of Vision Zero. The Safe System Approach focuses on minimizing fatalities by addressing potential human errors and fostering collaborative partnerships among stakeholders (Aarts, 2023). Despite proactive measures, accidents may still occur, prompting the need for effective management of vehicles, road infrastructure, and speeds to mitigate crash energies (Langford & Oxley, 2006). The Netherlands has started its approach based on Vision Zero, called sustainable safety. This approach emphasizes safe road design and comprehensive safety measures, as previously discussed in this chapter (Aarts, 2023). Aarts (2023) also references the Swiss Cheese Model, which can be applied to this research context (figure 4). This model visualizes a safe system, with slices of cheese representing different stages in system construction and use. The holes

symbolize latent errors and defense mechanisms, ensuring unsafe actions and errors do not coincide. Similarly, in crowd safety practice, the Swiss Cheese Model incorporates multiple layers of protection such as regulations, planning, and technology. This model emphasizes the importance of public education and awareness in preventing accidents. Despite criticisms, the model has been valuable in integrating systemic factors into accident prevention approaches (Haghani et al., 2023). While essential for integrating systemic factors into accident prevention and making organizational accidents accessible, the model's practical guidance efficacy is debated. Some literature suggests it is too broad, risking attribution to distant factors over immediate ones. Critics also worry it is oversimplified, neglecting simpler explanations such as human error (The decision lab, n.d.).

Figure 4

Swiss cheese model when used for road crashes (Aarts, 2023).



3.5.4 Reflection

The policy analysis theory suggests that in examining policies, embeddedness involves understanding how social, cultural, and economic factors influence policy implementation and finally also traffic safety behaviors. Drivers' compliance with rules is shaped by societal norms, enforcement practices, and economic conditions. Mechanisms explain how policies work. For example, enforcement needs execution by the police to deter rule-breaking by increasing the likelihood of being corrected or fined. Identifying these mechanisms helps policymakers understand processes leading to safer driving and fewer accidents. Context refers to specific conditions under which policies are implemented, such as existing road infrastructure or public awareness levels, which influence policy effectiveness. Contexts vary by location. Regularities are trends that emerge from the interaction of mechanisms and contexts, such as reduced speeds and fewer accidents due to speed cameras. Changes are shifts in behavior and outcomes resulting from the policy. Over time, drivers may adopt safer habits.

From the (traffic) safety theories it becomes clear that a focus on human factors is important. Behavior significantly influences many outcomes and events. Human minds are complex, and mistakes happen easily. Next to that, from systems theory, it becomes clear that interaction between stakeholders but also all other factors influencing traffic safety should be examined when making policy. Optimizing the interaction between drivers, vehicles, and traffic systems. By combining these theories, a comprehensive approach can be developed to find all factors in traffic safety and improve it.

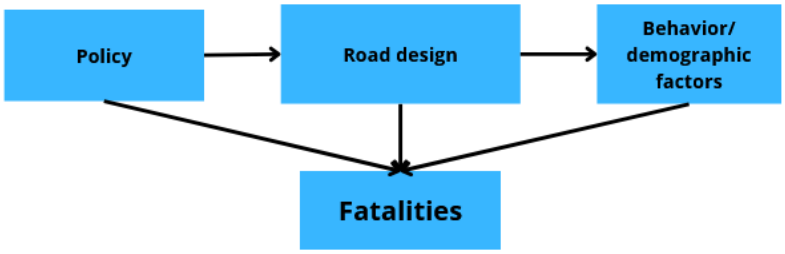
3.6 Conceptual framework

The conceptual framework offers a systematic approach to understanding how variables are interconnected in this research. It revolves around three key factors: policy, road design, and behavior. Policy can be divided into law and regulation, initiatives and education, and law enforcement. These factors collectively contribute to traffic fatalities. Each factor not only independently impacts fatalities but also interacts with the others. Policy decisions shape behavior and road design, which in turn affect the occurrence of fatalities. The framework's concepts stem from the inquiries posed in the research.

Positioned on the left side of the framework is policy. Policy exerts an overarching influence on traffic safety. It directly impacts fatalities, road design, and behavior. Policy decisions and regulations play a significant role in shaping behavior and infrastructure, affecting the occurrence of fatalities. In the middle is road design, which plays a crucial role in shaping behavior, which in turn affects traffic fatalities. The design and condition of roads, signage, and traffic management systems influence driver behavior and directly impact the occurrence of fatalities. Road design is influenced by policy decisions regarding transportation planning and funding allocations. On the right side is behavior. It is identified as a key factor influencing traffic fatalities. Positive behavior, such as adherence to traffic rules and safe driving practices, can lead to fewer fatalities. Behavior is influenced by policy decisions and, to some extent, by the quality of infrastructure and road design. Positioned beneath the other concepts is fatalities, fatalities are depicted as the outcome influenced by policy, road design, and behavior. They represent the direct consequence of these factors' interactions and their combined effects on traffic safety.

Figure 5

Conceptual framework



4. Methodology

The methodology describes how the research will be conducted. It begins by outlining the research design, followed by the approach and data collection methods. Next, it covers the sampling strategy, data analysis techniques, and operationalization of key concepts. Subsequently, the chapter examines the validity and reliability of the research. Finally, it discusses the limitations of the study.

4.1 Research design

A mixed-method approach was employed to validate findings, which are about traffic safety, such as, accident types, incident locations, and regulations. Additionally, Comparisons with studies from other countries were made to assess if the Netherlands could improve its practices. The research primarily relied on secondary data due to its availability and extensive history.

4.1.1 Approach

Table 1 provides an overview of the approach, data collection methods, and details for each sub-question, ensuring a systematic process. Information was gathered from organizations such as SWOV by analyzing regulations and reports on traffic accidents, aiding in answering the research questions. This research used non-probability sampling for selecting key documents. Purposive sampling was applied to choose relevant documents.

4.1.2 Data analysis

A combination of quantitative and qualitative methods was used to address the research questions. Table 1 outlines these methods and their corresponding research questions and results. In addition, the comparative analysis examined traffic-related deaths and differences across years. The 2022 results were compared to previous years and other studies, focusing on Vision Zero and systems theory implementation. The results were also analyzed from a policy perspective, aligning with the primary objective of this study. Vision Zero and systems theory were examined to address the main research question. These theories, relevant to road safety, were considered, with Vision Zero emerging as the most suitable for constructing a comprehensive framework.

Table 1

Methods and Data Sources.

	Approach	Data collection	Results
1	How have regulatory policies, including the enforcement of traffic regulations by law enforcement agencies, impacted road safety outcomes in the Netherlands in 2022?		
	• Comparative analysis	• Reports from Dutch institutions with data from 2022 and previous years • Other studies on this topic	• Implemented policies in the past years. • A thematic analysis with recurring themes • Literature from other studies • Analysis of theoretical framework and comparisons
2	What was the effect of non-regulatory initiatives, such as campaigns and infrastructure design, on road safety and the occurrence of traffic-related fatalities in the Netherlands in 2022?		

	• Comparative analysis	• Reports from Dutch institutions with data from 2022 and previous years • Other studies on this topic	• Implemented policies in the past years. • A thematic analysis with recurring themes • Literature from other studies • Analysis of theoretical framework and comparisons
3	What demographic and situational factors, along with behavioral aspects such as driver behavior and adherence to traffic regulations, contributed to the rise in traffic-related deaths among road users in 2022?		
	• Comparative analysis	• Reports from Dutch institutions with data from 2022 and previous years • Other studies on this topic	• Main demographic and situational factors involved in traffic-related deaths. • Differences through the years • Examination of types of behavioral aspects most involved in traffic-related deaths. • Analysis of theoretical framework and comparisons
M	What are the factors, including demographic factors, policy measures, and behavioral aspects, contributing to the increase in traffic-related deaths among road users in the Netherlands in 2022?		
	Connecting the sub-question, via the vision zero framework, to answer the main question, by writing a thorough conclusion of the five sub-questions.	Data from this research	A conclusion and recommendations with the Vision Zero approach and the systems theory framework.

4.1.3 Operationalization

Defining and measuring the variables and concepts for all research questions (table 2).

Table 2

Concept operationalization

Concept	Definition	Research question
Traffic-related deaths among road users in the Netherlands	Fatalities that occur because of accidents involving road users, including drivers, passengers, pedestrians, cyclists, and motorcyclists, within the Netherlands.	All
Policy measures	Policy measures encompass the strategies, regulations, interventions, and initiatives implemented by the government or other important actors to improve road safety and reduce traffic-related deaths. These measures can include legislation, educational campaigns, infrastructure improvements, or awareness programs aimed at preventing accidents and reducing fatalities.	1/2
Traffic enforcement	Traffic enforcement involves overseeing and controlling road use to ensure adherence to traffic laws and safety regulations. This includes issuing fines or penalties for infractions such as speeding, red light violations, or drunk driving. The goal of enforcement is to promote road safety and prevent accidents.	1
Road design factors	Road design factors refer to the physical characteristics and layout of the road environment. These factors include design elements implemented by institutions and companies, including advertisements and signage. Additionally, natural elements such as trees and ditches, as well as non-traffic features, also contribute to the road environment.	2
Demographic factors	The demographic profile of individuals who succumb to fatal incidents in traffic. Demographic factors encompass characteristics of individuals and groups within the population that may impact the occurrence of traffic-related deaths. Factors: age Gender Province/ region	3
Situational factors	The locations where individuals experience traffic accidents. Factors: Type of road Speed on road Mode of transportation	3
Behavioral aspects	Driver behavior and compliance with traffic regulations. Driver behavior are the choices made by individuals, examples are reckless driving (tailgating, frequent lane changes), driving under the influence of alcohol or drugs, and distracted driving (using a phone or navigation). This concept does not pertain to emotions because it is more difficult to research.	3
Compliance with traffic regulations	This is about following the rules in traffic. Examples are seat belt usage, following signs, following speed limits, driving 30 km/h because of road work, and more.	All

4.2 Validity and reliability

To ensure validity, the following strategies are employed. Firstly, the research questions are clearly defined, this helps ensure that the study addresses the objectives. Secondly, sampling techniques play a crucial role in ensuring validity. Selecting relevant reports helps ensure that the reports represent the target population accurately and minimizes sampling bias. The reports will be sampled based on their relevance to the study, which are reports that specifically mention policy measures, driver behavior, or road design factors. This helps ensure external validity. Thirdly, addressing potential confounding variables is essential and finally, triangulation is important, by using multiple data sources, both these methods help ensure the internal validity of the research. To ensure reliability, a standardized protocol is used to ensure consistency across data collection.

4.3 Limitations

The research uses existing police reports and accident investigations, which may have limitations in data quality, completeness, or accuracy, potentially not aligning perfectly with the research questions. A way to address this limitation is by mentioning it in the discussion. Challenges also include restricted access to certain reports, changes in reporting practices, and variations in data recording methods over time. Additionally, a descriptive analysis provides data at a particular point in time, which may not capture the full changes over time. For this, multiple researches over de past five years were examined. Potential bias will be avoided by doing multiple types of research and by using multiple documents.

5. Results

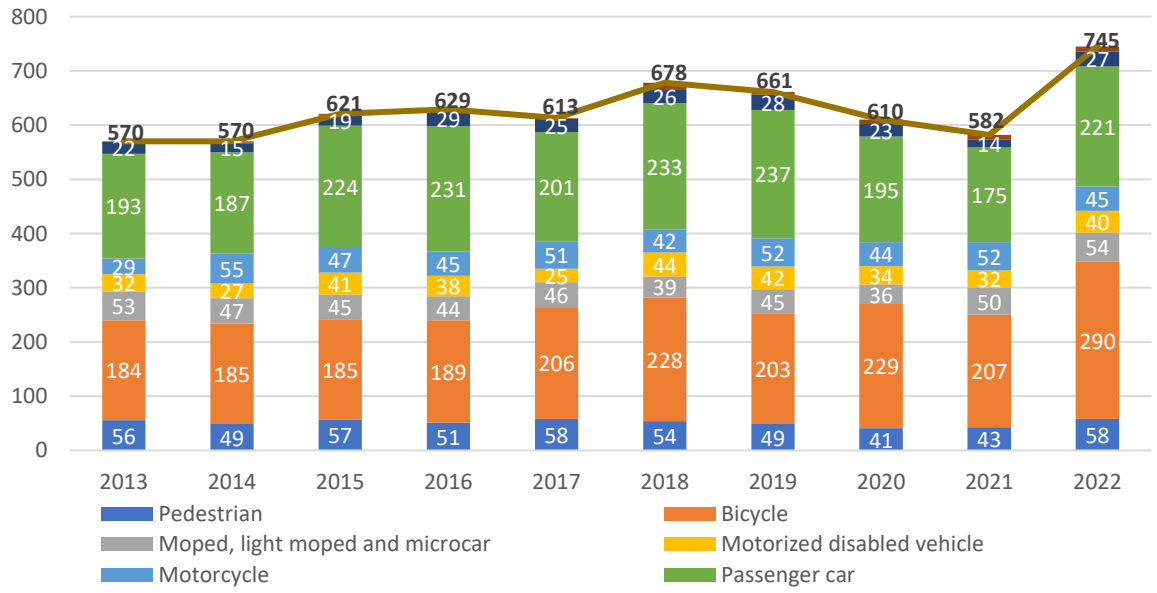
5.1 Background

There has been a significant decrease in road fatalities since 1973. This decline affected all road users, especially cyclists. From 2013 to 2021, traffic deaths ranged from 570 to 678, with the lowest recorded at 570 in 2013/2014 in the Netherlands. In 2022, there were 745 deaths, the highest in fourteen years. Before the 2022 surge, the Dutch government aimed for zero traffic deaths by 2050 and a 50 percent reduction by 2030, aligning with EU targets. Recent research indicates achieving this is unlikely despite new measures, increased deaths and injuries are expected (SWOV, 2023a). It is crucial to consider the impact of the COVID-19 pandemic on this research, as it significantly influenced mobility in 2020 and 2021, resulting in fewer casualties. The extent to which pandemic measures affected traffic safety remains uncertain. Whether the decline during that period is temporary or signifies a lasting improvement is also unclear (De Craen et al., 2022).

Recently, shifts in traffic patterns have become evident, including higher implementation of bike paths, or the rising popularity of electric vehicles. The increased accidents of older individuals are attributed to the aging population and sustained traffic participation, linked to the prevalence of electric vehicles and the trend of self-sustainability. Phone usage, extending beyond calls to access information and routes on in-car systems, introduces distractions. Moreover, specific attention is now on inexperienced drivers, as a notable number of fatalities occur among those aged 15 to 29, often due to overestimating their abilities. Additionally, cyclists face increased risks, even without other vehicles, and focus on traffic offenders addresses non-compliance risks leading to accidents (Ministerie van Infrastructuur en Waterstaat, 2018). A total of the deaths that occurred in the years up to 2022 is shown in figure 6, along with the mode of transportation.

Figure 6

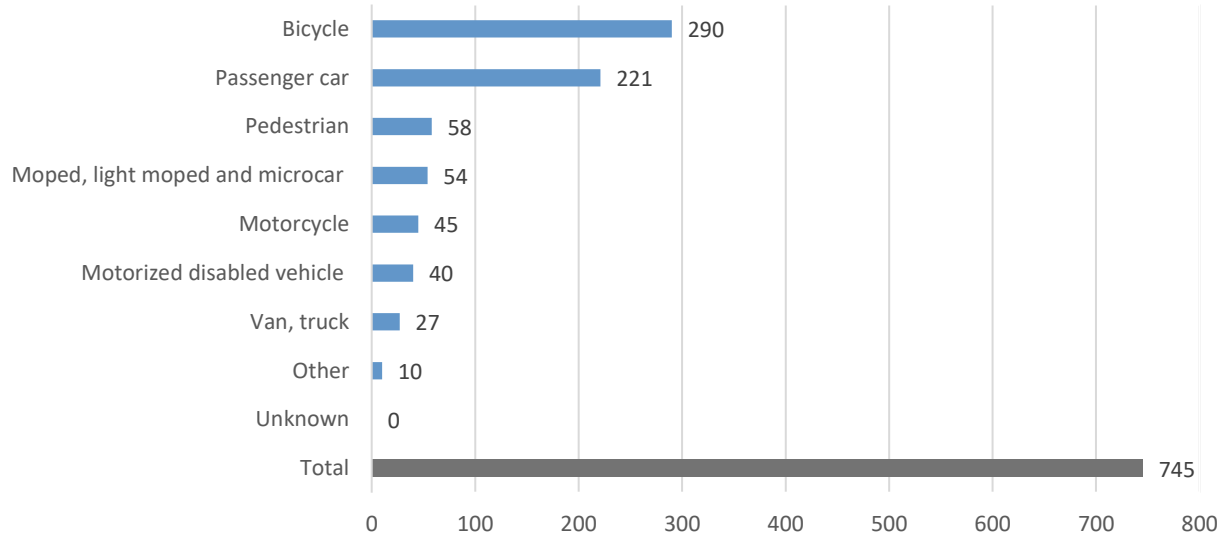
Road fatalities (2013-2022) (CBS, 2023b).



In 2022, cyclists constituted the majority of casualties, making up 290 of the total (39%). They were closely followed by car drivers. The lowest fatality rates were among freight truck drivers and mobility scooter users, as can be seen in figure 7 (SWOV, 2023a).

Figure 7

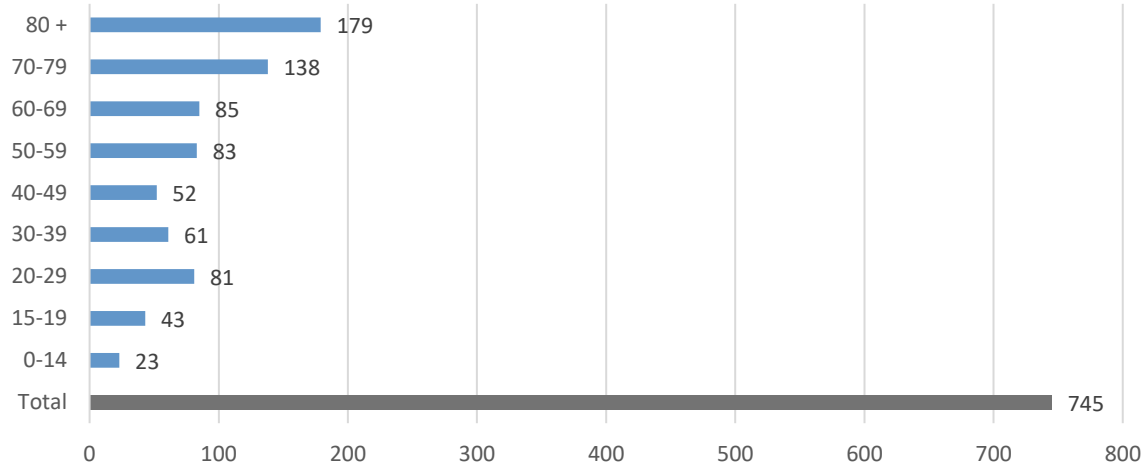
Deaths per vehicle (2022) (CBS, 2023b).



When examining age groups, the highest number of fatalities occurs among individuals aged 80 years or older, with the 70-79 age group following closely behind. Figure 3 indicates that over half of traffic deaths involve individuals aged 60 or older (SWOV, 2023a). Functional disorders are a significant concern among older individuals, leading to a higher frequency of accidents. Due to driving less frequently, this demographic has reduced familiarity with driving, increasing the likelihood of accidents. Furthermore, older people avoid highways but still use other roads with high risks (SWOV, 2015). In 2022, men accounted for 71 percent of traffic fatalities (SWOV, 2023a). Moreover, the ANWB highlights that accidents involving electric bikes increased from 80 in 2021 to 99 in 2022. Among these 99 incidents with e-bikes, 81 involved individuals aged 70 and above (ANWB, 2023).

Figure 8

Deaths per age (2022) (CBS, 2023b)

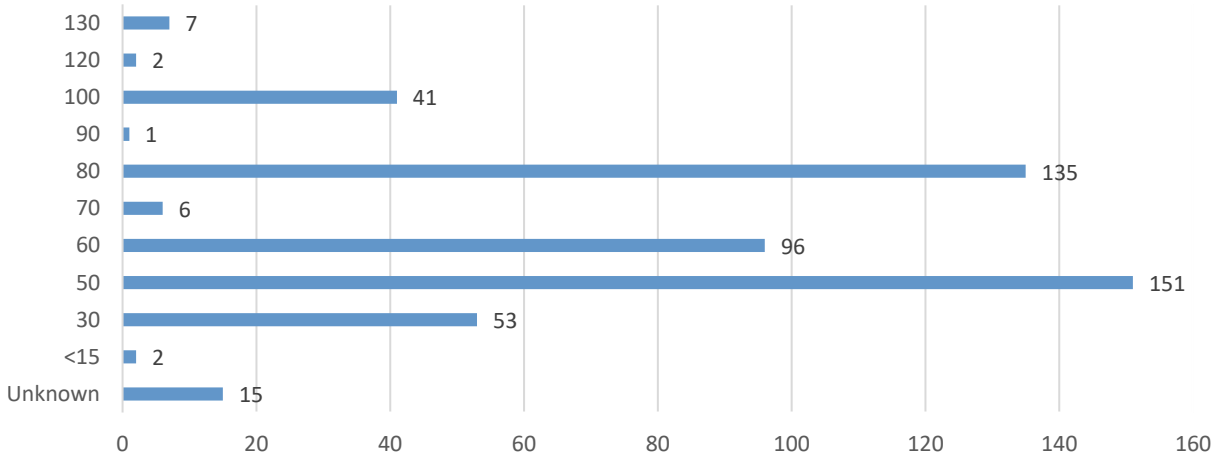


In 2022, 52 percent of fatalities occurred outside built-up areas, while 47 percent happened within built-up areas. Figure 4 reveals that most fatalities occur on 50 km/h (27%) and 80 km/h (19%) roads. Following closely are 60 km/h roads, contributing to 15 percent of the fatalities. The lowest fatality

rates are observed on 70 km/h and 130 km/h roads. For these, 14 percent of cases remain undisclosed regarding the specific type of road. In addition, 53 percent happened on road sections and 35 percent on intersections. Over 50 percent of the fatalities occurred on municipality roads, with an additional 18 percent on provincial roads. This emphasizes the potential hazards of these roads but also underscores their substantial traffic volume (SWOV, 2023a). Different road types contribute to varying accident risks. National highways, with limited access and high speeds, usually have lower risks due to fewer conflicts. Provincial roads, also fast-moving, have higher risks due to obstacles. Municipal roads, where various users interact, often have the most accidents. Additionally, lighter and slower road users face increased risks in scenarios involving differences in mass and speed among road users (Ministerie van Infrastructuur en Waterstaat, 2018).

Figure 9

Deaths per speed limit on roads (SWOV, 2023a)



5.2 Law & regulations and enforcement

This chapter focuses on Research Question 1: How have regulatory policies, including the enforcement of traffic regulations by law enforcement agencies, impacted road safety outcomes in the Netherlands in 2022? This question centers on the laws and rules governing traffic, and their enforcement by the police. The next chapter focuses on policies such as campaigns and education.

5.2.1 Law and regulations

To understand recent changes in Dutch laws and regulations, table 3 will highlight key changes from the five years preceding 2022. This analysis will compare these changes to relevant studies. Due to the volume of laws, only a selection will be included, with special regulations added if relevant.

5.2.1.1 Law and regulations before 2022

The law changes were categorized into those primarily aimed at enhancing safety and those driven by other motives. This categorization highlights the frequency of legislative adjustments over time and underscores that while laws are subject to regular updates, not all changes are intended to directly impact safety. Table 3 shows the law and regulation changes between 2016 and 2022, which are still expected to be relevant in 2022.

Table 3

Law and regulation changes between 2016 and 2022 (Verkeersmaatregelen, n.d.)

	Safety		Other
Year	**Law**	**Explanation**	**Law**
2021			Higher speed (agricultural) construction traffic
2020	Tougher penalties for traffic offenses	This broadens the scope for prosecuting drivers who engage in dangerous driving, such as speeding or ignoring red lights. It targets those who take unacceptable risks and cause serious accidents.	
2019	New electric cars must make noise		Self-driving cars on the public road
	Smartphone use while cycling is prohibited		Changes to the Traffic Light Regulations
2018	Mopeds are allowed on the road	Municipalities and road authorities can move light-moped riders to the roadway when cycle paths are crowded. When using the road a helmet must be worn. This helps reduce cycle path congestion, but some experts worry about moped safety due to speed differences with vehicles on the road.	
2017	Saliva test during traffic checks	The new regulations allow police to perform saliva tests during traffic stops to detect drug use, supplementing existing blood tests. This improves road safety by quickly identifying drivers under the influence. Similar measures in Belgium led to twice as many driver arrests.	Accessibility as a right
	14 new traffic signs	The new signs enhance clarity in traffic. They include signs for tram or bus lanes. New signs also mark passing lanes for	

		agricultural vehicles and passing places on narrow roads, guiding drivers in potentially hazardous areas.	
	Agricultural vehicles **do not** receive a license plate	There was no legal change in this case. The goal was to enhance safety and streamline enforcement and access to vehicle information. However, there was no evidence supporting these safety claims. Opponents argued that these vehicles were rarely on public roads and that it would lead to a tax hike for farmers.	
	Speed pedelec gets a license plate	The new European law mandates that speed pedelecs be registered as mopeds instead of scooters, enhancing road safety for both other road users and speed pedelec riders. They must now adhere to stricter traffic rules, such as wearing a helmet and using the moped path or roadway. A 2016 SWOV report confirms that these measures boost the safety of electric bicycles and speed pedelecs.	
2016	Headlights for new scooters and mopeds automatically switch on	In 2016, many vehicles still had manual on/off headlight controls. This change aims to reduce accidents.	Adjustment of driving license rules for electric and hybrid distribution vehicles

Changes in 2022 were made as well, the expectation is that these have had a low impact on traffic safety in 2022 because of how recent they were implemented. In table 4 the changes are shown.

Table 4

Law and regulation changes in 2022 (Verkeersmaatregelen, n.d.)

	Safety		**Other**
Year	**Law**	**Explanation**	**Law**
2022	Traffic fines adjusted to the degree of danger	The government has decided to increase penalties for serious traffic violations while reducing fines for minor offenses. These adjustments aim to enhance road safety by cracking down on severe violations while making penalties for minor infractions less severe (as of March 1).	
	50km/h become 30km/h roads		
	Advanced safety systems on new cars	Cars manufactured as of 2022 need certain new safety features. Emergency braking systems, speed limiters, reversing cameras or parking sensors, driver alertness monitors, and mandatory alcohol interlock connections.	

5.2.1.2 Other law changes

In March 2020, the Netherlands lowered the highway speed limit from 130 km/h to 100 km/h (06:00 to 19:00) to reduce nitrogen emissions, but not for safety reasons. Although lower speeds usually reduce traffic fatalities, data for this case is lacking. Enforcement is difficult due to limited police presence, and the COVID-19 pandemic introduced additional variables affecting outcomes (SWOV, 2021b). Moreover, as of July 1, 2019, holding a phone while cycling is illegal, with a 95 euros fine. This law aims to address the growing congestion and varying speeds on cycling paths, as well as the increased phone usage due to new features (De Fietser, 2019).

The tables also shows law changes not specifically implemented for safety reasons but which could impact traffic safety. For example, the 2016 adjustment to driving license rules for electric and hybrid distribution vehicles ensures drivers are adequately trained, potentially reducing accidents from inexperience. The 2017 accessibility law emphasizes infrastructure inclusivity, which might reduce accidents for vulnerable people. In 2018, changes to traffic light regulations aimed to improve traffic flow and pedestrian safety could reduce intersection accidents.

5.2.2 Relevant studies

Implementing laws can greatly enhance safety. However, if those laws are revoked, the associated benefits can disappear. Besides, laws do not always result in shifts in behavior, and people might return to their old ways once the constraints are removed. Moreover, laws are effective only when they can be properly enforced. Sometimes, laws are enacted that cannot be effectively implemented due to the absence of penalties or because only secondary enforcement is feasible. Secondary enforcement means giving out tickets for certain offenses when people have been caught for another one and stopped for it. Furthermore, laws are effective when violations lead to unavoidable consequences and when sanctions can be applied directly for breaking the law, rather than only when another law is also breached. Laws are never completely effective, as some individuals will always engage in delinquent or criminal behavior. Laws need support to be sustainable; without it, they can be revoked, even if they are effective. Therefore, laws should target significant risk factors contributing to accidents or injuries, but current legislation sometimes fails to do so, sometimes addressing less important issues instead (Tiwari & Mohan, 2021).

A study by Van den Berghe et al. (2020) found that support for safety measures varies based on cultural factors, specifically between individualistic and collectivist societies. The Netherlands, characterized by a high level of individualism, tends to have greater resistance to new safety measures, as people prefer to make their own decisions. Despite this resistance, such countries have higher road safety performance due to strong adherence to existing safety norms. Resistance in these countries stems from concerns about personal freedom, costs, and satisfaction with the current situation. In individualistic societies, people prioritize societal well-being over specific group interests, trusting others to make good decisions and feeling less need for strict rules. While skeptical of new regulations, they adopt a broader perspective. Laws are still necessary, but behaviors such as wearing seatbelts become habitual, reducing the need for enforcement.

There are more specific examples that can be applied, such as a point system, which many countries already use. This system is effective in reducing accidents. Penalty systems can influence attitudes toward violating traffic rules, especially when fines alone are not sufficient. The point system is an effective traffic enforcement measure. There are two types: one deducts points for offenses, and the other adds points. At certain thresholds, licenses are suspended or withdrawn. Regulations vary by country. In some countries, points last one year, with reinstatement requiring a course and test. Suspension can depend on the offense or be based on specific offenses, with repeat offenders facing

harsher penalties. Some countries reward safe drivers, such as earning extra points for offense-free years, resetting points after a year without offenses, or offering vouchers for no crashes. Many countries also provide car insurance discounts for crash-free periods and traffic education seminars to reduce points (Toriumi et al., 2022). In the Netherlands, a point system exists for drunk driving, where repeated offenses within five years lead to license suspension (Rijksoverheid, 2018). A similar system applies to novice drivers, encompassing offenses such as causing accidents, fatalities, serious injuries, or speeding. For new drivers, two serious offenses within five years result in license suspension, reflecting their higher accident risk (Allianz Direct, n.d.). Introduced in 2002 and updated in 2014 to include stricter measures, the system aims to mitigate accidents among new drivers, albeit its long-term efficacy remains uncertain (Goldenbeld, 2004; Rijksoverheid, n.d.-b).

5.2.3 Law enforcement

Law enforcement is the executive branch of the government that maintains law and order. They manage traffic, issue fines, conduct stops, and ensure overall safety (Politie, n.d.-a) The goal of traffic policing is enhancing safety, not punishing. Officers explain fines to raise awareness and educate about dangerous situations (Politie, 2023). The police have powers such as driving at high speeds, making arrests, using sirens and lights, or using force (Politie, n.d.-b). Roadside checks influence enforcement levels, and road users assess their risk of detection based on these checks. Regular, visible, and random checks boost the perceived risk of getting caught, discouraging violations. Consistent enforcement is more effective than severe penalties. Surveillance also improves safety by suspending the licenses of dangerous drivers (SWOV, 2019a). Since 2013, Dutch law enforcement consists of ten regional units spanning 43 districts, with 168 teams and a national unit, with each their tasks. Their activities are governed by agreements among the mayor, public prosecutor (OM), and police. The police use direct stops and automated monitoring for road safety. Automated surveillance efficiently handles high traffic, reducing violations and accidents, but delayed fines may disconnect offenders from the incident. Aggressive behavior requires manual intervention since it cannot be detected automatically. Direct stops allow immediate action and consequences, reinforcing norms with police presence. Traffic enforcement includes three sanctions: administrative judicial, criminal, and administrative. Administrative judicial sanctions, for example, fines, address minor violations such as improper parking. Criminal sanctions, for offenses such as driving bans, may include fines, license suspension, community service, or imprisonment. Administrative measures target serious violations such as dangerous driving and involve reporting to the CBR, which may impose penalties (Oude Mulders et al., 2023).

Traffic priorities in the Netherlands include repeat offenders, distractions, red light violations, alcohol or drug use, and speeding. The police dedicate a portion of their force to traffic duties and follow procedures for alcohol testing, license checks, and helmet and seat belt compliance (Oude Mulders et al., 2023). Table 5 illustrates the methods utilized for each priority type.

Table 5

Most used methods per offense (SWOV, 2019a)

Type	Stops	Surveillance
Alcohol and drugs	Breath test	-
Distraction	Driving surveillance	Smart cameras for handheld phone use (still in testing phase (2019))
Speed	Laser gun, video vehicle (chassis dynamometer for mopeds)	Speed camera, radar, section control
Ignoring red lights	Driving surveillance or observing	Cameras
Repeat offenders	Driving surveillance (police officer on a motorcycle or video vehicle)	-

The Netherlands enforces traffic priorities with targeted methods. Repeat offenders face increasing fines, but the impact is unclear. This group, 0.5 percent of the population, is involved in 6 percent of accidents. Warning letters reduced fines by 35 percent. Reducing phone use and strict enforcement can help combat distractions, but the effects may be temporary. In the USA, gains in reducing distractions declined with decreased enforcement. Similar alcohol and drug enforcement strategies reduced accidents from 2013 to 2017, but drivers use social media to avoid checks. Despite efforts, some still drink and drive. Harsher penalties have not proven effective for certain demographics. Stricter measures such as license revocation and monitoring may be needed. Some still drive without a valid license, so combining measures such as vehicle confiscation and ignition interlock devices works best. This device locks the car after a positive breath test. Introduced in 2011, it was abolished in 2015 due to concerns about not considering personal circumstances. Additionally, requiring individuals to cover the cost themselves, around 5,000 euros, proved ineffective (NOS, 2023b) Personalized feedback for speeders can deter violations, but stopping it may lead to a return to speeding. Rewarding good traffic behavior requires clear goals, fair rewards, and consistent repetition (Oude Mulders et al., 2023).

Examining the enforcement data leading up to 2022 shows that from 2010 to 2019, fines from automated surveillance stayed constant but fines from real-time stops declined from 2008 to 2016 and then rose in 2017 and 2018. This shift could be because of changes in priorities. Alcohol checks significantly increased from 2013 to 2016 (SWOV, 2019a). In 2022, fines rose slightly compared to 2020 and 2021 but stayed below 2013-2018 levels. Most fines were for speeding violations from automatic surveillance. Fines from vehicle stops increased slightly, especially for handheld calling and not wearing a helmet. Some offenses, such as phone use while driving and driving unnecessarily on the left, had higher fines, while minor speeding and creating noise had reduced penalties (Oude Mulders, 2023). The number of fines may not reflect changes in violations; it varies with traffic volume and police enforcement. Fewer fines may occur in years with less car travel or fewer police checks, even if violation rates stay the same. There is no data on the effects of drug enforcement (SWOV, 2019a). Data on non-car traffic users is limited. While they can be fined for behaviors such as cycling or walking under the influence or running red lights, it happens less often. Police target these issues through campaigns and checks on bike lights and mopeds for modifications. Moreover, enforcement on 30 km/h roads is less common due to caution with non-standard road designs (Oude Mulders, 2023). In 2022, The focus was primarily on issues such as driving and the influence, speeding, and phone use while driving in 2022. 8,153,043 traffic fines were recorded, a 1.6 percent increase from 2021's 8,024,118. The rise was primarily due to improper parking, standing still, and using handheld phones while driving. Parking violations increased post-COVID, and fines for phone use rose by 16.3 percent (from 45,778 in 2021 to 53,259 in 2022). Speeding was the most common offense, with 6,512,086 fines issued, up by 129,850 from the previous year. Most fines were detected via license plate enforcement, including 3,014,680 from speed cameras, a 6.5 percent increase. Speeding violations from speed control systems decreased by 3.7 percent due to inactive systems during road construction and heavier traffic (from 2,103,772 in 2021 to 2,026,939 in 2022). The average fine cost rose to €84.16, while the average fine for speeding slightly decreased to €62.88 (OM, 2023). The number of accidents increased in 2020 and 2021. This rise may partly be due to easing COVID-19 restrictions. The police introduced the mono-cam, a smart camera that detects drivers using a phone. Additionally, fine amounts increased in the second quarter of 2022. Discussions also centered around shared responsibility among road owners, the government, interest groups, and road users (Politie, 2022b). The government focused on promoting bike lights, discouraging drug and alcohol use, reducing distractions, and mandating courses for offenses. The impact of these measures remains unclear (Rijksoverheid, 2024). In recent years, enforcement has adapted to trends such as laughing gas in traffic, requiring new laws. Mobile speed cameras were introduced, and a pilot program was launched to monitor repeat heavy offenders. Officers also started fining cyclists for minor infractions. Additionally, the MONO-cam was introduced to catch distracted drivers, developed by local and regional enforcement officials (Aarts et al., 2022).

5.2.4 Relevant studies

Effective traffic enforcement requires regular monitoring to guide driver behavior by emphasizing the risk of detection and punishment. Consistent police checks, promoted through media or visible presence, encourage compliance. Enforcement should be ongoing, unpredictable, and a mix of visible and discreet methods, as well as focusing on hotspots during peak violation times. Sanctions should match the offense and be dissuasive.

Police face challenges due to competing priorities and limited personnel. Moreover, annual enforcement campaigns and social media updates are advised, and transparency is important to show how funds are used for road safety. Prioritize enforcement of speeding, drunk driving, seat belt use, and phone use with consistent, strategic measures. Combine roadside policing and automation, such as cameras, to enhance enforcement. Hold vehicle owners accountable for automated fines, focus speed enforcement on high-accident areas, and invest fines back into road safety projects. Implement a demerit point system for repeat offenses and increase camera use. Monitor speed patterns and share updates to identify trends and safety issues. In addition, improve systems for handling speeding penalties to boost efficiency and public trust. For drunk driving, combine lower alcohol limits, specific enforcement, alcohol interlocks, education, and awareness campaigns. Conduct targeted breath tests and make them mandatory in serious collisions. Intensify enforcement alongside publicity and rehabilitation programs for offenders. For seat belt use, always check during stops for other offenses and include violations in the penalty point system. For phone use, enforce laws intensively for one week twice a year, alongside publicity campaigns, and add illegal phone use to the penalty point system for better compliance (ETSC, 2016).

Several Dutch studies exist on enforcement where improvements are suggested. Goldenbeld (2004) found that a small group is unaffected by existing enforcement. Inconspicuous video cars are suggested for this issue. Another challenge was drug use while traveling without there being a clear legal limit or reliable screening options. Ways to improve were automated speed checks and frequent route checks over longer distances and periods to influence driver behavior. Experts also saw potential in-vehicle technology, such as adaptive cruise control, for voluntary speed control. He also noted the benefits of measures against driving under the influence. Driving under the influence was also a priority. In 2005, stricter limits (0.2‰) were set for new drivers. Experts advised targeting heavy drinkers and young male drivers, who cause 25 percent of alcohol-related accidents. A mix of measures, including education and expanded section checks, was recommended. Drug and medication use in traffic was seen as high risk, and taking this group off the road was necessary. Breath analysis was used to test impairment but was only applied in specific cases. Standard testing and accepted limits were considered beneficial (Goldenbeld, 2004).

Research from 2008 concluded that Intensified police supervision of drunk driving, coupled with public awareness campaigns, was still seen as a solution, as it had proven effective multiple times since the 1970s. Concerns were raised that automated enforcement may not sufficiently motivate behavior change. Citizens criticized speed checks, hidden radars, laser devices, and speed cameras, causing irritation. There was also annoyance with getting fined for light speeding offenses. But a small decrease in speed can already make a big difference in accidents. Another issue is that people slow down to avoid fines in certain areas but then resume speeding afterward. The research also recommended improving support for enforcement through rewarding drivers, which requires a strategic approach. Experts suggested that actors such as insurance companies, rather than the police, are better suited for this task. While the police focus on regulating and penalizing traffic behavior, insurance companies can offer rewards such as discounts for drivers who remain damage-free over a specific period (Goldenbeld, 2008). Differently, Toriumi et al. (2022) examined traffic

regulations across multiple countries, focusing on differences in speeding penalties. Some countries base fines on road type, others on income. Penalties can escalate, with consequences ranging from license suspension to imprisonment or vehicle impoundment.

Effective enforcement relies on a high perceived risk of being caught, swift punishment, and visible police presence. Increasing actual enforcement, publicizing police activities, varying enforcement locations, and conducting unavoidable checks enhance this perception. Publicity must be backed by consistent police action, even at reduced intensity over time, focusing on both general and specific prevention. Repeat offenders should face higher detection risks due to their greater danger. Compliance is driven by fear of punishment, social disapproval, and moral reasons. Rewards are more effective than punishments for promoting good behavior. Police should explain penalties to enhance understanding. Increased enforcement yields diminishing safety returns. People mimic others' behavior; when drivers see compliance with speed limits or seat belt use, they follow. Displaying compliance rates on roads can encourage adherence. As enforcement pressure increases, the additional safety gain becomes smaller and smaller. In other words, as enforcement pressure increases, its influence on road safety will become less and less (Goldenbeld, 2004).

5.3 Conclusion

5.3.1 Law en regulations

To enhance traffic safety, people must see the positive results of laws and feel supported rather than hindered. Effective implementation of laws requires public support and proper enforcement. Avoid enacting laws without effective penalties or secondary enforcement mechanisms, as they are unlikely to change behavior if not enforced. Utilizing technologies such as cameras to enforce traffic laws can ensure consistent monitoring and compliance. Ensuring widespread awareness of these enforcement measures is crucial for their effectiveness. Moreover, introducing a point system for traffic offenses, with thresholds for license suspension or withdrawal, can effectively deter violations. Rewarding safe drivers with extra points for offense-free years or resetting points after a period without offenses can further encourage compliance. A well-structured penalty system, with fines based on road type or income and serious consequences for repeat offenders, such as license suspension, prison sentences, or vehicle impoundment, is essential to influence attitudes toward traffic rules.

Effective communication and education are vital in making the public aware of enforcement measures and safety initiatives. Addressing cultural resistance to new measures through better communication and education can help gain public support. Legislation should focus on major risk factors contributing to accidents, rather than less critical issues, ensuring that laws target significant safety concerns. Although this research does not delve into the implementation of safety features for cars aligned with Vision Zero principles, it remains pertinent to mention their importance in ongoing efforts to enhance road safety.

By adopting these strategies, the Netherlands can enhance traffic safety, ensure sustainable enforcement of laws, and promote positive driving behaviors. An important note: law changes can be effective only when it is properly enforced. It is also important to know that laws alone may not change behavior, as people might revert to old habits if the laws are not enforced.

5.3.2 Law enforcement

Positive aspects of the Dutch traffic enforcement approach include regular monitoring to guide driver behavior, focusing on risk detection and education. This strategy aims to inform drivers about dangers rather than solely emphasizing punishment. Moreover, the use of direct stops and automated monitoring, including speed cameras and laser guns, enhances enforcement efficiency. In addition, the introduction of mobile speed cameras and the MONO-cam for detecting distracted drivers shows the Netherlands' willingness to embrace new technology and strategies to improve road safety. There are multiple campaigns and education programs to inform the public about road safety. These include initiatives to reduce phone use, encourage the use of bike lights, and promote safety measures such as seat belt use. It would be better if these were long-term campaigns combined with intensive enforcement. However, long-term campaigns could be less effective as time goes on. Lastly, the Dutch police target traffic priorities such as speeding, driving under the influence, phone use, and red-light violations. They use a mix of methods such as breath tests, driving surveillance, speed control systems, and smart cameras for handheld phone use.

There are still gaps in Dutch traffic enforcement. It is not considered a national priority, which may affect the focus and resources allocated to improving road safety. Improvement is needed in targeting high-risk areas and times for enforcement, as well as employing measures such as a demerit point system for major safety violations. This may be due to a shortage of police officers and its low priority. Additionally, while some measures have been taken for cyclists, more targeted enforcement and safety measures are necessary for non-car traffic users.

In summary, while the Netherlands has implemented effective measures for traffic enforcement, there is still room for improvement in areas such as prioritizing road safety at the national level, implementing strategic and targeted enforcement, and innovating enforcement measures to keep up with new trends and challenges. The Netherlands’ approach to traffic safety is in line with Vision Zero, mostly because they have their approach, sustainable safety.

5.4 Infrastructural design and non-regulatory initiatives

This chapter focuses on Research Question 2: What was the effect of non-regulatory initiatives, such as campaigns and infrastructure design, on road safety and the occurrence of traffic-related fatalities in the Netherlands in 2022? The road's appearance influences safety by preventing conflicts and minimizing accidents. Road design shapes user behavior (SWOV, 2023c). Campaigns, initiatives, or education also shape behavior, which will be examined in this chapter. The Netherlands has many laws for safe infrastructure, but not all can be examined due to the amount and varying relevance.

5.4.1 The effects of road design

Between 1998 and 2007, the Netherlands made big changes to its road network to improve safety in alignment with sustainable safety. These included categorizing roads, introducing more 30- and 60-kilometer-per-hour zones, and constructing approximately 2,300 roundabouts. Additionally, measures such as heightened enforcement and ongoing traffic education campaigns were initiated. These efforts resulted in a substantial enhancement of traffic safety (Weijermars & Wegman, 2011).

5.4.1.1 Dutch infrastructure

The Netherlands has three types of roads which are designed for specific purposes. Access roads are primary roads to residential areas where cars adjust their speeds to prioritize pedestrians. On flow roads cars have priority. These roads facilitate fast and safe movement between destinations. Distributor roads link main roads with access roads. Moreover, roads are categorized into residential areas for non-travel activities and traffic areas for vehicle flow. The network distinguishes between 'flow' (minimal interaction) and 'exchange' (interaction). Furthermore, road design revolves around three core categories: function, design, and use/behavior. These elements collectively shape road design to influence user behavior positively, ensuring that road design effectively communicates the intended function and category of roads to users (SWOV, 2023c).

A road is safe when there is parking on or next to the road, physical separation of directions, crossing facilities, and no yard connections. A road is also sufficiently safe if the speed and design are consistent. One of these two factors must therefore be adjusted if too many accidents occur (Kennisnetwerkspv, 2023a). Roads are also categorized based on location, within or outside the built-up area. Built-up areas have no roadside parking, clear separation between traffic directions, crosswalks, and no direct connections to properties to prevent conflict. Outside built-up areas, rules include a separation between traffic directions, obstacle-free zones, drivable shoulders, and no direct property connections (Kennisnetwerkspv, 2020). The same principles that govern other roads apply to cycling paths, contingent upon various factors. These factors include ensuring cyclists' stability to prevent falls, providing forgiving verges to accommodate cyclists in case they deviate from the path, and ensuring adequate space for safe overtaking of other cyclists. When designing the cycling paths there should be no obstacles, visual guidance such as road marking, spacious enough, a hardened surface that is not broken and clean, and forgiving verges, and these also need to be obstacle-free and big enough (Kennisnetwerkspv, 2020). Moreover, Dutch guidelines recommend a 6-meter obstacle-free zone, as non-compliance can cause 40 percent of accidents. Poorly designed curves with small radii and unclear markings contribute to 50 percent of accidents. To mitigate these risks, Dutch road design standards suggest a minimum curve radius of 300 meters and a 2.5 percent positive superelevation (van Petegem & Wegman, 2014).

5.4.1.2 infrastructure-based accidents

Design flaws can contribute to accidents. Conversely, well-designed infrastructure can mitigate human error and promote safer behavior. Finding comprehensive data on road design can be challenging. Research on road design tends to be conducted primarily in response to a high incidence of accidents. Below, the key types of road design will be discussed.

5.4.1.2.1 Intersections

In the Netherlands, data on safely designed intersections and their impact on accidents is scarce. About one-third of traffic fatalities occur at intersections annually, with no clear explanation. Despite safety engineering, fatalities can remain unchanged if traffic volumes rise or more intersections are built. From 2015 to 2019, cyclists accounted for 54 percent of intersection fatalities, followed by mopeds/scooters (42%), pedestrians (26%), and car drivers (19%). Fatalities are lower outside urban areas, but cyclists still dominate at 49 percent (SWOV, 2022). Urban areas see more fatalities due to congestion and diverse road users, while rural areas have fewer fatalities due to lower congestion (Kennisnetwerkspv, 2023b).

The Netherlands has various intersection types with no clear safest option. Selection depends on traffic conditions, cost, and space. Recommendations prioritize visibility, minimal conflict points, and extra facilities during peak times. Sustainable safety principles suggest urban areas have maximum speed limits, roundabouts, and speed bumps to reduce conflicts and enhance safety. Safe intersections share minimal conflict points, simplicity, and designs promoting slower driving. Roundabouts are considered the safest, while traffic light-controlled intersections are less safe due to complexity. Priority-controlled intersections are simpler with fewer accidents. The "voorrangsplein" (priority square) combines features of roundabouts and priority-controlled intersections, reducing accident frequency and severity. Intersection accidents are influenced by traffic volume, speed, and vulnerable road users, with higher motor vehicle volumes leading to more accidents. Safety measures should match traffic volume and bicycle facilities. The safety difference between intersections with and without zebra crossings remains unclear due to varying pedestrian usage (Kennisnetwerkspv, 2023b).

5.4.1.2.2 Roadsides

Between 2016 and 2020, approximately 160 fatalities involved roadsides, accounting for a quarter of all motorized traffic deaths. For cyclists, roughly 20 percent of ER visits were due to roadside accidents, from cycling into the roadside or hitting the curb. Most accidents occur on 60 and 80km/h roads, primarily affecting those aged 15 to 24. Roadside accidents include single-vehicle incidents, collisions followed by veering off, and vehicles returning to the road before colliding with others. About 75 percent of these fatal accidents happen outside built-up areas, often on straight roads, with 26 percent occurring in curves, which is significant given the few curved roads. Data for 2022 is not available (SWOV, 2023d).

SWOV identifies three main factors in accidents: human, infrastructural, and general. Human factors include high speed, fatigue, and substance abuse. The severity of these accidents is often influenced by factors such as speed and seatbelt usage. Infrastructural factors involve road design issues such as narrow obstacle-free zones, steep embankments, and tight curves, with unprotected obstacles such as trees and ditches increasing risks. General factors include wet conditions and darkness, with nighttime increasing risky behaviors. Improving roadside safety involves removing hazards and installing barriers along central reservations (SWOV, 2023d). Tree collisions are particularly dangerous, accounting for half of all run-off-road fatalities. Contrary to the belief that trees slow

down traffic, global research shows that trees increase accident risks by 1.5 to 2 times on roads with speed limits of 80 km/h and above (SWOV, 2023d).

5.4.1.2.3 Water next to roads

The causes behind cars plunging into water remain largely unknown despite the high casualty count. Foreign studies link these accidents to alcohol, drug use, and high speeds. Protective measures such as shielding water bodies and ensuring quick evacuation can reduce fatalities. Installing electric windows that automatically open upon water contact could improve survival chances. Fatalities are often due to delayed emergency calls, attempts to open doors instead of windows, and lack of swimming skills. Psychological stress further impairs decision-making. International studies highlight the roles of alcohol, drugs, and speed in such accidents. Prevention strategies include avoiding roads near water or ensuring sufficient space between them. Installing barriers, traffic signs, markings, and warning systems can deter vehicles from veering off the road. Ultimately, a comprehensive approach addressing infrastructure, education, and behavior is crucial to reduce these incidents (SWOV, 2021c). Education on escaping is vital, but instinct often overrides learned behaviors in stressful situations. Annually, these incidents claim fifty lives, constituting 8.5 percent of total fatalities, with 70 percent due to drowning. Most victims are car passengers, cyclists, mobility scooter users, or men aged 18 to 24. The cause for cyclists and mobility scooter users remains unclear, though panic-induced acceleration is suggested (SWOV, 2021c).

5.4.1.2.4 (Led-) advertising

Advertisements have always existed next to roads, more recently also with LED lighting. American research stated that this rarely leads to accidents. However, Belgian research shows that eye-catching LED signs influence traffic behavior. Moreover, sustainable safety does not justify placing advertisements where people must read traffic situations. Official guidelines for road advertisement exist in the Netherlands. Examples are avoiding high brightness or moving images. Examples of potentially dangerous street advertisements are short advertising before they change, or transition effects that do not fit the traffic scene (Aalbers, 2018). Dutch guidelines for roadside ads recommend adequate spacing, non-traffic-related content, and avoiding negative emotions to mitigate risks. Advertising can slow reaction times, increase braking distances, and cause winding. Dynamic elements and emotive messages in ads particularly divert attention from the road. Limited studies show varying outcomes. In addition, safety-oriented advertisements, such as those for traffic flow or congestion alerts, aim to enhance safety but can inadvertently distract drivers (SWOV, 2020a).

5.4.1.2.5 Built environment

Asadi et al. (2022) looked at the effect of the built environment on traffic safety in cities in the Randstad. Findings reveal that built-environment factors and land-use policies have impacts on safety, land-use density and diversity of transport options are important. Traffic and road network features, building density, and the proximity to destinations affect the likelihood, frequency, and severity of urban traffic crashes. Moreover, exposure, speed, and conflicts among road users, directly impact traffic collisions. Urbanization correlates with increased crash probability due to higher population density and trip attractions, while areas with diverse land use see decreased crash probability. In addition, proximity to grocery stores or schools impacts the crash frequency. For example, proximity to schools is linked to more severe bicycle-vehicle crashes. Areas with higher socioeconomic status are safer, and those with more children have fewer severe bicycle-vehicle crashes.

5.4.2 Relevant studies

A study published after 2022 examined the UN's 2022 resolution to enhance road safety, using the safe system approach, with a focus on self-explaining roads. These roads are designed to intuitively guide users to safe behavior, reducing the need for enforcement or education. In 2010, the WHO and the UN emphasized promoting the safe system approach. It avoids the need for physical obstacles that often cause annoyance or vehicle damage, resulting in noise and frustration for both drivers and residents. They rely on drivers' expectations from road types and environments. Roads should be designed to match speed limits, allowing drivers to adopt the appropriate speed naturally. For instance, pedestrian-friendly areas signal a lower speed compared to highways. Aligning road designs with drivers' expectations improves safety and helps drivers navigate intuitively (Theeuwes et al., 2024). Other studies on effective traffic design also focus on self-explaining roads to reduce speed. Rather than relying on law enforcement or calming measures, Abele and Møller (2011) suggest encouraging drivers to choose appropriate speeds voluntarily. It examines how road shoulders and trees influence driver behavior. While road shoulders guide drivers to stay near the road edge, they impact lateral positioning rather than reducing speed. In addition, Acerra et al., (2023) emphasize the importance of situational awareness in traffic accidents, highlighting how a lack of awareness of one's surroundings can contribute to human errors. Self-explaining roads provide a solution by being easy to understand and less cluttered, allowing drivers to process important information quickly.

Theeuwes et al. (2024) examined how various road elements affect speed choices and response times. A faster response time means quick decisions on driving speed, while a slower response time indicates a longer decision-making process. In city environments, elements that lead to a faster response time include a center line or physical separation compared to a one-way road, a speed bump, edge marking, and multiple lanes. Conversely, factors that contributed to a slower response time include a lack of separation compared to having a center line, using asphalt instead of pavers, and the presence of a bicycle lane. Regarding speed choice, certain road elements caused drivers to choose slower speeds. These included having a curve, no visible driving direction separation compared to a one-way road, no visible separation compared to a line separation, a physical separation compared to a line separation, parking spaces on the right side of the road, speed bumps, buildings on either or both sides of the road, and the presence of a bicycle lane. conversely, elements that lead to higher speed choices include having more than one lane, edge marking, a separate bicycle path compared to a bicycle lane, a line or physical separation compared to a one-way road, parking spaces on both sides, and asphalt instead of pavers. Outside city limits, road elements such as physical separation compared to a line separation, an urban environment compared to a rural environment, dashed edge marking compared to no edge marking, and the presence of a slip road contributed to slower responses. In terms of speeding effects, elements such as having no separation or a line separation compared to a one-way road, two or more lanes compared to one lane, guardrails compared to no guardrails, and continuous edge marking compared to dashed edge marking led to faster responses. Other factors that influenced slower speed choices included an urban environment compared to a rural environment, trees on either side of the road, continuous edge marking compared to dashed edge marking, a slip road, a line or physical separation compared to a one-way road, and no separation compared to a line or one-way road. Significant speeding effects were also observed with having two or more lanes compared to one lane, dashed or continuous edge marking compared to no edge marking, more than two lanes compared to two lanes, a guardrail compared to no guardrail, physical separation compared to line separation, and overhead signs compared to no overhead signs.

Oxley et al. (2010) discuss the increased accident risk among older drivers. With a growing number of older drivers, especially in urban areas, their vulnerability to injuries and decreased driving fitness became a critical concern. Common issues include attention failures and difficulties at intersections, where multiple conflicts and high speeds demand quick reactions. Older drivers often self-regulate by driving slower and avoiding challenging situations, but not all do. Proposed solutions include mandatory fitness tests and re-licensing, though their effectiveness is debated. A comprehensive approach combining road design, vehicle design, and user behavior is recommended, with an emphasis on long-term behavioral strategies. Improving road design with older drivers in mind involves addressing their difficulties with gap selection at intersections. Enhancements should focus on reducing intersection complexity, such as lowering vehicle speeds, shortening sight distance requirements, and allowing more time to process traffic information and make decisions. Roundabouts offer safer and simpler alternatives by naturally slowing down traffic, making accidents less severe. This can provide older drivers with the time they need to navigate intersections more safely. Intersections can be improved through various measures such as clearing obstructions, designing for longer perception-reaction times, and incorporating offset turning lanes (Oxley et al., 2010). Acerra et al. (2023) recommend infrastructural changes such as colorful roads, or warning signs with lights to boost visibility and safety at pedestrian crossings. They found that poor visibility of signs led to higher approach speeds and users failing to notice crossings. Furthermore, studies show that in open landscapes without trees, drivers go faster and stay further from the center, hold the steering wheel more often, and experience less stress. The lack of visual cues makes speed judgment harder. In contrast, trees along the road can raise the risk of injury and fatal accidents. Trees are often struck in off-road accidents, leading to severe damage when vehicles veer off-road (Abele & Møller, 2011).

5.4.3 The effects of campaigns, initiatives, and education

Road safety programs are important for policy efforts, historically maintaining a high political priority and resulting in reduced fatalities (Wegman et al., 2006). However, existing policies lack a universal framework and vary by target groups and methods. Despite considerable research and efforts, there is no unified categorization for road safety tools. These tools, often government-led, aim to reduce road trauma through various measures, and strategies differ in their application. Additionally, the safe systems approach broadens tool usage to include private entities and individuals (Hughes et al., 2016). This chapter will examine the most effective and widely used approaches, collaborations, initiatives, campaigns, and educational programs in the Netherlands.

5.4.3.1 Education & campaigns

Dutch traffic education covers rules, skills, attitudes, and decision-making for all ages and road users. Elementary school children receive mandatory safe cycling education to ensure consistent learning regardless of parental influence. In high school, traffic education is optional, and parents are expected to play a role in teaching safety. Adults can take voluntary courses, except for those mandated for offenders, and refresher courses are available to update traffic safety knowledge (SWOV, 2024). Various education methods and campaigns exist. The BOB campaign, launched in 2001, encourages designating a sober driver. Although still active in the Netherlands, its impact remains uncertain due to concurrent campaigns. While routine alcohol checks effectively reduce alcohol-related accidents, penalties such as higher fines or license revocation do not deter heavy drinkers. Targeted prevention and understanding underlying causes are vital for addressing this group. However, data indicate that the BOB message resonates with people (SWOV, 2023b). In 2022, the 'Don't App Me!' initiative under the MONO campaign aimed to curb distractions in traffic but fell short of its goals. Participants found phone use while driving normal, hindering the campaign's effectiveness (Oude Mulders et al., 2023). Other campaigns have also been launched. Between 2010 and 2015 in Zeeland, free helmets were distributed to children, leading to a rise in helmet usage in this age group. Although there was a slight decrease in the following year, it did not return to pre-campaign levels. The effectiveness of the campaign depended on the level of activities carried out each year (SWOV, 2019d). Various campaigns promote cycling safety, including light checks by organizations such as Veilig Verkeer Nederland and ANWB, with ANWB offering annual free light checks and using spray sets for street reminders (Drost Letselschade, 2018). In 2006, a new campaign was built on existing local initiatives, combining national information efforts with local actions and regional police enforcement. While it raised awareness, immediate visible improvements were lacking (Fietsberaad, 2007). In 2021, Zuid-Holland's "AAN in het donker" campaign saw increased light usage among cyclists, though larger cities showed lower compliance. Research revealed most cyclists either forget to turn on their lights or have malfunctioning lights (Maak Een Punt Van Nul, 2021). Moreover, training courses are available on how to react if a car plunges into the water, but their effectiveness remains uncertain due to instinctive responses in stressful situations. Education can improve understanding of swift action upon entry into water, but translating knowledge into practice under stress is challenging. Initiatives promoting safety hammers have raised awareness and adoption among motorists, though knowledge levels remain moderate Similarly, in Canada, there was a rise in individuals reporting intentions to abandon their vehicle in water following a campaign; however, this survey coincided with a tragic accident, complicating the assessment of the campaign's impact (SWOV, 2021c).

5.4.3.2 Initiatives

In recent years, the Netherlands has launched various initiatives to improve traffic safety, including the "Meer Veilig" program. This program aims to reduce traffic accidents by focusing on high-risk areas. Measures include making roadsides obstacle-free and enhancing road designs. Launched in 2018, the program consists of several phases: identifying high-risk locations based on accident patterns and implementing cost-effective measures such as reconstructing intersections and adding guardrails. The government continued working on this project through 2022. The program was part of the MIRT (Meerjarenprogramma Infrastructuur, Ruimte en Transport), established by the government to enhance traffic safety, accessibility, and spatial planning in the Netherlands. The annual report involves stakeholders such as provinces, municipalities, water boards, organizations, and businesses (Ministerie van Infrastructuur en Waterstaat, 2021). Another initiative by a different stakeholder is 'Iedereen veilig over straat'. It is an initiative by Veilig Verkeer Nederland, aimed at ensuring that vulnerable road users can navigate the streets safely. This aligns with the principles of sustainable safety, where emphasis is placed on the protection of the weakest traffic participants. The idea entails the sharing of public spaces and promoting social behavior in the layout, aiming to reduce the dominance of cars and other motor vehicles. Characteristics include the absence of physical separations between traffic types and minimal road markings and signs. Achieving the desired streetscape requires changes to half of the current roads and finding new parking areas. Rapid implementation is not feasible, but annual road renovations offer gradual progress. By estimating adjustments frequency on various road types and considering new residential area designs, a feasible outlook for 2025 can be established according to Veilig Verkeer Nederland (Veilig Verkeer Nederland, 2010). This initiative was documented in 2010 when the year 2025 seemed distant. However, there is limited information available about the initiative beyond that point. It is more of a concept than an active initiative, considering Veilig Verkeer Nederland's continual efforts to enhance road safety. Another article was discovered, detailing a campaign launched in line with the principles of "Everyone Safely on the Streets," specifically targeting meal delivery workers. This campaign directly aimed to educate and inform these workers about the traffic hazards they face while on the job (De Vereende, 2023).

In the context of public spaces, particularly residential areas, there are significant parallels with the principles of sustainable safety. Central to both approaches is the concept of considering car drivers as guests, emphasizing the need for low speeds to mitigate risks to slower traffic. Similar to sustainable safety, an effective road network structure with well-designed flow routes is crucial to deter undesirable behaviors resulting from cut-through traffic within residential areas. Both approaches advocate for minimal traffic signage to reduce conflicts and uncertainty in traffic situations. This promotes heightened attention and collaborative conflict resolution among road users, emphasizing the importance of recognizability and predictability. In contrast to traditional approaches where responsibility often falls on road users, shared space, and sustainable safety place greater emphasis on the design of the environment itself. They prioritize natural aesthetics and encourage safe, low-speed interactions. While they share common ground in promoting natural elements and safe interactions, sustainable safety also advocates for speed-reducing measures such as speed bumps and narrowings, which may not align entirely with the principles of shared space. However, both approaches aim to create safer and more harmonious public spaces (SWOV, 2019c).

5.4.3.3 Approaches

Sustainable safety (Duurzaam Veilig) was introduced in the Netherlands in 1991 as a new approach to address road safety issues, focusing on preventing unsafe road conditions rather than reacting to accidents. This shift acknowledges the centrality of human factors in planning, provision, and operation. Sustainable safety emerged when it became clear that traditional methods were insufficient to meet long-term safety goals set in the 1970s and 1980s. Since the 1990s, it has become a core policy, replacing previous strategies and forming the basis for future road safety initiatives (Wegman et al., 2006). Moreover, it focuses on reducing the amount and severity of accidents through strategies involving traffic environment design and policy. By embedding safety considerations into every facet of road design and policy-making, sustainable safety aims to minimize risks and lower traffic fatalities. This approach resulted in a notable 30 percent decrease in traffic fatalities in the Netherlands from 1998 to 2007, underscoring its effectiveness. Several obstacles hinder this approach. These include insufficient knowledge, space constraints, conflicting interests, and financial limitations. Furthermore, decentralization leads to variations in the approach across regions, resulting in uneven implementations. Collaboration among actors is crucial in achieving sustainable safety or Vision Zero. Dutch law recognizes human error and vulnerability, emphasizing the role of laws, vehicles, and technology in providing support and protection. Professionals and the government bear responsibility in this regard, while individuals are tasked with education on rules and responsible behavior. Additionally, aftercare is deemed important in this framework (SWOV, 2019c).

5.4.3.4 Collaborations

In the Netherlands, multiple collaborations between stakeholders exist. One of them is the SPV Knowledge Networks. The SPV Knowledge Network (Kennisnetwerk SPV) is a partnership between CROW and SWOV representing the Ministry of Infrastructure and Water Management, which focuses on aiding local authorities in enhancing road safety through a risk-based approach (Kennisnetwerkspv, n.d.) They conduct risk analyses on local traffic systems to pinpoint areas requiring safety improvements (Kennisnetwerkspv, 2019a). The network has set ambitious goals for 2030 and has developed initiatives such as " quick-start measures" to swiftly enhance road safety (Kennisnetwerkspv, 2018 & Kennisnetwerkspv, 2019b) In this collaboration The SPI Monitor, developed through collaboration, tracks five key risk indicators—safe infrastructure, speeds, road users, vehicles, and trauma care—to promote traffic safety. Regularly updated, it helps government agencies make informed policy decisions. (Kennisnetwerkspv, n.d.b). They partnered with the 2020-established, ministry-funded Traffic Safety Data Taskforce, linking government agencies and research institutions. The task force aims to generate risk indicator data and evaluate new data sources, integrating valuable vehicle data that meets repeatability, scalability, and cost-effectiveness criteria (Kennisnetwerkspv, n.d.).

5.4.4 Relevant studies

Education is crucial, enabling governments to share essential knowledge. Despite limited data on its effectiveness, combining education with repetition and other measures yields positive results. Community involvement is key, and social media should be used, though it presents the challenge of unfiltered information (Kennisnetwerkspv, 2019b). Most research focuses on school programs, where small behavioral changes and increased knowledge have been observed. The effects of education are mostly measured in behavior and knowledge instead of accidents. It is not clear how well these measures predict crash risk. Changes in attitudes because of education are also often not lasting. Moreover, skid courses can have negative effects if drivers rely too much on their skills. The 'Doortrappen' program, aimed at safe cycling for seniors, also showed no evidence for improvement but was positively received by the participants. Overall, evaluation is important for traffic education programs. Measuring the effectiveness of education through accident rates is challenging. Accidents are infrequent, requiring extended periods to gauge significant effects and other factors must also be considered. Additionally, relying on observation over self-reporting is preferred due to inaccuracies in self-reports (SWOV, 2024).

Effective education needs to be logical and follow multiple steps to ensure high quality. The key steps for effective education include selecting a relevant subject, targeting a clear audience, setting specific learning goals, using appropriate methods, providing suitable content, conducting interim evaluations, establishing clear guidelines, and offering detailed descriptions. Education should motivate learners, align with their prior knowledge, be applicable and observable, encourage proactivity, involve repetition, and cater to diverse learning styles (SWOV, 2024). Litman (2018) finds conventional safety programs less effective as traffic fatalities rise, suggesting a need for new strategies. He notes a direct correlation between increased travel hours and higher accident risks and suggests limiting travel distances. Additionally, he advocates shifting focus from specific risk factors to acknowledging the inherent risk in all travel. In contrast, Hughes et al. (2016) found that road safety strategies have become more complex. However, many existing strategies are too narrow and do not cover enough aspects. There is now more emphasis on road design and vehicle standards, not just driver behavior. Recent strategies focus on systems theory but lack a solid scientific foundation. Additionally, involving stakeholders is crucial. When creating educational programs, it is vital to recognize that a standardized approach is ineffective because individuals have distinct needs and utilize different modes of transportation. The first step is identifying which participants need the most improvement and in which areas. While traffic education is discussed in the literature, the specific needs of different participants are often overlooked (Obregón-Biosca et al., 2018). Additionally, teaching rarely used skills can lead to overconfidence and more accidents. Furthermore, motivation is crucial for effective learning, so making education enjoyable and highlighting immediate benefits can promote safe behavior (Tiwari & Mohan, 2021).

Tiwari and Mohan (2021) note that changing behavior through education is challenging and often less effective than legal enforcement, which can feel repressive. People are good at preventing accidents, so there is limited room for improvement. Moreover, in educational settings, using videos featuring traffic accident victims or their testimonials, especially targeting pre-drivers and cyclists, has been considered. However, the study did not conclusively prove the effectiveness of this approach. There is a concern that fear-based initiatives may either provoke defensive reactions or encourage riskier behavior (Feenstra et al., 2014). A 1982 study showed that home study and in-class programs for first-time drunk drivers reduced recidivism but had little impact on overall drunk driving, suggesting a broader approach might be more effective (Reis, 1982).

Some researchers suggested more specific ideas to improve road safety. Litman (2018) proposed a system with more transportation options. People will choose alternatives if they are convenient, comfortable, and affordable. Another approach involves urban planning that prioritizes mixed-use neighborhoods with accessible transportation options because it makes extensive travel less necessary and lowers associated risks. Lastly, he advocates for a transportation demand management program to offer drivers alternative options instead of their vehicle during peak hours. Li (2022) explored the concept of game-based learning, highlighting its potential to promote safe driving and enhance knowledge retention among young people. According to Li, the engaging nature of game-based learning can effectively aid in understanding and remembering road rules and safety measures. In contrast, traditional traffic education tends to be short-term, with individuals often forgetting crucial information soon after obtaining their driver's license.

Various studies have focused on young drivers, including a study by Cutello et al. (2020). Young people, especially men, take more risks in traffic, which are major causes of accidents. Effective interventions include skill-based training, public initiatives, education, and mass media campaigns. These approaches show short-term success but mixed overall results, often due to negatively framed messages. Peer-led education, targeting 16- to 20-year-olds, has shown promise. The Peer2Peer program also effectively addressed risky behaviors using student peer leaders. Cutello et al. (2020) highlight the need for personalized interventions and gender considerations. Fisa et al. (2022) found that individually targeted interventions, such as sobriety checkpoints and classroom sessions for drivers, are more effective than other approaches. They emphasized the need for versatile methods. Enforcement interventions such as speed cameras proved to be particularly effective, more so than legislation alone. Additionally, mass media campaigns also showed effectiveness.

5.5 Conclusion

5.5.1 Road design

Self-explaining roads are crucial for safety to naturally encourage the right behavior. Curves, no visible separation, speed bumps, and bicycle lanes slow down drivers in urban areas, while multiple lanes, edge markings, and separate cycling lanes increase speeds. Outside urban areas, trees, continuous edge marking, and slip roads lead to lower speeds, whereas multiple lanes, guardrails, physical separation, and overhead signs result in higher speeds. These features also impact drivers' response times. Moreover, effective road design improves situational awareness, aligning drivers' expectations with road conditions and guiding them safely. Overall, road design significantly influences driving behavior and safety.

The Netherlands excels in road safety through a structured approach that includes sustainable safety measures, effective road design, and ongoing education campaigns. This comprehensive strategy has significantly reduced traffic accidents and fatalities. In addition, the country categorizes its roads into access, flow, and distributor roads, prioritizing safety for various users. It boasts an extensive network of cycling paths with dedicated lanes, forgiving verges, and overtaking spaces. Speed limits are rigorously enforced, varying from 30 km/h in residential areas to 130 km/h on highways. Investments in roundabouts, physically separating traffic, and distinguishing built-up from non-built-up areas further enhance safety. Regular traffic education initiatives promote safe driving, complemented by laws governing the development of safe infrastructure and measures to minimize roadside hazards. When it comes to vision zero (the Dutch sustainable safety approach) and systems theory, the Netherlands integrates safety features into infrastructure, accounting for human error with forgiving roadsides, safe speeds, and well-marked lanes. Extensive cycling infrastructure enhances safety, though the high cyclist death rate in 2022 indicates a need for better cyclist road design. The country uses intelligent transportation systems and data-driven decision-making to improve safety. Systems theory guides road design with forgiving roadsides, roundabouts, and appropriate speed limits. Road user education on safe behaviors is emphasized, alongside data and technology for traffic management.

The Netherlands has made progress in road safety through infrastructure design, regulations, education, and a safe system approach. However, there is still room for improvement. Intersection safety, especially in urban areas, remains a concern despite the presence of various types of intersections such as roundabouts and priority squares. Cyclists are particularly vulnerable at intersections, highlighting the need for enhanced measures and better design. Ongoing data collection and analysis are essential to understand traffic trends and emerging safety issues. Additionally, roadside advertising could also pose as a distraction, though data on its impact is limited. Overall, while road design in the Netherlands is effective, further improvements in addressing roadside hazards, intersection safety, and cyclist protection are needed. Nonetheless, driver behavior and enforcement may have a more significant impact on road safety than design.
In conclusion, studies on specific types of road design and its ways to improve are hard to find or too specific to use for this research. Studies suggest self-explaining roads. Which the Netherlands already has lots of. But situations with more cluttered situations are unavoidable as many types of users use the road. For this, other types of safety enhancements are needed. Moreover, the Netherlands has made substantial progress in road safety through a combination of infrastructure design, regulations, education, and its safe system approach. However, there are still areas where improvements can be made, such as in addressing roadside hazards, improving intersection safety, and continuing efforts to protect cyclists and drivers from various risks. But in the Netherlands' case, there does not seem to be one big problem with road design, and it might not have as much impact as driver behavior or enforcement.

5.5.2 Non-regulatory approaches

Many studies on this topic are over ten years old, suggesting that education, strategies, and initiatives are increasingly viewed as less effective or less important. Several studies also conclude that while more research is needed, educational interventions tend to lose effectiveness over the long term. This indicates a potential need for alternative measures, such as better enforcement, a concept supported by more recent research.

The Netherlands has made strides in road safety through various programs and initiatives, even making approaches based on ideas such as the Vision Zero vision, which in the Netherlands case is called sustainable safety (Duurzaam Veilig). This strategy focuses on preventing unsafe conditions by integrating safety considerations into all aspects of road design and policy. The approach has led to a reduction in traffic fatalities, demonstrating its effectiveness. Moreover, the collaboration among stakeholders, such as the SPV Knowledge Network, has been influential in identifying and mitigating traffic risks through data-driven strategies and risk analyses.

In many ways, the Netherlands excels in traffic safety, especially when compared to relevant studies and the principles of Vision Zero and systems theory. The Netherlands also excels in traffic safety through collaboration and targeted campaigns. Initiatives such as BOB and 'Don't App Me' address specific issues such as drunk driving and distractions, enhancing public awareness and behavior change. Moreover, the Netherlands uses data-driven approaches. Initiatives such as the SPI Monitor and the traffic safety data taskforce, provide valuable insights and data for improving road safety. On the other hand, there are also ways to improve. The most important one is the long-term impact of campaigns. While campaigns have been launched, their long-term effectiveness remains uncertain, highlighting the need for continuous evaluation and adaption. Especially, as often with these campaigns improvements are shown in the beginning while going back to normal after a while. Furthermore, some studies indicate that more group-specific interventions are needed.

When evaluating Vision Zero and systems theory, several aspects stand out regarding what the Netherlands is doing well and areas for improvement. The Netherlands' sustainable safety initiative aligns with Vision Zero by emphasizing laws, vehicle technology, and infrastructure design to protect road users. Similar to systems theory, the Netherlands takes a holistic approach to road safety, integrating various elements including behavioral interventions and educational campaigns. However, further improvements are needed. A more uniform policy framework, targeted interventions for different demographic groups, and ongoing evaluation of campaign effectiveness are essential. Effective application of systems theory requires robust feedback mechanisms to continuously monitor, evaluate, and adjust strategies. While this research used online data sources, private databases might offer more comprehensive information. Systematic collection and analysis of data from accidents, near-misses, and traffic violations can help refine safety measures. Additionally, systems theory advocates for collaboration across different sectors. Strengthening partnerships between government agencies and other actors can lead to more comprehensive and innovative solutions. In Dutch studies, most actors mentioned are governmental agencies, traffic safety institutions, or companies concerned with traffic safety. There is limited mention of cross-sector collaboration with experts, for example, public health professionals, urban planners, or even truck drivers, who could also provide valuable insights.

5.6 Demographics and behavior

This part focuses on Research Question 3: What demographic and situational factors, along with behavioral aspects such as driver behavior and adherence to traffic regulations, contributed to the rise in traffic-related deaths among road users in 2022? The initial step is analyzing data from 2021 and 2022.

5.6.1 Fatalities by gender and age

In 2022, the highest number of fatalities among men occurred in the over-eighty age group, totaling 123 deaths—a significant increase from 79 in 2021. Men aged 70-80 and 20-30 also showed high fatality rates. Men aged 60-70 and 50-60 saw an increase in fatalities. For women (figure 11), the highest number of fatalities in 2022 occurred in the 70-80 age group, followed by women older than eighty, with both groups showing significantly higher fatality rates compared to 2021. Fatalities among women aged 30-40 doubled in 2022 (CBS, 2023a).

Figure 10

Amount of deaths of men in 2021 and 2022 (CBS, 2023a).

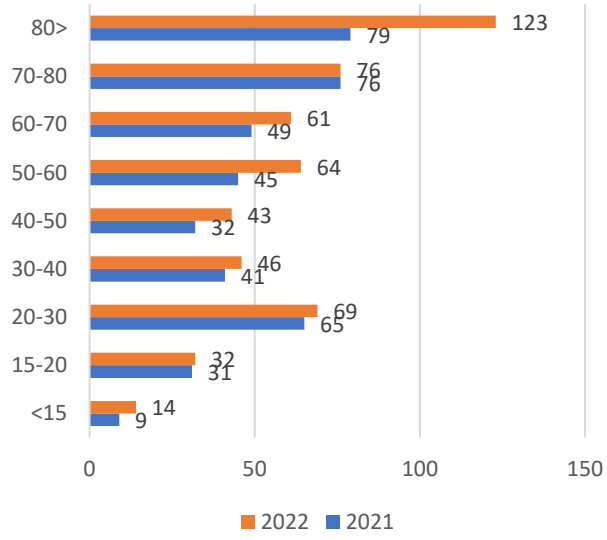
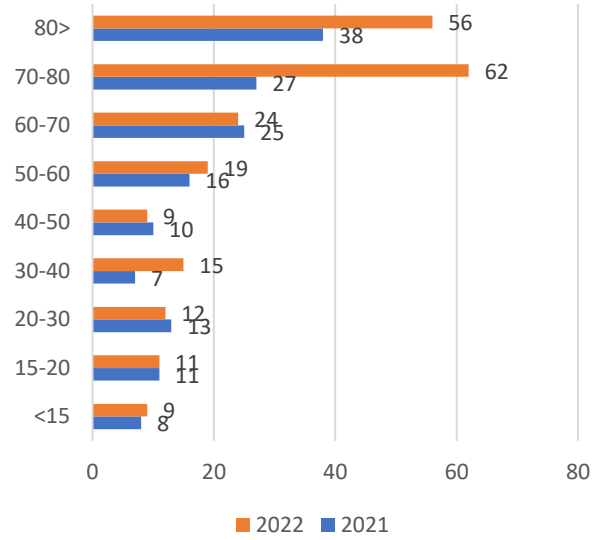


Figure 11

Amount of deaths of women in 2021 and 2022 (CBS, 2023a).

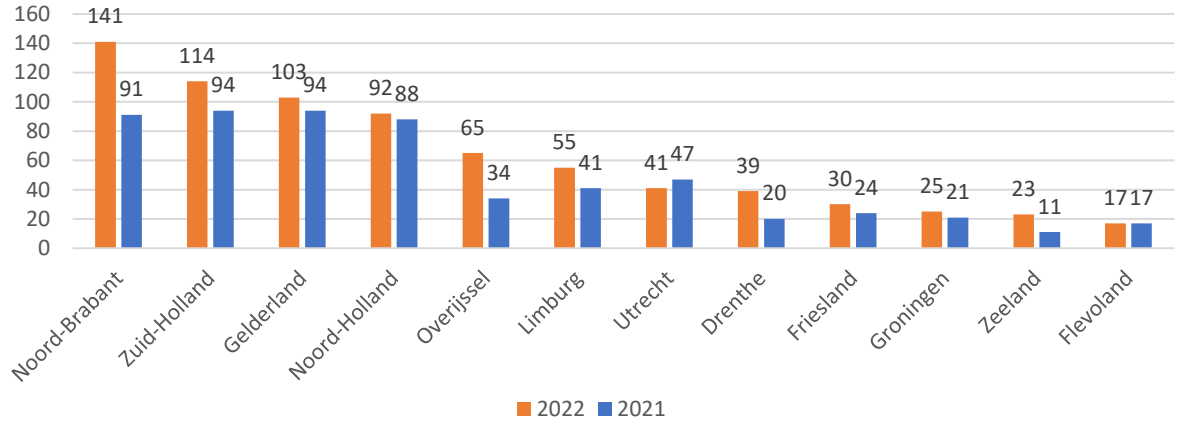


5.6.2 Fatalities by province

Noord-Brabant recorded the highest number of fatalities, with a significant increase from 91 in 2021 to 141 in 2022. Zuid-Holland followed and Overijssel experienced a near doubling of fatalities. While provinces such as Limburg, Drenthe, and Zeeland also saw significant increases in fatalities, their overall numbers remained lower than those of Noord-Brabant and Zuid-Holland. Conversely, Utrecht witnessed a decrease in fatalities, dropping from 47 in 2021 to 41 in 2022 (figure 12) (CBS, 2023b).

Figure 12

Amount of deaths by province in 2021 and 2022 (CBS, 2023b)

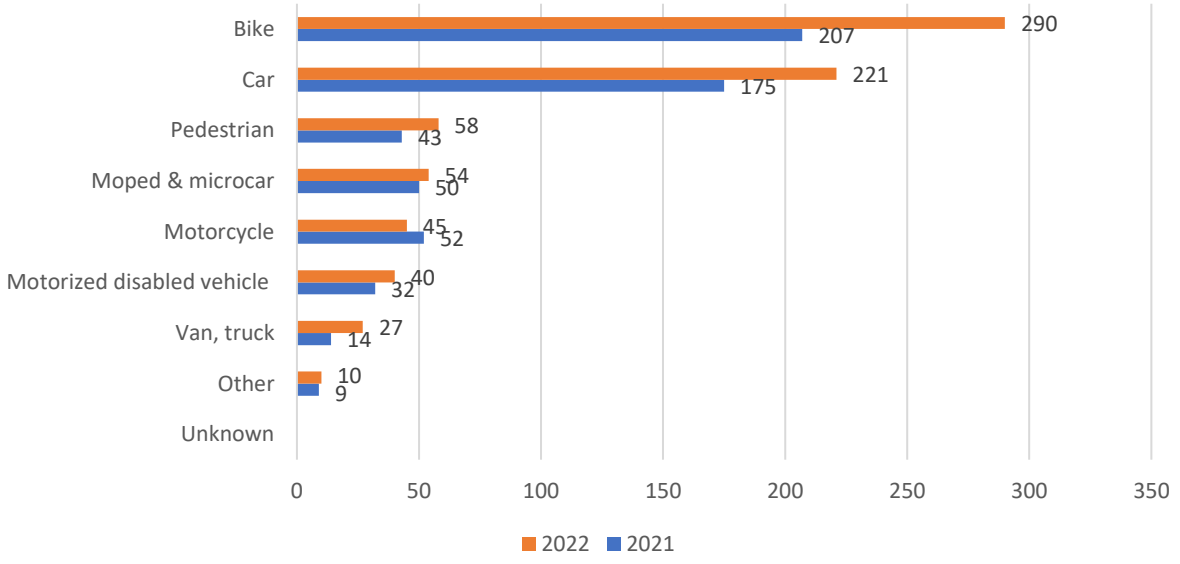


5.6.3 Fatalities by mode of transport

Figure 13 illustrates that cycling accounted for the highest number of fatalities in 2021 and 2022. Followed by car-related fatalities. Pedestrian fatalities were notably lower. There is a slight decrease in motorcycling fatalities in 2022 (CBS, 2023a)

Figure 13

Amount of deaths by mode of transportation in 2021 and 2022 (CBS, 2023a).

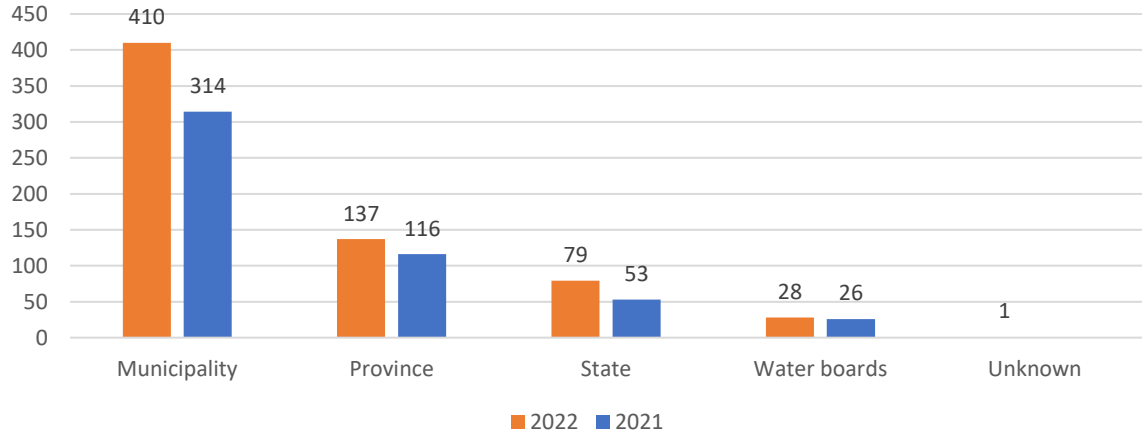


5.6.4 Fatalities by road manager

Not all data on fatalities managed by road authorities is known due to a lack of registration. Most fatalities occur on municipal roads, followed by provincial roads, and state roads. All three categories show significant increases since 2021 (figure 14) (Rijkswaterstaat, n.d.).

Figure 14

Amount of deaths by road manager in 2021 and 2022 (Rijkswaterstaat, n.d.).

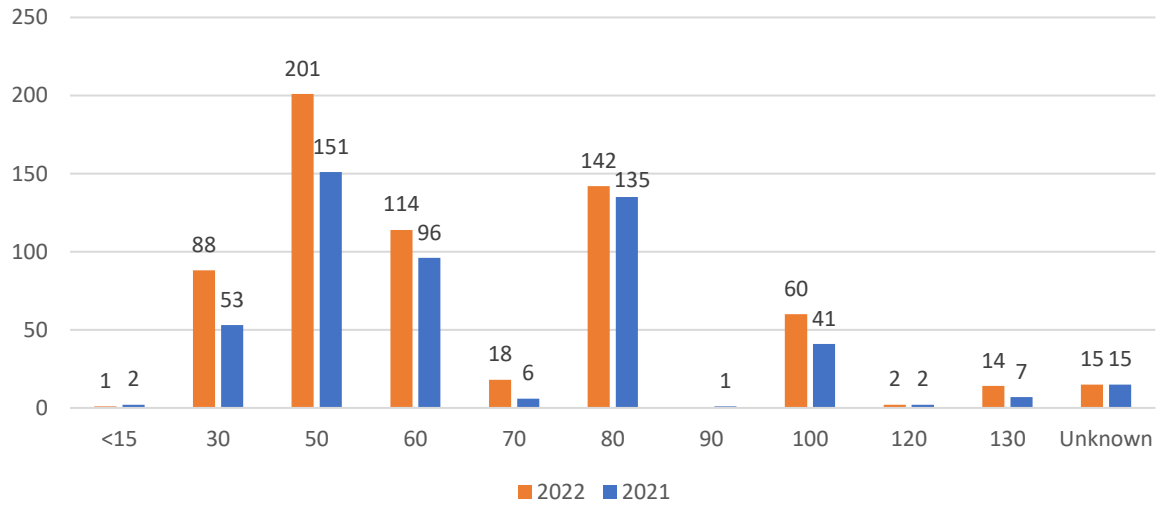


5.6.5 Fatalities by speed driven on the road

Fatalities are highest on 50 km/h roads (figure 15). Following this, 80 km/h roads recorded 142 fatalities, with no significant increase compared to 2021. Meanwhile, 60 km/h roads saw 114 fatalities in 2022. Additionally, fatalities on 100 km/h roads increased. It is important to note that there are fewer 90 km/h roads, resulting in fewer victims (Rijkswaterstaat, n.d.).

Figure 15

Amount of deaths by speed on the road in 2021 and 2022 (Rijkswaterstaat, n.d.)



5.6.6 Fatalities because of behavior

Behavior is not as simple as examining demographic factors alone. While demographic factors may focus solely on age or gender, behavior encompasses aspects of decision-making and personality, making it more complex. Comprehending the relationship between demographic characteristics, behavior, and adherence to traffic regulations offers a more comprehensive insight into the increase in traffic-related fatalities among road users. Although, behavior can be observed, what people are thinking cannot. Minds are complex, making it difficult for people to explain their actions. This could make it harder to develop effective initiatives to change behavior. Certain types of behavior are more prevalent in traffic, which will be discussed below.

5.6.6.1 Distracted driving

Distractions while driving can stem from emergencies, habitual actions, or addiction, with smartphones being a major culprit. Other distractions include adjusting the radio, using navigation systems, making calls, eating, talking, reaching for objects, or daydreaming. External factors such as billboards, other vehicles, or accidents, also contribute to distractions. Distraction is more common in low-demand traffic, familiar routes, or monotonous conditions, and increased automation worsens the problem by causing multiple distractions. Interestingly, some distractions, such as using a phone for music, can increase alertness. Distraction impairs driving by diverting attention, slowing reaction times, and causing erratic behaviors such as speed variations and swerving. Surprisingly, no significant difference in dangerous driving was found between handheld phone use and phone use with a holder, despite the latter being legal (SWOV, 2020a).

Despite the well-known risks, a 2017 Dutch study found that 65 percent of drivers occasionally use their phones while driving, despite 76 percent acknowledging the dangers. Many justify this by citing work needs or forgotten essentials (CROW, 2017). Studies rely on witness testimonies as law enforcement rarely investigates distraction as a factor. A 2008-2009 Dutch study on cyclists found phone use in 3-4 percent of accidents and music listening in 3.5-5 percent. A more recent study reported that 19 percent of hospital cases involved distraction, with conversations causing 4 percent and daydreaming 2 percent. Phone use was involved in less than 1 percent, but this is likely higher now due to increased phone usage (SWOV, 2020a). Children use phones in traffic more than adults, due to lower risk perception, though adult phone use in traffic is also significant (CROW, 2017).

5.6.6.2 Reckless driving

Risky behavior in traffic includes actions that compromise safety, such as driving intoxicated, speeding, driving while fatigued, running red lights, and improper use of safety equipment. Repeat offenders are particularly dangerous (SWOV, 2021a). Speeding is prevalent, in 2021, drivers were surveyed about speeding in the past month, with over half admitting to doing so (69% outside built-up areas, 58% inside built-up areas). Observations confirm that 55-60 percent of vehicles exceed limits on 50-70 km/h roads, 50 percent on 80 km/h roads, and 35-40 percent on 100 km/h roads. Factors include time, location, enforcement, habitual fast driving, underestimating speed, and modern car comfort (SWOV, 2021b). Aggression is also a problem in traffic, it refers to intentional actions that harm, such as tailgating, honking, flashing lights, yelling, or making gestures. This behavior often stems from anger, impatience, aggravation, hostility, or hurry (SWOV, 2021a). There is no comprehensive record of the frequency or number of victims of traffic aggression. In 2019, one in eight surveyed reported occasional traffic conflicts, with half in dangerous situations. Cyclists were involved in over a quarter of these conflicts. Reports of traffic conflicts doubled from 3140 in 2013 to 6340 in 2018, with a significant increase in police involvement in 2018 (SWOV, 2021a).

Different demographics show unpredictable risky behaviors, making it unclear which groups are most sensitive to them. Motorists often speed and use phones while driving; motorcyclists speed; and cyclists use phones and sometimes alcohol while riding. Men and young people exhibit the riskiest behaviors, including aggressive driving and repeat offenses, driven by traits such as a need for excitement and anger. Age influences aggression more than gender, with aggression decreasing as people age. Those who display aggression in traffic often do so in other areas, linked to traits such as impulsivity, or sensation-seeking (SWOV, 2021a).

5.6.6.3 Driving under the influence

5.6.6.3.1 Alcohol

In 2022, measures were taken to evaluate the prevalence of alcohol influence among car drivers. On weekend nights, it was noted that 2.6 percent of drivers were driving under the influence of alcohol, nearly double the rate observed in 2017. This rise could be associated with decreased enforcement and a reduced perception of the risk of getting caught. The police's shift to a risk-based approach and fewer alcohol checks between 2020 and 2021 likely contributed to the rise in drunk driving. In addition, with a blood alcohol content of 0.5‰, the crash risk for motorists increases by 1.4 times compared to driving sober. At 1.0‰, the risk jumps to almost four times higher, and at 1.5‰, it exceeds twenty times higher. Cyclists also face higher crash risks with increased alcohol levels, especially younger drivers. The exact number of deaths from alcohol-related accidents is unclear, as consistent checks for alcohol are not performed post-accidents (SWOV, 2023b). Despite lower alcohol consumption in traffic, young drivers still have high rates of alcohol-related accidents due to inexperience and heightened vulnerability. In 2009, drivers aged 18-24, 4 percent of license holders, represented 29 percent of seriously injured motorists who had consumed alcohol, with over 90 percent being male. Serious alcohol offenders, typically males aged 30-40, single, with lower education, often resist traditional measures such as license suspension and fines. These individuals exhibit high alcohol dependence, psychiatric issues, and antisocial tendencies, and are frequently involved in non-traffic crimes and drug use (SWOV, 2023b).

5.6.6.3.1 Drugs

Between 2017 and 2022, drug-related road incidents reported by police surged from 1,834 to 13,147, continuing to rise in 2022. This increase followed the 2017 introduction of saliva tests, which heightened scrutiny of drug-impaired driving. Previously, drug use was not treated as a standalone offense, and erratic driving often received lenient penalties (Politie, 2022a). In 2022, about 18,000 fines were issued for drug-related offenses (NOS, 2023a). There is some data discrepancy between police reports and fines, making it unclear if the rise in incidents reflects increased occurrences or more effective enforcement.

In 2018, 5,1 percent of Dutch car drivers stated to have driven under the influence of drugs in the past 30 days, and 14,9 percent stated to have driven under the influence of medicine that can decrease their fitness to drive. SWOV looked at older data and examined that cannabis was the most used drug, followed by cocaine, ecstasy, amphetamine, and laughing gas. It is not known how many accidents happen because of drug use in traffic. The risk groups here are young people (drugs) and older people (medicine). Elderly individuals consume three times more medication compared to other age groups, yet the extent of impairment these medications pose to driving abilities remains uncertain. There is limited awareness regarding the dangers associated with drug usage among drivers, even with educational efforts. Particularly among young drivers, many fail to fully grasp these risks (SWOV, 2020b). Moreover, the demographic frequently apprehended for driving under the influence of drugs tends to overlap with those caught for reckless driving or antisocial behavior on the road. These individuals are typically men in their early thirties with a criminal record, not only for drug-related offenses but also for speeding violations or non-traffic-related crimes such as theft or

assault (WODC, 2023). Reasons for driving under the influence of drugs include overestimating their driving ability, optimistic thinking, and viewing drugs as less dangerous than alcohol. Also, the lack of transport alternatives was mentioned (SWOV, 2020b).

There was an increase in cycling accidents due to drug use in 2021, with cyclists involved in three out of four drug-related accidents. Over half of these accidents involved individuals aged 20 to 49, and one-third were single-vehicle incidents (Verkeerskunde, 2022). Car drivers and or scooter riders each accounted for ten percent of these accidents. Additionally, 87 percent of those involved were men (Valkenberg & Nijman, 2022). The exact number of traffic deaths due to drug use is unknown. There is no research available regarding individuals using alternative modes of transport (SWOV, 2020b).

5.6.6.4 Other

Some critical factors resist categorization into specific themes but are crucial contributors to fatalities and deserve careful consideration.

5.6.6.4.1 Helmet use

In the Netherlands, helmet use among cyclists is uncommon, as mandatory helmet laws are opposed to avoid discouraging cycling. However, helmets significantly reduce the risk of serious head and brain injuries, potentially preventing up to 85 fatalities. Studies show a risk reduction of 54-65 percent for serious head/brain injuries and 44-85 percent for fatal head/brain injuries with 95 percent certainty. While sports cyclists often wear helmets due to higher speeds, everyday cyclists cite reasons such as short trips, discomfort, and style concerns for not wearing them. Campaigns temporarily increase helmet use, especially among children, but it declines afterward. Mandating helmets is debated due to concerns about personal freedom (SWOV, 2019d).

5.6.6.4.2 Fatigue

Studying fatigue concerning traffic accidents is challenging because its role may not always be clear. Fatigue leads to reduced alertness, slower reactions, and increased irritation and frustration, potentially contributing to 15-20 percent of traffic accidents. However, estimates vary among researchers. Police studies in 2015 struggled to detect fatigue as a cause due to its complex manifestations and overlap with stress and adrenaline. As a result, accidents are often attributed to other factors. Fatigue was cited as a cause of only one percent of fatalities in 2015, but experts believe this figure underestimates its actual prevalence. Generally, people recognize when they are tired and grasp the risks involved, along with suitable precautions such as taking a break or handing over the driving. However, they frequently opt out of these measures or resort to ineffective ones such as opening windows, turning up the music, or a short stop to eat. Occupations and demographics prone to fatigue include freight drivers, taxi drivers, night shift workers, individuals with sleep disorders, and young men (SWOV, 2019b).

5.7 Conclusion

The increase in fatalities was especially seen among specific demographics. Men over the age of eighty, and women above the age of seventy. Significant geographical differences were also noticed, with Noord-Brabant and Zuid-Holland recording the highest number of fatalities. important to note is that these provinces have more inhabitants than other provinces, but so does Noord-Holland which is not in the top two. For transport modes, cycling accounted for the most deaths. Furthermore, road fatalities were most frequent on municipal roads and 50km/h roads, indicating specific areas and speed limits as critical factors.

Behavioral aspects played a significant role in the rise in fatalities, with distracted driving and reckless behavior such as speeding and aggressive driving being primary contributors. Despite awareness of the dangers of phone use while driving, a large percentage of drivers admitted to this behavior. Additionally, alcohol and drug use were prevalent, with a notable increase in drivers under the influence during the weekend nights and a significant rise in drug-related driving incidents due to increased police surveillance. The lack of helmet use among cyclists and fatigue among drivers also emerged as critical risk factors. Initiatives to address these issues, such as traffic safety campaigns and education, have had limited success in reducing accidents, underscoring the complexity of changing driver behavior and the necessity of understanding the interplay between demographic factors, behavior, and adherence to traffic regulations.

Overall, while there are significant increases in certain demographic groups and behavioral factors contributing to traffic fatalities, no significant decreases have been observed. This underscores the urgency.

6. Discussion

Some of the traffic safety issues observed in this research cannot be described as trends due to the exceptional circumstances during the COVID-19 pandemic years (2020-2022). The periods of restrictions imposed during these years significantly reduced road usage, resulting in fewer accidents. Therefore, the data from these years cannot be reliably compared to previous years, and the overall influence of the pandemic on traffic safety remains unclear. In addition, this research drew upon studies from other countries for comparative purposes. These studies provided insights into the specific traffic safety challenges faced elsewhere and how different approaches were implemented to enhance safety. However, a notable challenge arose from variations in driving cultures between countries. For instance, the Netherlands' strong cycling culture distinguishes it from others, potentially affecting the applicability of foreign cycling studies. This cultural difference might also contribute to the Netherlands' higher cyclist fatality rates compared to other countries. Furthermore, while the importance of vehicle safety features in reducing fatalities was acknowledged in this research, it was not examined as a separate factor. Numerous studies emphasize the significant role of safe vehicles in improving overall traffic safety outcomes. This also goes for Vision Zero which uses vehicle safety standards as an important factor in improving safety.

Given the broad scope of this study, conducting follow-up research would be beneficial. This follow-up research could encompass various types of studies, including but not limited to conducting a detailed examination of the role of vehicle safety features and their potential for reducing fatalities. Narrowed down research about cycling safety or car driver safety or a further look into safer road design or specific group education. It could also be beneficial to quantify the impact of the pandemic. Exploring statistical data or trends during the pandemic years compared to previous years could strengthen the argument about the challenges in comparing data across different periods.

7. Conclusion

This conclusion answers the main question: What are the factors, including demographic factors, policy measures, and behavioral aspects, contributing to the increase in traffic-related deaths among road users in the Netherlands in 2022? Despite the Netherlands' strong position in traffic safety, with its excellent infrastructure, and robust cycling culture, there is still a need for improvement to meet the government's goals for reducing traffic accidents. According to various studies, including those aligned with the Vision Zero approach and system theory, the Netherlands has areas where further enhancement is possible.

In 2022, cyclists constituted most traffic fatalities, followed by car drivers, with older individuals being the largest demographic among these casualties. The vulnerability of these groups, due to age and limited protection options, contributes significantly to this trend. Additionally, there has been a notable rise in electric bike fatalities, primarily affecting older people who may lack the necessary familiarity with these faster modes of transport. Most fatalities occurred on 50 km/h (27%) and 80 km/h (19%) roads, which are more hazardous, crowded, and have higher speed limits. These roads are also widely implemented, and 90km/h not so much. This could also be a factor influencing the high fatality numbers.

In the five years leading up to 2022, multiple changes in traffic laws were implemented, though the effectiveness of these changes is not well-documented. Law changes are only effective if there is sufficient and consistent enforcement and if they are supported by the public. For instance, laws should target dangerous behaviors, such as phone use while driving, or demonstrate clear benefits, as seen with the requirement for new electric cars to make noise, which does not affect anyone in a bad way. Conversely, reducing speed limits on roads where drivers feel safe traveling faster may not be as effective without proper justification and enforcement. People may revert to old behaviors over time, diminishing the effectiveness of new laws. This highlights the importance of consistent enforcement. Laws should be carefully considered and well-designed, though some individuals may never comply. Therefore, education, enforcement, and road design are all crucial components in ensuring traffic safety.

Enforcement has adapted to new trends, such as the use of laughing gas in traffic, and has introduced measures such as mobile speed cameras and the MONO-cam to catch distracted drivers. However, there is public irritation with these methods, and their long-term effectiveness is debated. Effective enforcement relies on a high perceived risk of being caught, swift punishment, and a visible police presence. Strategies include increasing actual enforcement, publicizing police activities, varying enforcement locations, and conducting unavoidable checks. While rewards are more effective than punishments in promoting good behavior, penalties should be explained to enhance understanding. Increased enforcement yields diminishing safety returns; as enforcement pressure increases, the additional safety gain becomes progressively smaller. People often mimic others' behavior, so displaying compliance rates on roads can encourage adherence.

Road design in the Netherlands focuses on self-explaining roads and safer infrastructure, such as roundabouts, which have contributed to safer traffic over the past 50 years. However, intersections remain a common site for accidents. Slower speeds and more enforcement can improve safety, but measures such as speed bumps and reduced speed limits may cause public annoyance.

Non-regulatory initiatives and education play a significant role in improving traffic safety. Group-specific interventions and ongoing evaluation of campaign effectiveness are essential. Collaboration across different sectors and disciplines, including public health professionals and urban planners, can lead to more comprehensive and innovative solutions. Strengthening partnerships between government agencies and other actors can provide valuable insights and enhance traffic safety measures.

Behavioral aspects play a critical role in traffic safety, with research suggesting that 90 percent of road accidents are attributed to human actions. Behavior encompasses decision-making and personality traits, making it more complex than demographic factors alone. Distracted driving, often due to smartphones, radios, navigation systems, and external factors, significantly impairs driving by diverting attention and slowing reaction times. Risky behaviors such as speeding, driving under the influence, and aggressive actions such as tailgating and honking are prevalent, particularly among young men and repeat offenders. Despite measures to curb these behaviors, many drivers continue to drive under the influence, with young drivers and males aged 30-40 being more prone to these behaviors. When discussing behavior, improving actions involves enforcement.

In conclusion, while the Netherlands has made significant strides in traffic safety, there are still areas for improvement. Enhancing enforcement, improving road design, developing targeted education campaigns, fostering cross-sector collaboration, and focusing on vulnerable groups can further reduce traffic-related deaths and help achieve the government's safety goals.

8. Recommendations

To enhance traffic safety in the Netherlands, a multifaceted strategy is essential. Firstly, increasing enforcement efforts is critical despite challenges such as limited resources and prioritization. This includes increasing police patrols, employing technologies such as mobile speed cameras, and ensuring consistent penalties for offenses such as distracted driving and speeding. For most problems encountered in traffic safety, this could greatly positively impact safety. This appears to be infeasible because there are not enough personnel and traffic is not enough of a priority. This situation is unlikely to change soon, as other areas of policing also play a significant role in the overall safety of the country. Additionally, simply increasing the number of police officers is not a viable solution. Therefore, alternative approaches that require no or minimal increases in police staffing are outlined below.

Firstly, the points system, already in place in the Netherlands, should extend beyond new drivers and cases of drunk driving. Currently, the system may appear less effective when penalties are limited to fines for speeding, without escalating consequences for repeat offenses. A more robust approach would involve a system where repeated violations accumulate points based on severity, frequency, and circumstances. Having a certain number of points would result in license suspension or even legal consequences such as jail time. Shifting from a punitive to a reward-based approach could further enhance effectiveness. In addition to penalties, incentivizing safe driving practices by rewarding people for maintaining a clean record could be explored. Some countries achieve this through insurance incentives, promoting a broader coalition of stakeholders aligned with a Vision Zero strategy. However, coordinating such efforts with insurance companies might pose challenges due to varying corporate policies. This approach emphasizes the importance of a balanced system that not only penalizes but also encourages safe driving behaviors.

Secondly, long-term educational campaigns and non-regulatory initiatives are pivotal in enhancing traffic safety. However, there is a need to shift away from telling individuals to behave safely and embrace a more systemic approach. Educational efforts should focus on developing and expanding initiatives that raise awareness about safe driving practices and the consequences of risky behaviors, rather than repeatedly telling vulnerable road users to be safe. While it is important for children to understand traffic dangers, adults, especially drivers, need this knowledge as well. Tailoring campaigns to diverse demographic groups and leveraging digital platforms and community engagement are crucial strategies to maximize effectiveness and foster a culture of safe driving across society.

For road design, it is essential to continue investing in infrastructure that prioritizes safety, especially at intersections and high-speed zones. Implementing additional measures such as traffic-calming devices, enhanced signage, and pedestrian-friendly crossings can significantly reduce accident risks. According to Vision Zero, rural roads need safer designs as they currently encourage speeding and distractions. Further research into the placement of trees and advertisements alongside roads is necessary. Open landscapes without trees can lead to faster driving and decreased attention, as visual cues are lacking. Conversely, trees along roads increase the risk of severe accidents in off-road crashes, highlighting the need for careful planning and study in road design strategies.

Finally, adopting a comprehensive approach that integrates road design, vehicle safety features, and user behavior is essential. The emphasis of this research was less on vehicle design, but future advancements in smart technologies could offer additional safety benefits. By implementing these measures, the Netherlands can advance its road safety initiatives, striving towards Vision Zero goals of eliminating traffic fatalities and severe injuries.

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