Making the un safest roads in Drenthe safe: How to improve traffic safety in the Dutch province of Drenthe?

A study about traffic safety in the province of Drenthe

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Abstract

Road safety is a critical issue that affects individuals, communities, and societies worldwide. Drenthe is one of the Netherlands' smallest provinces in size and population. However, this province also has the highest number of traffic fatalities per inhabitant in 2022 of all the Dutch provinces, with the number of fatal accidents in 2022 nearly doubling from 2021. This study aimed to investigate key traffic safety issues in Drenthe and propose effective policy and infrastructural changes to reduce traffic accidents and their severity. This research employed a mixed-methods approach, combining a literature review, statistical analyses on data provided by CBS and SWOV, expert interviews, and the development of a conceptual model. Key findings indicate that traffic accidents and fatalities predominantly occur on rural roads and N-roads, and there is a significant correlation between traffic fatalities and the average distance to essential facilities, highlighting rural-urban disparities. Statistical tests, including Pearson correlation and a Chi-Square test, confirmed that rural areas experience higher fatality rates and more severe accidents than urban areas. Urban areas experience more, but less severe accidents. Existing literature and interviews with traffic experts reveal contributing factors to traffic safety such as road-design, traffic volume, speeding, age, e-bikes, impaired driving, trees near the road and driver behaviour. Recommendations to improve traffic safety in Drenthe include decelerating rural roads to a speed limit of 60km/h, improving the consistency and believability of road-design, developing more segregated cycling lanes as well as implementing more safe passing havens for cyclists on rural road crossings. N-roads should be categorised and receive a median barrier or doubling of lanes where needed. Finally, rewarding drivers for good driver behaviour can incentivize positive driver behaviour.

Keywords: Traffic safety, Infrastructure, Cyclists, Drenthe, Netherlands, Rural roads, Road-design analysis, Driver behaviour, Traffic volume and speed analysis, SWOV, CBS, Traffic fatality, Traffic accident prevention

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List of Abbreviations

AV= Agricultural vehicle
CBS= Centraal Bureau voor de Statistiek
ETW= Erftoegangsweg (access road)
GOW= Gebiedsontsluitingsweg (distributor road)
SWOV= Stichting Wetenschappelijk Onderzoek Verkeersveiligheid
SW= Stroomweg (connector road)

1. Introduction

1.1 Background

Road safety is a critical issue that affects individuals, communities, and societies worldwide. In the Netherlands, Drenthe is a province known for its picturesque landscapes and relative calmness compared to the crowded Randstad. Drenthe is one of the Netherlands' smallest provinces in size and population. However, this province also has the highest number of traffic fatalities per inhabitant in 2022 (CBS, 2023a; 2023b). The number of fatal accidents in 2022 nearly doubled from 2021 (CBS, 2023a; 2023b). Moreover, Drenthe has more fatal traffic accidents per inhabitant than all its neighbouring provinces. A rising trend of fatal traffic accidents can be observed in Drenthe in the past few years, apart from the less traffic intense covid-years.
Therefore, this research aims to investigate the reason for the rising trend in traffic fatalities in Drenthe and provide insight into measures that could reduce traffic incidents. According to Pérez-Zuriaga et al. (2013), driver behaviour and road-design are the most important factors influencing road safety. This highlights the need for research focused on driver behaviour and road-design as critical components for reducing traffic accidents.

1.2 Societal Relevance

This study on traffic safety in Drenthe can contribute to safer planning practices in several ways. First of all, this study can identify safety issues in Drenthe's transportation system, such as high-crash locations, unsafe road-designs, or driver behaviour patterns that contribute to unsafe traffic situations. This information can help planners and policymakers prioritise safety improvements and allocate resources more effectively to improve traffic safety. Each year, numerous lives are lost or altered due to road incidents, leading to emotional trauma, financial burdens, and disruption within communities. By prioritising traffic safety, Drenthe can work towards creating a safer and more secure environment for its residents, visitors, and commuters.

Moreover, this study can build capacity within Drenthe's transportation agencies and planning organisations to conduct safety assessments, analyse data, and develop better traffic safety strategies. This can help ensure that safety considerations are integrated into planning processes and that safety expertise is developed and maintained. This study therefore contributes to safer and more sustainable infrastructure in Drenthe by informing evidence-based decision-making and building capacity for safety planning and implementation.

1.3 Research Problem

The research problem is the excessive amount of traffic fatalities in Drenthe in comparison with neighbouring provinces and the Dutch average as well as the rising trend of traffic accidents and fatalities. Despite existing research in this area, there is still a knowledge gap regarding the specific influences of driver behaviour and road-design on traffic safety in Drenthe. When looking at traffic safety literature, urban clusters in developed countries get researched plenty, as do rural areas in developing countries. It is suggested that researchers tend to overlook rural areas in developed countries such as the province of Drenthe, given its size and relatively low population numbers, most traffic-related research tends to pour into densely populated areas such as the Randstad. Additionally, the concerning rising trend of traffic fatalities in Drenthe is relatively young, adding to the research gap. This research aims to bridge that gap by conducting a comprehensive investigation to identify the key risk factors associated with driver behaviour and road-design and to propose effective measures to mitigate these risks and improve traffic safety in Drenthe. All tables and Figures are analysed per 10,000 inhabitants to help normalise the accident data based on population size, providing insights into the relative safety of each municipality or province.
Problematic is that the number of traffic accidents in the Netherlands has increased by 6,8% in 2022 compared to 2021 (Dijcks, 2024a). According to Independer, a Dutch insurance comparator, the traffic

accidents in Drenthe rose from 2,533 to 2,667, in 2022 compared to 2021, an increase of 5%, whereas the population of Drenthe grew 0,6% in this timespan. Furthermore, Dijcks (2024a) predicts this rise to continue in 2023 due to an ever-increasing number of people active in traffic. The number of accidents, in reality, is higher due to this data being based on police and insurance reports, as not all accidents are reported to the authorities.
Another problem is the fatality rate of traffic accidents in Drenthe. As can be seen in Figure 1, the province of Drenthe is in the lower segment of traffic accidents per inhabitant in comparison to comparable provinces and the Dutch average. However, when looking at Figure 2, it can be seen that the province of Drenthe yields vastly more traffic fatalities per inhabitant than the Dutch average and comparable provinces.

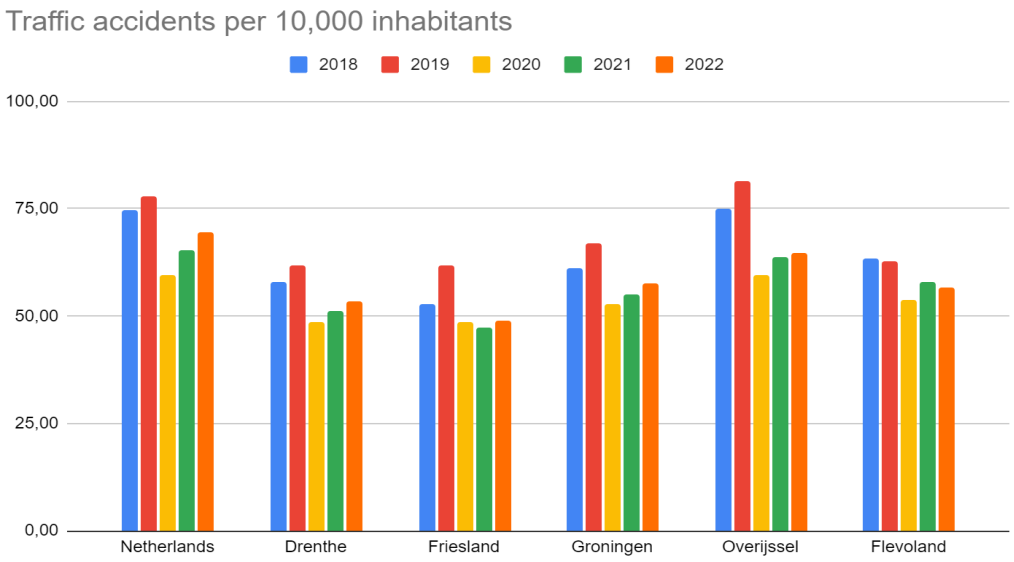

Figure 1: Traffic accidents per 10,000 inhabitants per province in the period 2018-2022 compared to the Dutch average (SWOV, 2023a, Allecijfers, 2023)

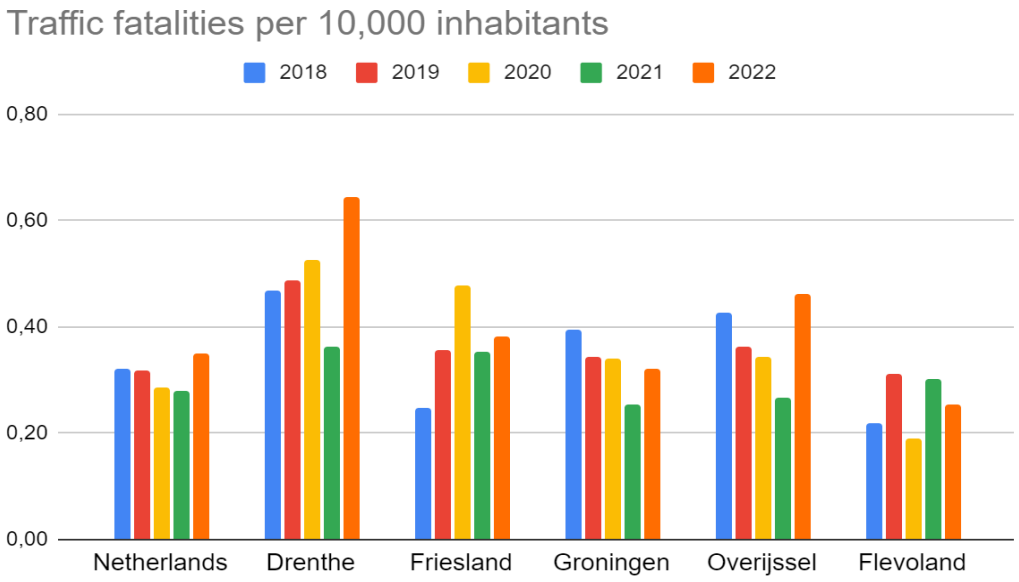

Figure 2: Traffic fatalities per 10,000 inhabitants per province compared to the national average in the period 2018-2022 (SWOV, 2023a, Allecijfers, 2023)

Another problem is that the number of traffic fatalities is following a rising trend, with the number of traffic fatalities in 2022 being the highest since 2008 in Drenthe (SWOV, 2024a; 2024b, SWOV 2023a; 2023b; 2023c; 2023d).
As can be seen in Figure 3, 39 traffic fatalities occurred during traffic accidents in Drenthe in 2022 (SWOV, 2024). This is nearly double the amount of 20 from 2021. In 2017, 20 people were fatally injured in traffic in Drenthe, signalling an all-time low since SWOV started collecting this data in 1996. Since 2017, a rise in traffic fatalities can be observed up until 2022. However, 2020 and 2021 are an exception in the trend because of the lockdown concerning the COVID-19 pandemic. During this time, a lot less traffic appeared due to the advice from the Dutch government to stay home as much as possible (Rijksoverheid, 2020). For 2023, there is no data yet, but the contemporary news reports and Dijcks (2024a) indicate that this upward trend will not stop in 2023.

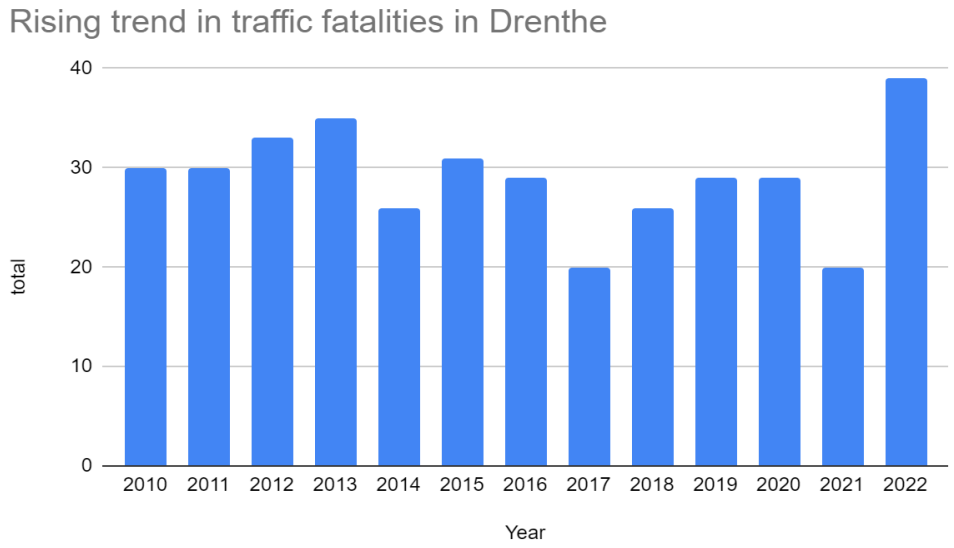

Figure 3: Rising trend in traffic fatalities in Drenthe (SWOV, 2023c)

Another problem is the severity of traffic accidents in Drenthe. Figure 4 shows that 0.9% of traffic accidents turned into fatal traffic accidents in Drenthe in the period of 2018-2022, which is double the Dutch average of 0.45%, and most of any province (SWOV, 2023a; Allecijfers, 2023).

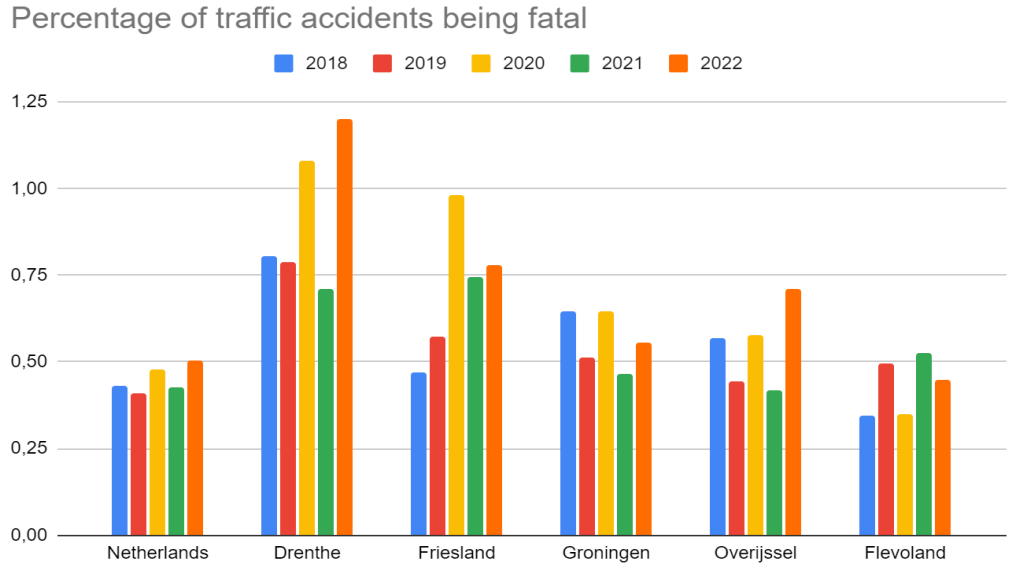

Figure 4: Percentage of traffic accidents turning out to be fatal in the period 2018-2022 compared to other provinces and the national average (SWOV, 2023a; Allecijfers, 2023)

Finally, Drenthe tops the number of total traffic fatalities compared to the provinces of Groningen, Friesland and Flevoland as can be seen in Figure 5. This is especially worrisome as Groningen and Friesland boast approximately 100,000 and 150,000 more inhabitants than Drenthe.

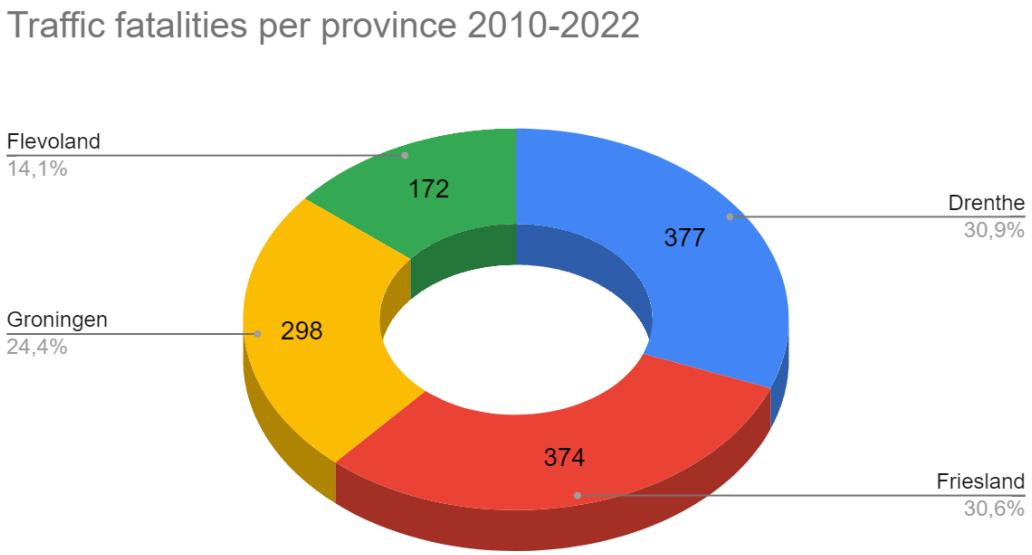

Figure 5: Total amount of fatal injuries per province from 2010-2022 (SWOV, 2023c)

1.4 Research Aim and Research Questions

This study aims to improve traffic safety in Drenthe by inspecting driver behaviour and road-design and finding the best practices to improve traffic safety. This leads to the following main research question:

How can policymakers and transportation planners improve traffic safety and reduce traffic fatalities in Drenthe?

With the following sub-questions:

SQ1: How do key factors in traffic safety contribute to and influence traffic safety in Drenthe?
SQ2: What policy and infrastructure changes could be made to improve traffic safety in Drenthe, and what are the potential benefits and drawbacks of these changes?
SQ3: How can road-design reduce the frequency and severity of traffic accidents?

The literature review suggested that rural roads are more dangerous than urban roads. Therefore, this research also aims to determine if rural roads are more dangerous than urban roads in Drenthe.

1.5 Thesis Outline

This study is structured as follows: First, the reader is introduced to the background of traffic safety in Drenthe. In Chapter 2 a literature review of existing theories and factors regarding traffic safety is conducted. This gives a detailed overview of which factors contribute to traffic safety. Additionally, Chapter 2 reviews the current status and trends of traffic safety in Drenthe and compares them with adjacent provinces in the Netherlands. Chapter 3 explores the methodology used for this research. In Chapter 4 the results are discussed. Chapter 5 explores how the results of this research can be used in practice. In Chapter 6, a concise conclusion can be found. Finally, Chapter 7 explores recommendations for future research and the limitations of this research.

2. Literature Review

To reach the goal of reducing traffic crashes and thus traffic fatalities, it is important to determine the factors that influence the probability of crashes and their severity. There are a multitude of factors that can have an impact on the risk and severity of a traffic accident. Theoretical debate in road safety research concerns the relationship between road-design, driver behaviour and safety.

The most common performance metric for road safety performance is the number of fatal crashes. The Netherlands uses the internationally recognised definition of a traffic fatality as follows:

'Road user who died as a result of a sudden event on public roads related to traffic, involving at least one moving vehicle. Persons who die thirty days or more after the accident date are not counted as road fatalities.'- (CBS, 2022).

The Minister of Infrastructure of the Netherlands set the ambitious target of achieving zero traffic fatalities within its borders by 2050 (SWOV, 2024b). Furthermore, the country is actively striving to align with the European Union and United Nations objectives of reducing the number of traffic fatalities by half by 2030 compared to the figures recorded in 2020 (Geurts, 2021). An essential aspect of achieving this objective involves gaining an understanding of the risk elements contributing to fatal traffic fatalities (SPV 2030, 2018).

Subsequently, SWOV has assessed the potential effects of a series of additional measures to reduce traffic fatalities in the Netherlands. The most significant casualty reductions are expected from:
- Improving bicycle safety: implementing safe cycling facilities, promoting helmet use for cyclists
- Infrastructure measures: reducing speed limits from 50 km/h to 30 km/h in urban areas and enhancing safety on N-roads.
- Enforcement and speed management: increasing automated speed enforcement, introducing mandatory Intelligent Speed Assistance (ISA) systems (SWOV, 2022).

Another theoretical debate concerns the role of driver behaviour in traffic safety. By analysing data on traffic accidents and injuries in Drenthe, this research can identify patterns of driver behaviour that contribute to accidents, such as speeding, distracted driving, heavy braking or accelerating zones or impaired driving. These findings can help inform theoretical debates on driver behaviour and contribute to the development of interventions and policies that address these behaviours.

In addition, studying traffic safety in Drenthe can contribute to theoretical debates on the effectiveness of various safety interventions, road-design and policies. By evaluating the impact of these interventions on traffic safety in Drenthe, insights and theories about what works and what does not work can be generated to improve road safety. The most influential factors on the risk of traffic accidents and fatalities are discussed in Chapter 2. This thesis aims to identify these factors and develop a best practices approach to recommend the best solutions that will reduce both the occurrence and severity of road accidents.

2.1 Variables Contributing to the Risk of Accidents

2.1.1 Human Factors in Driving Behaviour

Driver behaviour plays a crucial role in road safety, with drivers being a central factor in establishing safety on the roads. Jafarpour and Rahimi-Movaghar (2014) categorised the determinants of risky driving behaviour into three primary factors: environmental, vehicular, and human, with the latter being identified as the predominant factor influencing such behaviours. While safety measures are essential in enhancing road safety, the effectiveness of these measures heavily relies on drivers' compliance. Therefore, the interaction between humans and their physical environment plays a huge role in traffic safety.

Driving styles are influenced by demographic and personality variables, with age and gender being the most notable human factors in traffic safety (Taubman-Ben-Ari & Yehiel, 2012). Understanding these factors is essential for designing interventions that target specific driving behaviours and promote safer traffic.

2.1.2 Age and Gender

Age has a strong influence on distracted driving behaviour, with younger drivers being more likely to be distracted compared to middle-aged and older drivers (Chen & Terken, 2022). Taubman-Ben-Ari & Yehiel (2012) reported a difference in all 4 of their different driving styles between males and females. Men were found to drive more recklessly and angrily, whereas women tended to drive more anxiously and carefully, aligning with the findings of Chen & Terken (2022). They also found that higher age was related to lower reported recklessness and angered driving styles and higher outcomes for the 'careful' driving variable (Taubman-Ben-Ari & Yehiel, 2012) using a Pearson correlation.

Additionally, whenever a driver drives more distance per year, the variable 'anxious' driving style has a diminishing outcome. Thus, it can be concluded that the more distance a driver drives, the driver is less likely to drive anxiously. On average, men drive more kilometres than women (Taubman-Ben-Ari & Yehiel, 2012). The traffic fatalities in Drenthe per gender can be seen in Figure 7. It can be seen that the male traffic fatality rate in Drenthe is double the traffic fatality rate of females (SWOV, 2023c).

Higher age is also a fundamental predictor, showing that older individuals were less likely to endorse reckless and angry driving styles but more inclined to report a careful driving style. These results aligned with previous research findings (Taubman-Ben-Ari & Yehiel, 2012). However, it is worth noting that no participants exceeded the age of 60. Drenthe's inhabitants are older than the Dutch average age. Twenty-four percent of Drenthe's inhabitants are 65+ years old with a further 29% being 45-65 years old (Allecijfers, 2023). Age has a significant impact on driving simulator parameters, with older drivers showing slower driving speeds, lower accelerations, and longer brake reaction times (Economou et al, 2021). Owsley (2016) adds that elderly drivers who experience reduced visual processing speeds are at a heightened risk of being involved in traffic accidents. Phillip et al., (2005) noted that the effects of sleepiness on driving performance are more pronounced in younger drivers. A third of the traffic fatalities in Drenthe are aged 70+, with an additional 20.2% of the traffic fatalities being aged 50-69 as can be seen in Figure 6 (SWOV, 2023c).

Moreover, age influences how much risk a driver is willing to take and plays a particular role in gap acceptance. Gap acceptance refers to the process by which drivers decide whether to proceed with a manoeuvre, such as turning at an intersection or merging into traffic, based on their judgement of the available gaps in the oncoming traffic stream. This decision-making process is influenced by several factors, including the size of the gap, the speed of the oncoming vehicles, the driver's perception of risk, and individual driver characteristics such as age and driving experience. Weather, lighting, and road conditions can also affect gap acceptance. Poor visibility or slippery roads may lead to drivers requiring larger gaps (Hamed, 2001). Additionally, older adults may find night driving particularly challenging. Age-related declines in vision, including difficulties with glare recovery and reduced contrast sensitivity, can exacerbate the risks associated with nighttime driving (Owsley, 2016).

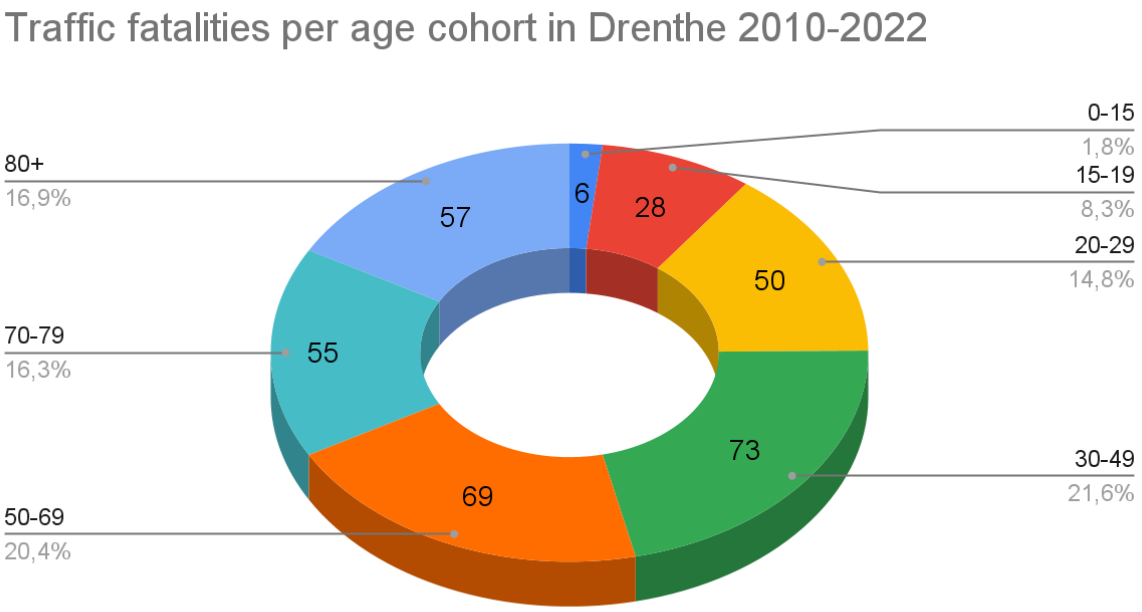

Figure 6: Traffic fatalities in Drenthe per age cohort from 2010 - 2022 (SWOV, 2023c)

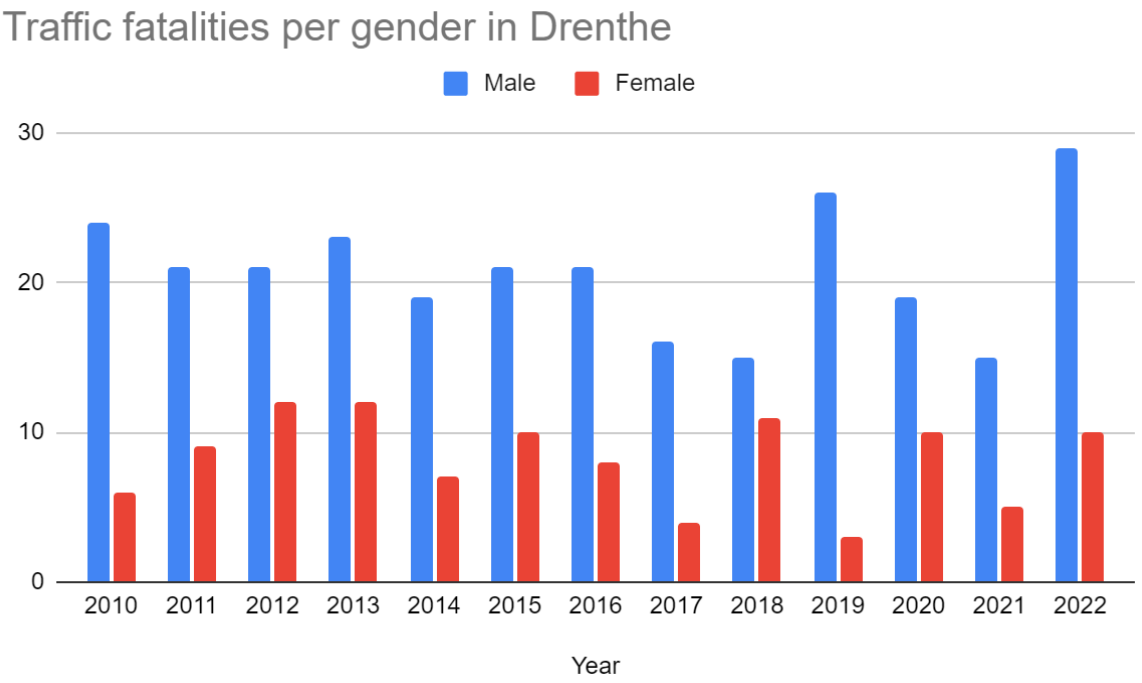

Figure 7: Traffic fatalities in Drenthe per gender per year (SWOV, 2023c)

2.1.3 Personality Traits and Education

Personality traits like agreeableness and conscientiousness influence driving styles, with reckless and angry styles associated with lower levels of these traits. Reckless and angry drivers seek benefits like thrill-seeking and control, while careful drivers prioritise kindness and cooperation. Anxious driving was associated with neuroticism and lower conscientiousness. Education level also impacts driving styles, with more educated individuals perceiving more risks (Taubman-Ben-Ari & Yehiel, 2012).

Therefore, future interventions should consider these diverse factors for effective road safety measures, as one approach may not suit all drivers. Promoting safety motivations and understanding individual differences can enhance driver education and intervention strategies. Therefore, de Waard et al. (1995) highlight the importance of considering drivers' physiological responses to road environments in road-design and traffic safety interventions, as all drivers tend to react differently.

2.1.4 Impaired Driving

Alcohol constitutes a significant risk factor that not only elevates the likelihood of road traffic collisions but also intensifies the severity of injuries sustained in such incidents (Pawowski et al., 2019). The focus on alcohol as a contributory factor in road accidents predominantly centres on its impact on driver behaviour. Its pharmacological effects on the central nervous system compromise visual acuity, consciousness, perceptual functions, reaction times, and concentration capabilities, thereby increasing the propensity for traffic accidents (Behnood & Mannering, 2017). Furthermore, alcohol intake impairs spatial and distance estimation, boosts self-confidence, and overall diminishes the capacity for safe vehicle operation (Chen et al., 2016). Consequently, drivers under the influence of alcohol present a heightened risk of crash involvement compared to their sober counterparts (World Health Organization (WHO), 2018). During the most recent assessments in 2022, it was observed that 2.6% of motorists were driving under the influence of alcohol during weekend nights, representing nearly a doubling from the lowest recorded violation rate of 1.4% in 2017 (SWOV, 2023b). The exact number of fatalities and injuries in the Netherlands resulting from alcohol use in traffic is unknown. However, as can be seen in Figure 8, there is a rising trend in the national fatality rate due to impaired driving, bar the covid-years. In 2022, nearly 10% of the total traffic fatalities in the Netherlands were attributed to impaired driving, indicating a serious issue (NOS, 2023). Deterioration in driving behaviour is more pronounced among younger drivers. The impact of the national awareness campaign "Bob" is unclear due to the absence of an evaluation of its effect on accidents (SWOV, 2023b). Moreover, increasing penalties, such as higher fines, more frequent or longer driving disqualifications, or revoking driving licences, appeared to have little effect on serious alcohol offenders (SWOV, 2023b). For this group, more prevention-oriented measures need to be developed, with a broader approach to the underlying problem of alcohol violation, possibly in combination with an alcohol interlock device or an ankle monitor (SWOV, 2023b).

According to Dijcks (2024b), the amount of fined impaired drivers has increased by 32% nationally since 2019. For provincial data, the number of fines given is the most reliable data as of yet. With 19.5 fines per 10,000 inhabitants in 2023, Drenthe scores the best (lowest) out of all the Dutch provinces. However, a possible explanation for this could be attributed to less police control or a lesser amount of the total population. The national average is 28.4 fines per 10,000 inhabitants. As can be seen in Figure 9, where the municipalities of Drenthe are ranked, only Hoogeveen scored above average, with the average of Drenthe being 17.2. It is worth noting that the more urban municipalities (Meppel, Hoogeveen, Assen, Emmen) yielded more fines per inhabitant than the rural municipalities. A final, well-documented form of impaired driving is using the mobile phone whilst driving. As there is no reliable data on traffic accidents in Drenthe in combination with mobile phones, it is out of the scope of this research.

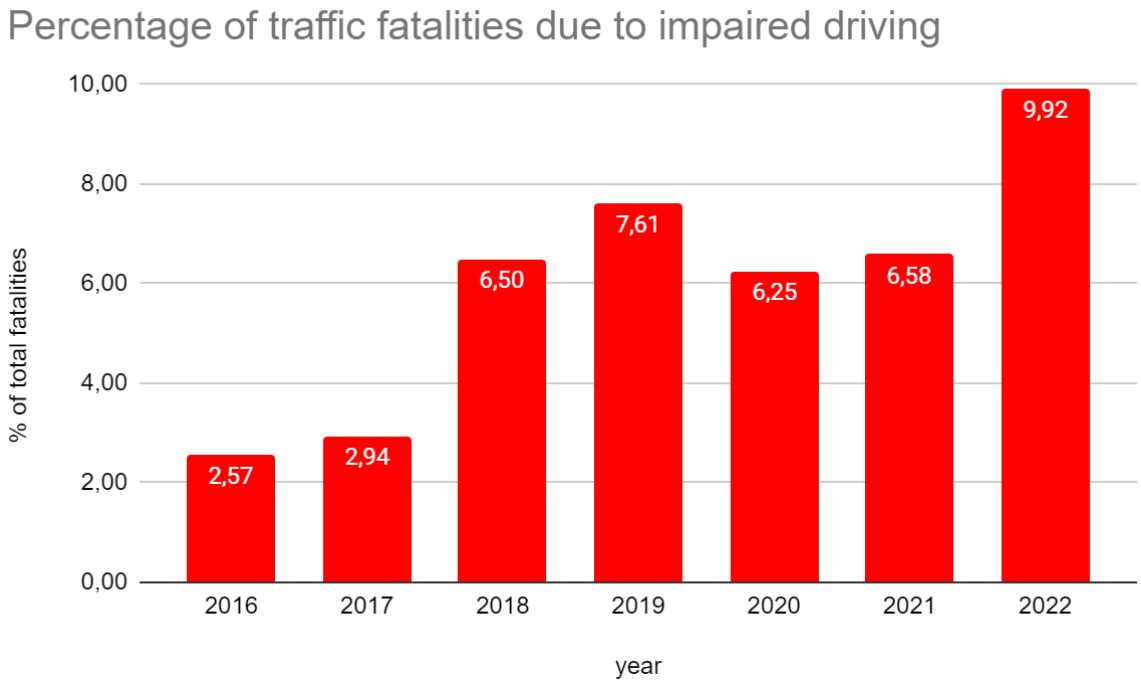

Figure 8: Percentage of traffic fatalities in the Netherlands due to impaired driving (NOS, 2023)

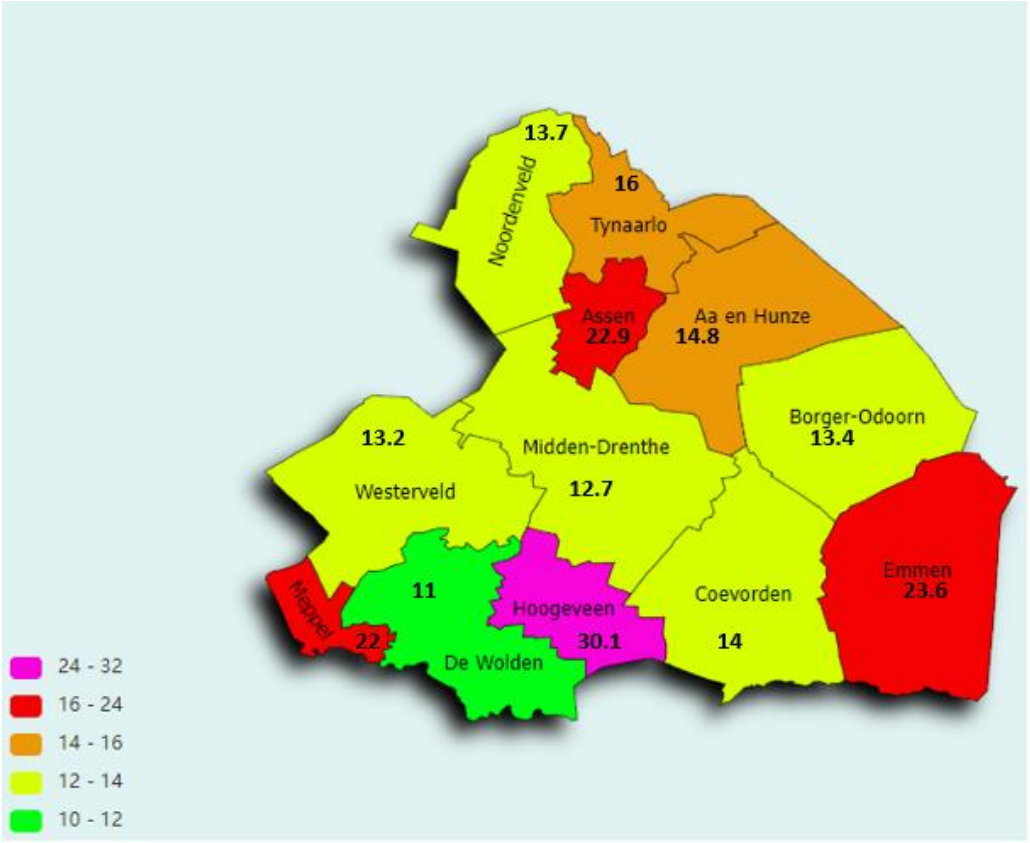

Figure 9: Fines per 10,000 inhabitants for impaired driving in 2023 (Dijcks, 2024b)

2.1.5 Tools to Improve Driver Behaviour

A way to encourage good drivers' behaviour is the so-called ‘safety-safe’. This is a speedometer near the road that rewards road users with a monetary bonus for adhering to the speed limit. The speedometer displays a monetary amount corresponding to the driven speed. If you comply with the speed limit, a positive amount is displayed, which then goes into a designated community fund, as shown in Figure SS1(ab). However, if you exceed the speed limit, a negative amount is displayed, and deducted from the fund. The final balance of the ‘safety safe’ is donated by the municipality to a local charity or project near the safety safe, such as a playground or neighbourhood initiative (Leesman, 2023). By adhering to the speed limit in their own area, motorists can raise funds for the entire community (RTLnieuws, 2023). According to Safetysafe (2023), since the installation of the safety-safe, a reduction of 25% was seen in speeding. Additionally, drivers received a positive feeling with their new behaviour, making it the social norm. However, a safety-safe is a short-term solution, as behavioural change is difficult to hold on to. Therefore, it serves as a kickstart to encourage behavioural change.

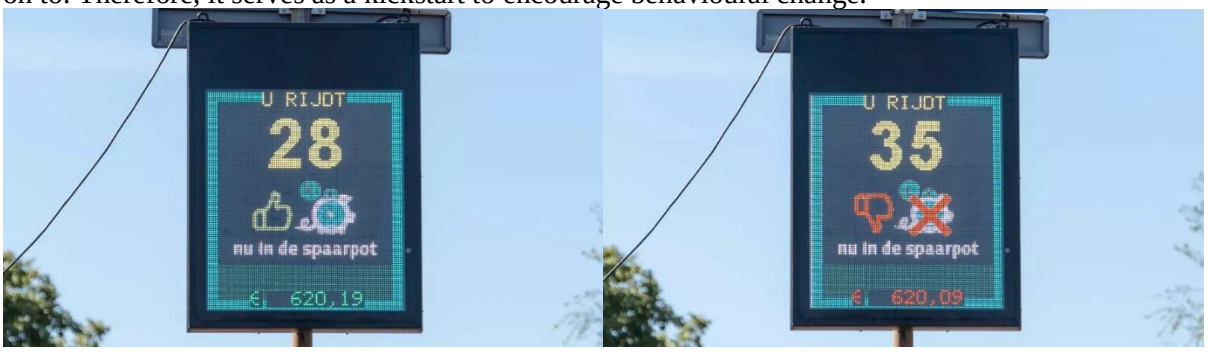

Figure SS1(a)The safety safe shows an increase in the amount when adhering to the speed limit (Leesman, 2023)

Figure SS1(b)The safety safe when speeding shows a subtraction of the amount (Leesman, 2023)

According to Fogg (2003), technology can influence behaviour by providing tools that shape the way tasks are performed, making them easier or restructuring their execution. In line with the concept of persuasive technology, as proposed by Fogg (2003) reward programs act as a medium to convey a message to the community about the significance of their involvement, which in this case is good traffic management efforts. By offering rewards for positive contributions towards reducing congestion and enhancing safety, these programs communicate the value of community engagement in achieving shared transportation goals (Fogg, 2003).

Furthermore, coach systems in cars that monitor driver behaviour and provide feedback/suggestions for improvements, may be a useful tool to change driver behaviour (Chen & Terken, 2022). Social actors may induce behavioural change in several ways, including praise and compliments like ‘Congratulations’ or ‘Good job’ whenever a driver brakes gently, accelerates slowly or does not exceed the speed limit (Chen & Terken, 2022). Cameron and Pierce (2002) analysed the academic dispute regarding intrinsic motivation and rewards and found that intrinsic motivation can be bolstered by incentivizing people with rewards and that there is no inherent negative property related to rewards and intrinsic motivation. Moreover, Cameron and Pierce (2002) suggested that rewards increase motivation and performance on tasks that are of low initial interest. On high-interest tasks, rewards tend to work best when people are verbally praised for their actions and tangible rewards are offered that must be explicitly tied to performance standards of success. However, rewards do not work if they signify a person’s failure or are not tied to a person's behaviour (Cameron and Pierce, 2002). Thus, the idea of rewarding drivers to incentivize positive driver behaviour has merit.

Another example of incentivizing good driver behaviour with rewards is an insurance company that enables drivers to install a dedicated device in their customer’s cars to collect information about their driving habits. By rewarding calm driving with a discount on their insurance fee, the company encouraged safer driving practices among drivers. This approach not only promotes safer driving but also provides a tangible benefit to the drivers, creating a win-win situation. This also checks the boxes for improving intrinsic motivation with rewards as stated by Cameron and Pierce (2002).

2.2 Road-Design & Infrastructure Types

Road-design exerts a significant influence on both the incidence and severity of traffic accidents. Van Petegem & Wegman (2017) suggested that the probability of a run-off-road crash is higher on roads with narrow shoulders, and sharp horizontal curves. This aligns with the findings of, Milton & Mannering (1998), who concluded that these types of roads increase crash frequency as well. Driving on a curved road led to slower driving speeds, higher physiological arousal, and a greater appreciation of the road than driving on a straight road (De Waard et al.,1995). Similarly, Milton and Mannering (1998) demonstrated that the presence of sharp horizontal curves, increased slope of horizontal curves, and reduced tangent lengths preceding curves were associated with a reduction in crash frequency. These road characteristics are typical for roads in rural Drenthe, accompanied by trees next to the road. A looming danger when running off the road in rural Drenthe is hitting a tree beside the road, causing a frontal dangerous collision. Effective road-design must incorporate a comprehensive suite of interventions aimed at mitigating the possibility of vehicle over-speeding. This necessitates the strategic implementation of various traffic calming measures, including but not limited to, the deployment of traffic signage, the application of road surface markings, the installation of speed bumps, the construction of dedicated pedestrian and cyclist pathways and crossings, and the establishment of designated animal crossing zones. These interventions are designed to enhance road safety by systematically reducing vehicle speeds, thereby diminishing the likelihood of accidents, and improving the overall safety for all road users, including drivers, cyclists, pedestrians, and wildlife (Gichaga, 2017).

2.2.1 Current Road-Design

The contemporary road-design in the Netherlands is based on the ‘Sustainable Safe’ paradigm of the early 1990s, with its countrywide application still in progress (Wegman et al., 2008). Aarts and Dijkstra (2018) stated that Dutch roads are categorised into distinct types predicated on their primary function, delineating between traffic flow and traffic exchange. The term 'flow' is employed to describe rapid transit from one point to another, whereas 'exchange' pertains to the facilitation of interactions among different traffic entities and the provision of access to specific locations. In alignment with these foundational principles, the Dutch road infrastructure is optimally segmented into three principal categories:

ETW: Erftoegangsweg (access road): These roads have the ‘exchange’ function on all of their surface, leading to GOW roads. An example is roads inside villages.

SW: Stroomweg (connector road): These roads have the ‘flow’ function on all its surface. They are designed so that cars do not interfere with each other. For example, the N-roads.

GOW: Gebiedsontsluitingsweg (distributor road): These roads have the ‘flow' function on road sections and the ‘exchange’ function at crossroads. For example, rural roads that connect villages.

The ‘Sustainable Safe’ road-design paradigm needs to adhere to 3 pillars: functionality, (bio)mechanics and psychology. The psychology part refers to consistency in road-design, making roads predictable and not creating unexpected situations whereby road users need sufficient time to respond. However, the design principles of the ‘Sustainable Safe’ have not been implemented everywhere, leading to inconsistencies in road-design. An example given is a GOW road with a speed limit of 50km/h with a non-segregated bicycle lane. This creates incompatible traffic ‘flow’. However, various villages in Drenthe currently have this situation. SWOV proposes a new sub-category in road-design to combat this issue, the ‘GOW30’. This means that they alter the speed limit of a distributor road from 50km/h to 30km/h inside the built-up area. This could be implemented in places where creating a separate bicycle lane is not possible or feasible (Dijkstra & Van Petegem, 2019). To achieve this speed reduction, besides changing the speed limit sign, is to change the spatial design of the road by implementing traffic calming measures such as speed bumps, type of road surface, or narrowing the road.

2.2.2 Road Maintenance

Another factor influencing traffic safety is road maintenance. Badly maintained verges can lead to a perceived reduction in roadway width. Drivers may feel constrained, leading to changes in driving behaviour such as reduced speeds or swerving, which can increase the risk of accidents. The

psychological impact of perceived narrow lanes, due to overgrown or encroaching verges, can significantly affect driver confidence and performance. When vehicles inadvertently leave the roadway, well-maintained verges can provide a recovery area for drivers to regain control. However, poorly maintained verges, characterised by uneven surfaces, potholes, or soft ground as can be the case in Drenthe, can decrease vehicle stability, making it difficult for drivers to steer back onto the road safely. This can lead to loss of vehicle control and potential rollover accidents or crashes. Additionally, since there are a lot of agricultural vehicles (AVs) in Drenthe, drivers have to revert to the verges of the road often, amplifying the importance of proper verge management. The effect of (semi) hardening the verges is estimated to eliminate around 20% of traffic accidents in the Netherlands (Schoon, 2003).
However, a more effective solution would be to make verges obstacle-free, eliminating an estimated 55% of all traffic accidents in 15 years (Schoon, 2003). Schoon (2003) notes that when conducting a cost-benefit analysis on constructing (semi-hardened) verges are best implemented during great maintenance, which most municipalities do once every 15 years. However, when implementing (semi) hardened verges outside of the great maintenance period, the benefits still outweigh the costs significantly. An additional danger of trees close to the verge of rural roads is the roots of the tree damaging the asphalt, causing a dangerous bobble in the road. For example, nine traffic accidents happened in de Streek, a rural road in the village of Hooghalen in the municipality of Midden-Drenthe between 2017 and 2020, of which three had a fatal outcome. Additionally, 18.9% of all traffic fatalities in Drenthe between 2018 and 2022 were due to road users colliding with trees (SWOV, 2023a). Even though the municipality of Midden-Drenthe decided to replant the damaged trees after the accidents, local citizens destroyed them because they believed that the trees obstructed sight distance (Tax, 2022).

2.2.3 Proposed Solutions for Road Maintenance & Verges

According to SWOV (2021), a driver increases his speed when verges are cleared and fails to offer signage regarding the maximum allowed speed. Kloeden et al. (1999) established that the design of road verges significantly influences both the probability and severity of crashes. Kloeden et al. (1999) indicated a higher incidence of accidents in areas where lethal hazards are situated within a 9-metre proximity to the roadway. They proposed a guard rail near the road if a hazard closer than 9 metres near the road cannot be removed. Thus, there is a strong impetus for the province of Drenthe to maintain its verges properly. A solution for trees near the roads is removing the roots from below the road surface to prevent the roots from damaging the asphalt and re-asphalt the road surface. In this way, the trees adjacent to the road do not have to be cut, as has been done in the municipality of AA en Hunze. Instead of cutting down 348 trees, they only had to cut 2 trees down (Guit, 2022). However, it is of paramount importance to consult a tree expert beforehand to estimate the feasibility of removing the root of the tree, to avoid the tree from collapsing with strong winds.

2.2.4 N-Roads

Pérez-Zuriaga et al. (2013) identified risky driver behaviour, such as excessive speed, unsafe overtaking, and sudden braking as the main causes of accidents. The results showed that drivers have a higher likelihood of exceeding speed limits and overtaking other vehicles on road sections with straighter alignments and better visibility. Drenthe has a lot of N-roads. The characteristics of these roads are a speed limit of either 100 km/h or 80 km/h. N-roads are part of the Dutch national roadwork, managed by the province of Drenthe, and they have either no physical separation (1x2 connected lanes) or physical separation (2x1 separated carriageways). Drentse N-roads are a significant area of concern due to their traffic fatality rate, with provincial N-roads accounting for a quarter of all fatal crashes nationwide. (RTL Nieuws, 2024). Visser (2021) highlighted that N-roads without physical separation between lanes in opposite directions are considered the least safe roads in the Netherlands.

2.2.5 Safer Road-Design

Most roadside accidents involving motorised vehicles occur on 60- and 80 km/h roads, with young individuals (aged 15-24) being relatively frequent participants in such accidents (Kennisnetwerk SPV, 2023). The primary measure to enhance roadside safety is the removal or secure shielding of obstacles within the designated obstacle-free zone. Additionally, installing a median barrier with a secure shielding structure is a crucial measure to prevent vehicles from crossing into the opposite lane (Kennisnetwerk SPV, 2023).

The findings of Kennisnetwerk SPV (2023) aligned with two measures outlined in the Effectiveness Guide of the Road Safety Knowledge Network. The construction of a median barrier is deemed 'likely effective' according to the Effectiveness Guide. This assessment is derived from accident data analysis on similar roads before and after the implementation of a median barrier.

Another safety measure highlighted in the Effectiveness Guide is the implementation of Safe Edges and Roadside Areas along cycle paths. While these safe edges have not been specifically studied within the framework of the European project SafetyCube, which serves as the basis for the Effectiveness Guide, research has been conducted in the Netherlands. Many single-cycle accidents occur when a cyclist deviates from the cycle path and collides with a curb or falls onto the roadside. An inclined edge along the cycle path can help prevent such incidents.

For N-roads in particular, evidence suggests that the presence of a physical barrier delineating opposing directions of travel significantly reduces the incidence of head-on collisions. Additionally, it prevents drivers from crossing into the opposite lane (Kennisnetwerk SPV, 2023). Such barriers may take the form of guard rails or a median of adequate width physically separating the lanes. Historical analyses revealed that roads equipped with these forms of barriers exhibited a lower probability of fatal crashes and a heightened probability of non-fatal crashes in comparison to roads devoid of any barrier. Of all the 122 fatal traffic accidents in Drenthe between 2018 and 2022, 37 (30.3%) occurred on N-roads (SWOV, 2023a). Implementing no-overtaking zones or the installation of non-traversable median barriers will reduce traffic accidents significantly in Drenthe (SWOV, 2013). Although this method is being implemented in certain regions, it is not universally feasible due to financial, spatial or environmental limitations. Additionally, not all N-roads are the same, as some N-roads allow AVs on them, and with a no-overtaking zone, faster vehicles cannot pass the slower vehicles. Temporary measures, such as speed limit reductions and the installation of temporary barriers for opposite traffic separation on select high-risk roads, have been introduced. For instance, a temporary reduction in the speed limit has been enforced on the N50 (Rijksoverheid, 2022). The utilisation of temporary speed limit reductions raises an intriguing inquiry. There exists a research gap concerning the correlation between speed and crash risk on single-lane N-roads. Prior studies have indicated that lower speeds result in decreased fatality risks (SWOV, 2021). However, these findings did not consider the structural characteristics of N-roads.

2.2.6 Consistent Road-Design

Consistency in road-design is key to improving traffic safety. The consistency on whether the cyclist or car gets priority on roundabouts in the built-up area is currently troublesome in Drenthe. The municipality of Noordenveld is the only municipality that gives cyclists priority on roundabouts. The municipality of Meppel is contemplating it at the moment, as a majority of the municipalities in the Netherlands give cyclists priority at roundabouts inside the built-up area (Klomp, 2024). The CROW Institute in the Netherlands is a pivotal organisation that operates as the national knowledge platform for infrastructure, public space, traffic, and transport. CROW develops and disseminates a wide range of guidelines, tools, and knowledge products that are considered best practices in the field. These resources cover various aspects, including road-design, traffic safety and bicycle infrastructure. However, their guidelines and designs are not legally binding. Adhering to their guidelines for infrastructure adds consistency in road-design. A consistent road environment reduces the cognitive workload on drivers. When drivers encounter familiar road characteristics, they expend less mental effort interpreting these features, which decreases driver fatigue and improves concentration (Patten et al., 2006) and aids in better decision-making, aligning with the findings of Theeuwes & Godthelp (1995), who suggested that consistent road-design enhanced the predictability of the road environment for drivers. When drivers encounter familiar and consistent cues, they are better able to anticipate upcoming road conditions and adjust their driving behaviour accordingly. This predictability reduces the likelihood of sudden manoeuvres that can lead to accidents. The same applies to consistent signage, which sometimes is inconsistent or missing in Drenthe. When drivers are presented with a road environment that consistently communicates the appropriate speed, through both explicit signage and implicit design cues, they are more likely to adhere to speed limits, reducing the incidence of speeding-

related accidents (Montella, 2010). Consistent road-design also benefits vulnerable road users, such as pedestrians and cyclists, by creating predictable spaces for these users to interact with vehicular traffic. For example, consistent use of crosswalks and cycling paths across a road network signals drivers to expect and respect the presence of these users, enhancing safety for all (Rosén & Sander, 2009). Giving cyclists priority on all roundabouts inside the built-up areas in Drenthe would make the road-design more consistent, and thus safer.

The design of a relatively large number of 80 km/h distributor roads, managed by the province, appears to be inadequate in various aspects and deviates considerably from the CROW requirements. Deviating examples are the separation of driving directions, parallel facilities for agricultural and local traffic (service roads), obstacle-free shoulder marking, demarcation, and obstacles. These deviations in the CROW requirements are probably the reason for the low scores of safety on provincial roads in Drenthe (SWOV, 2013). In 2019, the CROW released new guidelines for the verges of non-motorways as well. It would be beneficial for the province of Drenthe to adhere to these guidelines for consistency because, at the moment, a lot of verges are not compliant with the CROW guidelines for verges of non-motorways.

2.3 Traffic Volume & Differences Rural & Urban Areas

In urban settings, the incidence of traffic accidents typically surpasses that observed in rural areas, as shown in Figure 10. Urban environments are characterised by a higher prevalence of intersections, lower speed limits, increased conflict zones, and a greater presence of pedestrians and cyclists compared to rural regions. The correlation between traffic volume and crash incidence is well-documented. Increased traffic volume is directly associated with a heightened risk of crashes and, typically, a greater number of accidents (Chang & Xiang, 2003; SWOV, 2010).

Retallack & Ostendorf (2020) revealed a non-linear increase in accident frequency at higher congestion levels, underscoring the significance of traffic management in mitigating accidents. Notably, no discernible rise in accident frequency was observed as congestion decreased, indicating that reducing congestion would not have adverse effects on public health. Retallack & Ostendorf (2020) also examined changes in accident severity across congestion levels but found no significant correlation, potentially due to the absence of severe and fatal accidents in the dataset.

Some research suggested a decrease in crash severity during congestion, particularly noting a rise in property damage-only crashes (Lord et al., 2005). However, Zhou and Sisiopiku (1997) observed that the number of crashes increased with an increase in traffic volume, but that also confirms that the crash severity decreased. Moreover, Harwood et al. (2013) suggested that higher traffic volume increases the chances of material damage rather than crash severity. This trend is attributed to reduced speeds in congested conditions and the known correlation between speed and crash severity (Elvik et al., 2019). For instance, median-divided roads, typically experiencing high volumes, tend to have fewer severe crashes on average compared to undivided roads with lower volumes. This aligns with Dickerson et al. (2000), who stated that with more traffic volume, the average traffic speed is lower, and thus the driving behaviour is safer. However, Wang (2010) did not find a link between crashes, crash severity and traffic volume.

As traffic volume increases, the likelihood of multi-vehicle crashes escalates as well, potentially at a greater rate than the rise in traffic volume itself (Elvik et al., 2009). Conversely, single-vehicle crashes predominantly occur in low-volume scenarios. Factors such as monotony and boredom, prevalent on roads with low traffic volumes, are commonly associated with single-vehicle crashes (Armstrong et al., 2008; Candappa et al., 2013). The reason for this could be that the surrounding landscape on roads significantly impacts driver behaviour, as evidenced by Yu, Chen, and Bao (2019), who, in their investigation primarily centred on two-lane rural roads, discovered that features of the roadside landscape, such as trees, plants, tunnels, and mountainous regions, are associated with reduced instances of speeding. Conversely, open fields presented less of a deterrent to speeding, while built-up areas exerted a particularly pronounced inhibitory effect on the occurrence of speeding.

Crashes at higher speeds generally result in more severe outcomes than those at lower speeds, yet high-speed roads, often characterised by high volumes, exhibit a higher safety level. Consequently, predicting the precise relationship between traffic volume and crash severity proves challenging due to the complex interplay of various contributing factors (Elvik et al., 2019). Ewan et al. (2015) suggested that roads with lower traffic volumes typically demonstrate narrower widths, sharper bends, and steeper inclines, factors that potentially contribute to increased incidence of road traffic accidents (Høye & Hesjevoll, 2020). For the case of Drenthe, when looking at Figure 10 and Figure 11, it can be seen that there are more traffic accidents in urban areas than in rural areas. However, when looking at the traffic fatality rate, the rural area yielded more traffic fatalities than the urban area. Therefore, it is suggested that traffic accidents on rural roads tend to be a lot more severe than traffic accidents in urban areas. To illustrate this, in 2021, 49% of all traffic fatalities in the Netherlands took place outside built-up areas, whereas 35% happened inside built-up areas (SWOV, 2024b). Moreover, Gonzalez et al. (2007) found that traffic fatalities for car drivers are significantly higher in rural areas than in urban areas. This discrepancy happens because higher rates of speeding occur on rural roads in comparison to urban areas. This notion is supported by Clark and Cushing (2004) who found that rural-urban disparities influence the relationship between traffic mortality rates and other contributing factors. Particularly in rural areas, an inverse relationship exists between population density and traffic mortality rates, a correlation that is absent in urban settings.

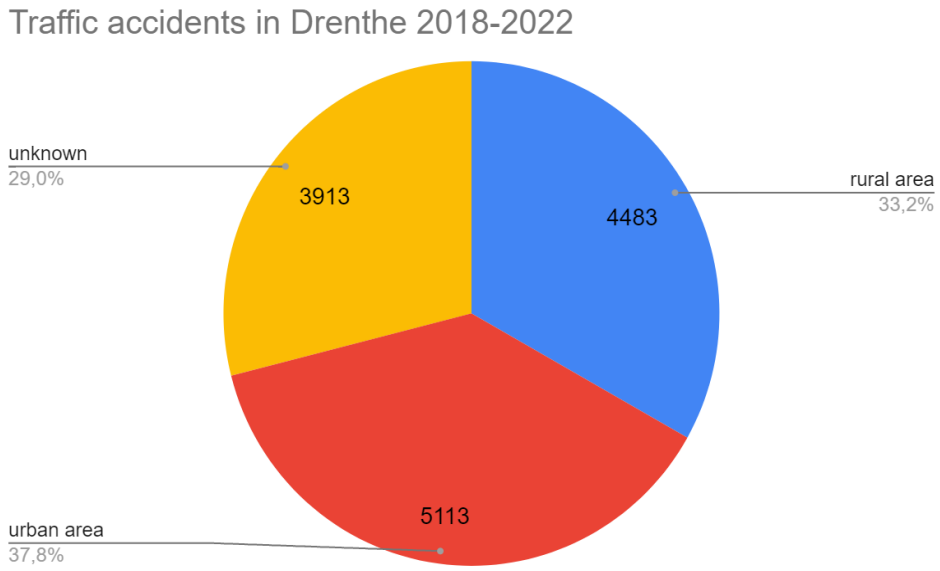

Figure 10: Traffic accidents in Drenthe divided into rural and urban areas (SWOV, 2023a)

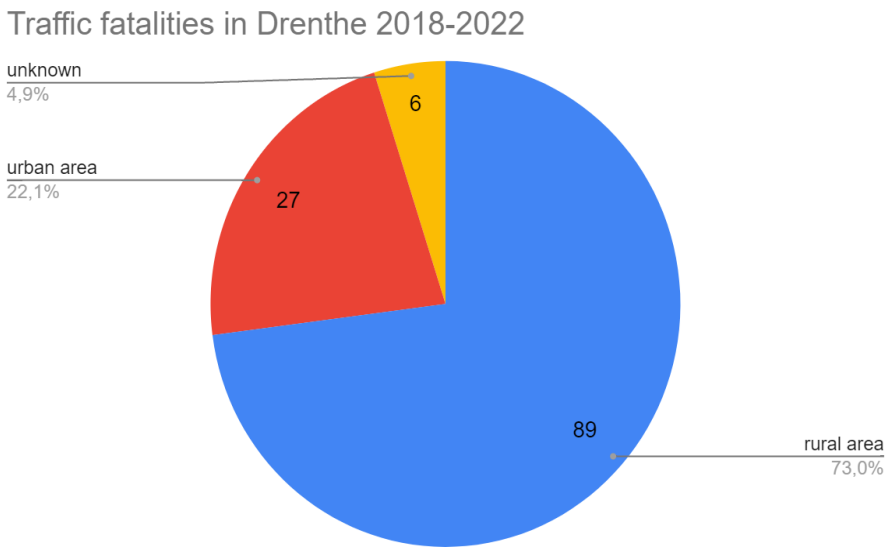

Figure 11: Traffic fatalities in Drenthe divided into rural and urban areas (SWOV, 2023a)

The relationship between traffic volume and crashes may exhibit variations across distinct types of road infrastructure. Notably, the distribution of single-vehicle and multiple-vehicle crashes differs among different road categories (Martensen and Dupont, 2013). Single-vehicle crashes tend to be more prevalent on low-volume rural roads, whereas multiple-vehicle crashes are more frequently observed on high-volume, multilane roads. Additionally, the same level of traffic volume can result in varying traffic densities on different road types, with traffic density demonstrating a correlation with the frequency of crashes (Lord et al., 2005).

2.4 Traffic Speed

Speeding is a critical factor influencing traffic safety, with numerous studies highlighting its significant impact on traffic fatalities and accidents. Studies consistently demonstrated a strong association between speeding and the severity of road traffic injuries and fatalities. Viallon and Laumon (2013) reported findings from the European Road Safety Observatory (ERSO), indicating that speeding contributed to approximately 30% of fatal collisions in Europe.

A comprehensive meta-analysis conducted by Nilsson (2004) reaffirmed the disproportionate contribution of speeding to road fatalities, particularly in rural contexts characterised by high-speed limits and expansive road networks. An increase in speed variability diminishes the available reaction time for road users to respond to the actions of others, including braking and executing overtaking manoeuvres with a greater differential in speed. Jaarsma et al. (2011) analysed changes in driving speed, traffic volume, and road safety measures before and after the implementation of 60 km/h speed zones in previously 80 km/h zones. Jaarsma et al. (2011) found that the implementation of 60 km/h speed zones led to a significant decrease in driving speed and traffic volume, and an increase in road safety measures, such as road markings and signage. Additionally, Jaarsma et al. (2011) found that the number of fatal and injury accidents decreased after the implementation of 60 km/h speed zones. The results suggested that the implementation of 60 km/h speed zones can be an effective measure for improving road safety on minor rural road networks.

The relationship between average traffic speed and road safety is strongly supported by empirical evidence, demonstrating a significant impact on both traffic fatality rates and the frequency of injury-related accidents (Elvik et al., 2019). The study also suggested that the association between speed and road safety does not exhibit diminished strength in research articles released post-2000 compared to earlier publications. Thus, speed continues to be a significant risk factor for both the incidence of traffic

accidents and the severity of injuries (Elvik et al., 2019). Additionally, Imprialou et al. (2016) identified that the probability of crashes escalates in direct proportion to speed until the speed reaches stability. Once that occurs, the crash likelihood subsequently diminishes. This trend may be attributed to a reduction in crash-prone reactions once a certain high-speed threshold has been surpassed.

2.4.1 Correlation Road-Design, Driver Characteristics and Speeding

Charly & Mathew (2023) found that driver characteristics and road geometry have a significant impact on driving performance metrics, indicating a positive correlation between speeding, jerk events, and crash occurrences. While speed variability alone does not directly correlate with crashes, it is noted that low-speed variation occurs at high speeds. Consequently, situations, where both speeding and speed variability are elevated, pose a safety risk and increase the likelihood of accidents. A jerk event means hard-braking events. The analysis of crash frequency models highlights the importance of speeding, jerk events, and mean gradients in predicting crashes on a road section. Therefore, Charly & Mathew (2023) underscored the role of driving performance indicators, specifically speeding and jerk events, in identifying hazardous driving behaviour. Sections of the road where drivers often need to brake hard result more frequently in crashes and, thus, can be considered unsafe (Charly & Mathew, 2023). Additionally, they suggested that the higher the speeding offence, the more crashes tend to happen. This aligns with the statement of SWOV (2021) implying that vehicles operating at velocities exceeding the average speed of road traffic are associated with an elevated risk of involvement in traffic accidents. An increase in speed limits was correlated with elevated travel speeds on roadways, which in turn, results in an augmentation of traffic fatality rates (Farmer, 2016).

2.5 Driver Workload

Drenthe is a rural province with few high schools in its cities or larger villages and no high schools in rural areas. This results in a lot of children aged 11-19 cycling to school daily during rush hour. The presence of cyclists resulted in a significant reduction in driving speed and an increase in workload, as drivers need to take into account the presence and movements of cyclists when making decisions at intersections (Duivenvoorden et al., 2014). To underline the danger of cyclists in traffic, Farah et al. (2015) found that drivers tend to overestimate the lateral distance between their vehicle and a cyclist during overtaking on rural roads, and they tend to have shorter lateral distances when overtaking faster cyclists. Additionally, Farah et al. (2015) suggested that drivers' overtaking strategies are affected by factors such as cyclist speed, oncoming traffic, and road characteristics. These findings can be used to inform the design of road infrastructure and the development of training programs to improve drivers' overtaking behaviour and reduce the risk of car-on-cyclist crashes in Drenthe.

2.5.1 Agricultural Vehicles

Drenthe is a rural province with a lot of agriculture. On minor roads, AVs may conflict with vulnerable road users such as pedestrians and cyclists, whereas on rural roads differences in speed between AVs, cars and trucks are the main safety problem (Jaarsma & de Vries, 2012). Distance travelled with AVs on public roads to access the farmland is getting longer through an ongoing enlargement of scale in agriculture (Gkritza et al., 2010). The once-quiet rural roads are getting busier every day through urban, technological and economic developments in the rural area (Costello et al., 2009). The confluence of extended travel distances associated with AVs and heightened non-agricultural traffic significantly amplifies the potential for collisions between AVs and conventional road users. This unsafe traffic milieu poses a substantial threat to the allure of rural areas as multifaceted spaces catering to recreational pursuits and agrotourism. Among the various modes of transportation, soft green modes such as walking and cycling are particularly susceptible to these hazards (Jaarsma & de Vries (2012). Consequently, the absence of vehicle safety design requirements mandated for traditional motor vehicles has left AVs lacking in safety measures on public roads (DSB, 2010). Additionally, challenges arise with the lighting standards of AVs, as they pose difficulties for other drivers in identifying them as such, particularly in low-light conditions (Gkritza et al., 2010). Jaarsma and De Vries (2013) noted that AVs, including tractors and harvesters, are involved in a significant number of accidents on rural roads. The reasons for this include the size and speed of the vehicles, the lack of separate cycling lanes, and the low visibility of the vehicles (Jaarsma & de Vries, 2013). They also proposed several solutions to improve

traffic safety, such as improved signage and markings, segregated cycling lanes, and the development of new vehicle technology (Jaarsma & de Vries, 2013). Jaarsma & de Vries (2012) also shared a more holistic solution regarding traffic safety and AVs. They proposed the farmers arrange a land consolidation plan to concentrate the farm plots in a way that each farmer has to travel the least possible distance to his plot. Another solution is to detour or prohibit AVs on larger roads, decreasing the need for drivers to engage in possibly dangerous overtake actions. (SWOV, 2013).

2.5.2 Collisions and Accident Severity

The majority of collisions occurred between motor vehicles. Users of lighter modes of transportation face a higher risk of severe injuries in such incidents. For instance, in collisions involving cars and lorries, individuals using lighter transport modes have a greater amount of energy to dissipate and are less shielded by their vehicle compared to occupants of heavier vehicles (Huang, Siddiqui, & Abdel-Aty, 2011; Tolouei, Maher, & Titheridge, 2013). The protective measures afforded by the structure of lighter vehicles are substantially inferior, thereby exacerbating the potential for serious injury (Schoon & Bos, 2002).

The total number of fatal injuries in the Netherlands has risen from 582 to 754 in 2022 compared to 2021, an increase of nearly 30% (CBS, 2023). The mode of transport with the heaviest increases in fatal injuries is the car, at 26% and the bicycle, with an increase of 40% as shown in Figure 12.

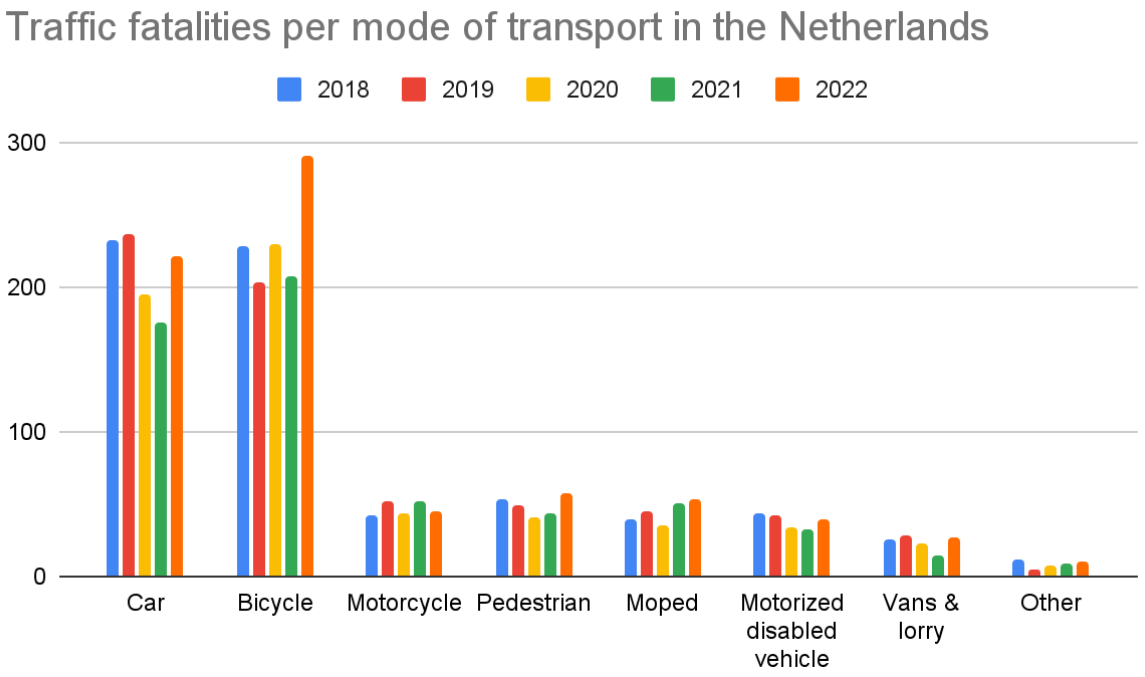

Figure 12: Fatal injuries per mode of transport in the Netherlands (SWOV, 2024a)

2.6 Day and Night Differences

Charly & Matthew (2023) found that during the nighttime, the number of hard-braking events is higher than during the daytime for all road categories. However, during the daytime, speeding happens more often than during the night. During nighttime, speed variability is greater than during daytime for road categories with a flat gradient or up-gradient. Drivers often face significantly reduced visibility at night, affecting their ability to detect pedestrians, obstacles, and other vehicles. The human eye relies on light to see, and in low-light conditions, depth perception, colour recognition, and peripheral vision are compromised (Sullivan & Flannagan, 2002). This reduction in visibility is a critical factor that contributes to the increased risk of accidents during nighttime. Furthermore, nighttime driving is also associated with a higher likelihood of encountering drivers under the influence of alcohol or drugs.

Studies have shown that the rate of alcohol impairment among drivers involved in fatal crashes is higher at night. According to the National Highway Traffic Safety Administration (NHTSA, 2022), the rate of alcohol impairment among drivers involved in fatal crashes was 3.1 times higher at night than during the day.

The human body operates on a circadian rhythm, an internal clock that regulates sleepiness and wakefulness over 24 hours. This rhythm naturally dips and rises at various times of the day, with peak sleepiness occurring between midnight and 6 a.m., coinciding with the body's natural inclination to sleep (Connor, 2001). Driving during these hours, therefore, conflicts with the body's biological clock, significantly increasing the risk of fatigue-related incidents. Finally, Philip et al. (2005) found that sleepiness could lead to a nearly twofold reduction in driving ability, akin to the impairment observed with alcohol consumption.

2.7 Identifying the Hotspots

To look for potential hotspots of fatal injuries in the province of Drenthe and potential trends, SWOV aggregated data for periods of 5 years was used. The traffic fatalities per inhabitant per municipality are visualised in Figures 13 and 14. As shown in Figure 13, the most traffic fatalities per inhabitant in the period of 2014-2018 occurred in the municipalities of Borger-Odoorn and de Wolden.

Figure 13: Traffic fatalities per 10,000 inhabitants in Drenthe per municipality from 2014-2018 (SWOV 2023)

For the period 2018-2022, the municipalities of Midden-Drenthe and AA en Hunze were the provinces that had the most traffic fatalities per inhabitant, as showcased in Figure 14. More worryingly, the municipality of Midden-Drenthe saw a surge of 88.89% in traffic fatalities in 5 years. It can be seen that the municipality of Borger-Odoorn had a reduction of nearly 30% in traffic fatalities. The number of traffic fatalities more than doubled in the municipality of Noordenveld, and the municipality of AA en Hunze nearly doubled in the given period of 5 years.

Figure 14: Traffic fatalities per 10,000 inhabitants in Drenthe per municipality from 2018-2022 (SWOV, 2023)

De Waard et al. (1995) suggested that driving in an urban environment leads to higher physiological arousal and a greater appreciation of the road than driving in a rural environment. Therefore, it seems logical that the municipalities scoring the lowest traffic fatalities per inhabitant are located in Assen, Meppel, Hoogeveen and Emmen because they are the 4 most urban municipalities of Drenthe. As shown in Figure 15, the municipality of Midden-Drenthe stood out as the municipality with the most traffic accidents per inhabitant out of all Drenthe's municipalities between 2018 and 2022.

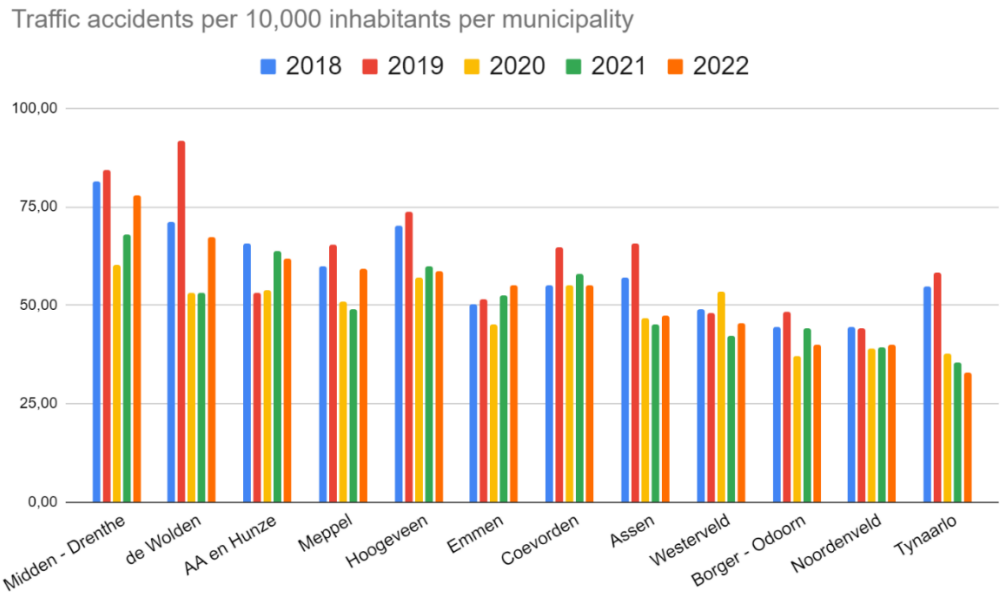

Figure 15: Traffic accidents per 10,000 inhabitants per municipality in the period 2018-2022 (SWOV, 2023a; Allecijfers, 2023)

The percentages of traffic accidents being fatal traffic accidents can be observed in Figure 16, with the

municipalities of Midden-Drenthe, AA en Hunze, Borger-Odoorn, Westerveld and Noordenveld yielding the most traffic fatalities per traffic accident, again signalling the discrepancy between rural and urban municipalities.

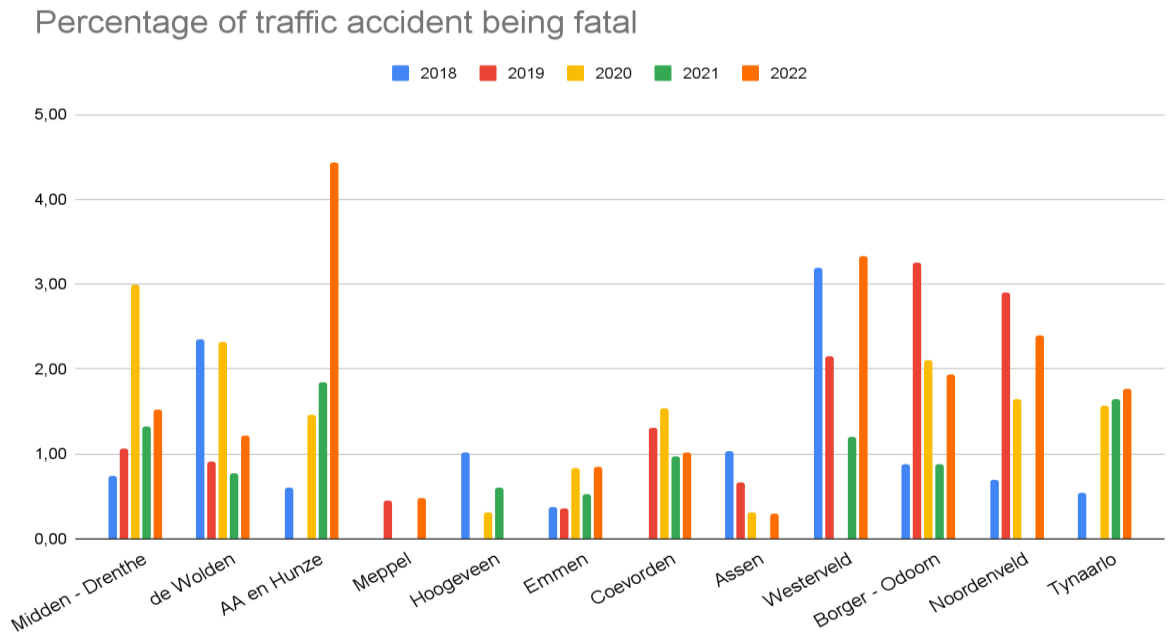

Figure 16: Percentage of traffic accidents turning out to be fatal in the period 2018-2022 (SWOV, 2023a, Allecijfers, 2023)

2.8 Traffic Fatalities Drenthe in Comparison to Adjacent Provinces

Drenthe is the third least populous province of the Netherlands out of twelve. When comparing the number of traffic fatalities in the province of Drenthe with the provinces of Groningen and Flevoland, which are the 9th and 11th most populous provinces in the Netherlands respectively, it can be seen that Drenthe had a significantly higher amount of fatal injuries compared to these provinces, as shown in Figure 17. Moreover, when comparing Drenthe's fatal traffic accidents to Friesland, the 8th most populous province of the Netherlands, with around 150.000 more inhabitants than Drenthe, it can be seen that Drenthe amassed 377 fatal injuries from 2010 till 2022, 3 more than Friesland as shown in Figure 5. When looking at the annual traffic fatalities from 2010 onwards, as shown in Figure 17, Drenthe frequently boasted or equalled the highest amount among the comparable provinces. Finally, when looking at Figure 18, it can be seen that Drenthe consistently scored the highest traffic fatalities per inhabitant in comparison with adjacent and comparable provinces in the Netherlands. In Figure 18, the final adjacent province of Overijssel is also taken into account.

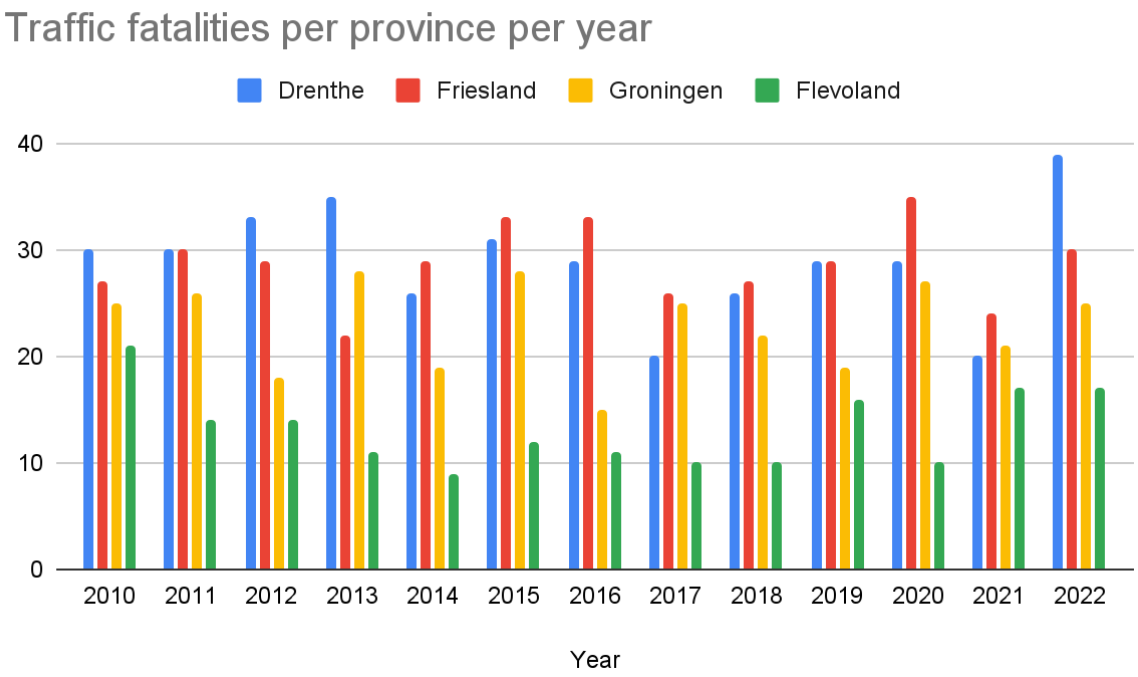

Figure 17: Fatal injuries in traffic per province per year (SWOV, 2023c)

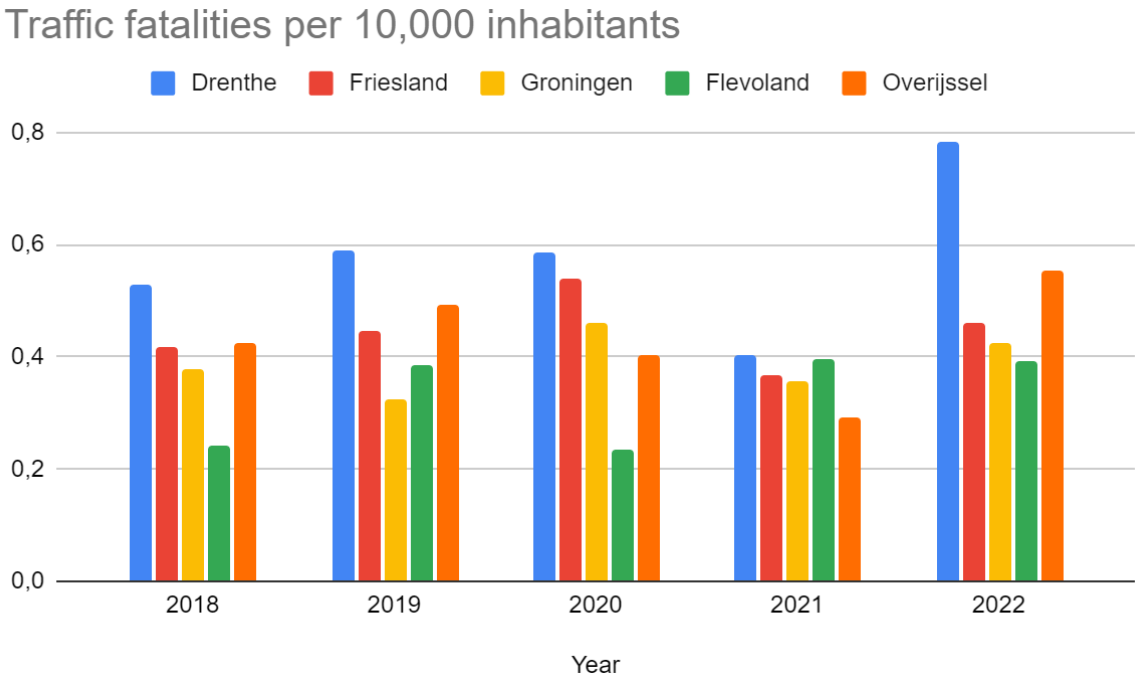

Figure 18: Total traffic fatalities per 10,000 inhabitants per province per year (SWOV, 2023c)

2.9 Distance Travelled & Distance to Facilities

Hakkert et al. (2002) suggested that more vehicle kilometres travelled is associated with an escalation in the frequency of crashes. It can be seen in Figure 19 that in Drenthe, the average distance to facilities is relatively high. Facilities taken into account were hospitals, supermarkets, primary schools, libraries, kindergartens, middle schools, General Practitioners and pharmacies.

The accessibility of facilities such as schools, General Practitioners, and public transport has a direct impact on travel patterns, road usage, traffic volume, and, consequently, traffic safety. Longer distances to the aforementioned facilities can result in increased vehicle usage, longer travel times, and a higher likelihood of engaging in risky driving behaviours. Furthermore, areas with limited access to facilities may see a higher concentration of traffic as residents converge on fewer locations for essential services, thereby elevating the risk of accidents. The municipalities of Borger-Odoorn, Midden-Drenthe and Westerveld had the furthest distance to facilities as shown in Figure 19. When looking at the average distance to the nearest train station, the municipality of Borger-Odoorn again scores the worst as is depicted in Figure 20. The more urban municipalities Assen, Hoogeveen, Meppel and Emmen, are the top performers regarding distance to facilities and distance to the nearest train station. In terms of traffic fatality rate per inhabitant, these municipalities also score as the top 4 least fatal municipalities per inhabitant, as shown in Figure 14, again demonstrating the difference between urban and rural areas. This can be attributed to a lower average speed in urban areas, more pedestrians, and more cyclists travelling to facilities that are closer nearby on average, which in turn means less traffic volume.

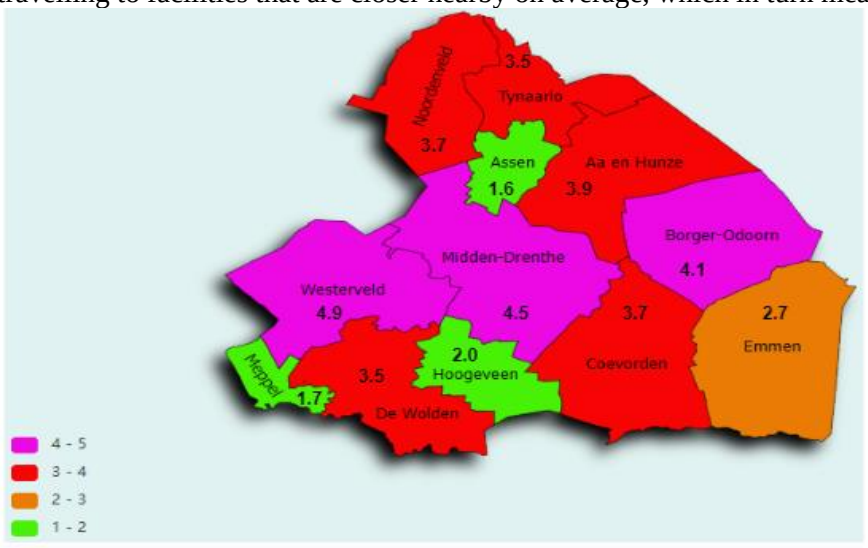

Figure 19: Average distance in kilometres to facilities per municipality in 2022 (CROW Databank, 2024a)

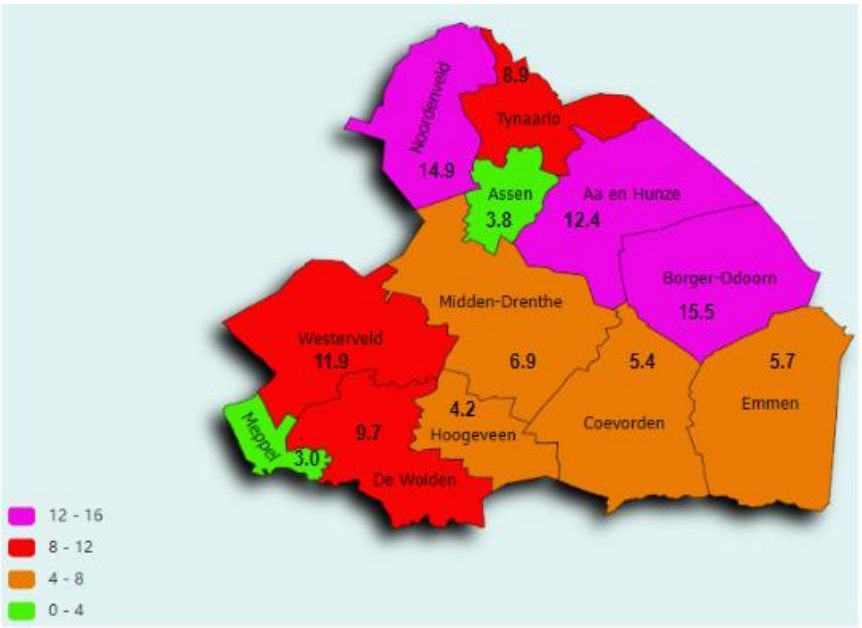

Figure 20: Average distance in kilometres to train stations per municipality in 2022 (CROW Databank, 2024b)

When looking at traffic fatalities per billion travelled kilometres on provincial roads, the municipalities of Borger-Odoorn and Westerveld scored the worst, as shown in Figure 21. Thus, it can be stated that the N-roads in these municipalities yield the highest fatality rate in the period of 2018-2022.

Figure 21: Traffic fatalities per 1 billion travelled kilometres in the period 2018-2022 on provincial roads (CROW Databank, 2024c)

However, when looking at the traffic fatalities per municipality in Drenthe, with the exclusion of national roads (highways), it can be seen that again the municipality of Midden-Drenthe scored worst, as shown in Figure 22.

Figure 22: Traffic fatalities per 1 billion travelled kilometres in the period 2018-2022 excluding national roads (CROW Databank, 2024d)

Finally, this study looked at the number of cars per inhabitant in Drenthe. As shown in Figure 23, the municipality of Tynaarlo boasted 7,060 cars per 10,000 inhabitants. Thus, the assumption that the municipalities that have the most traffic fatalities per driven kilometre (Borger-Odoorn) or have the farthest average distance to facilities (Westerveld) or train stations (Borger-Odoorn) contained the most cars per inhabitant, is not accurate.

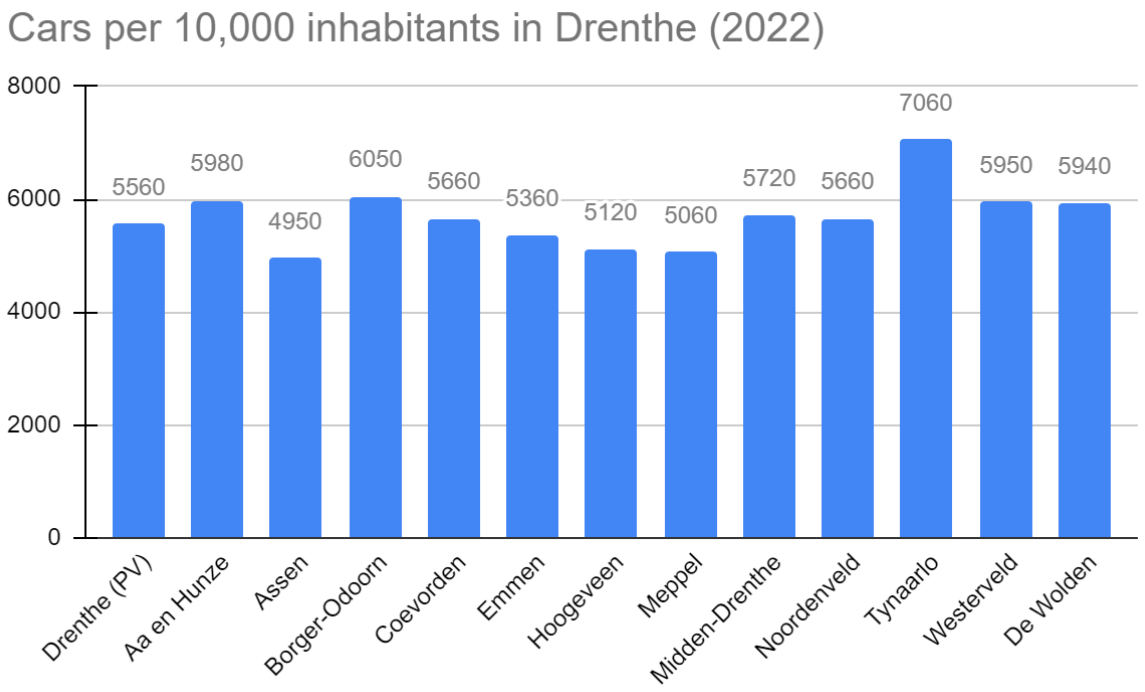

Figure 23: Cars per 10,000 inhabitants in 2022 (CBS, 2024)

2.10 Conceptual Model

The diagram in Figure 24 represents the conceptual model of this study on how to improve traffic safety in Drenthe. The diagram starts at the current state of traffic safety. Based on the literature, the 3 main causes of traffic accidents are listed below. These 3 factors also interact with each other, as different driving behaviour tends to lead to speeding, just as differing road-design, with some roads being more inviting to speeding than others. The factor of speeding also relates to road-design, as frequent speeding offences on a road causes a reaction from the road authority to possibly alter the road-design. Human factors, speeding and road-design lead to traffic accidents. To prevent traffic accidents from happening, (spatial) traffic planners want to mitigate the possibility of another traffic accident happening. The diagram is split up into 2 different mitigation strategies to reduce the cause and severity of traffic accidents. Mitigation strategies on human behaviour such as coaching systems in cars, rewarding good driver behaviour and the so-called ‘safety safe’ can aid human behaviour in traffic, and thus reduce traffic accidents in Drenthe. Mitigation strategies on road-design and speeding consist of installing median barriers on N-roads, having more consistent road-design, altering the speed limit of rural roads and segregating bicycle lanes from car traffic. When implemented correctly, this will also result in a reduction in traffic accidents in Drenthe. Together, these mitigation strategies lead to improved traffic safety in Drenthe.

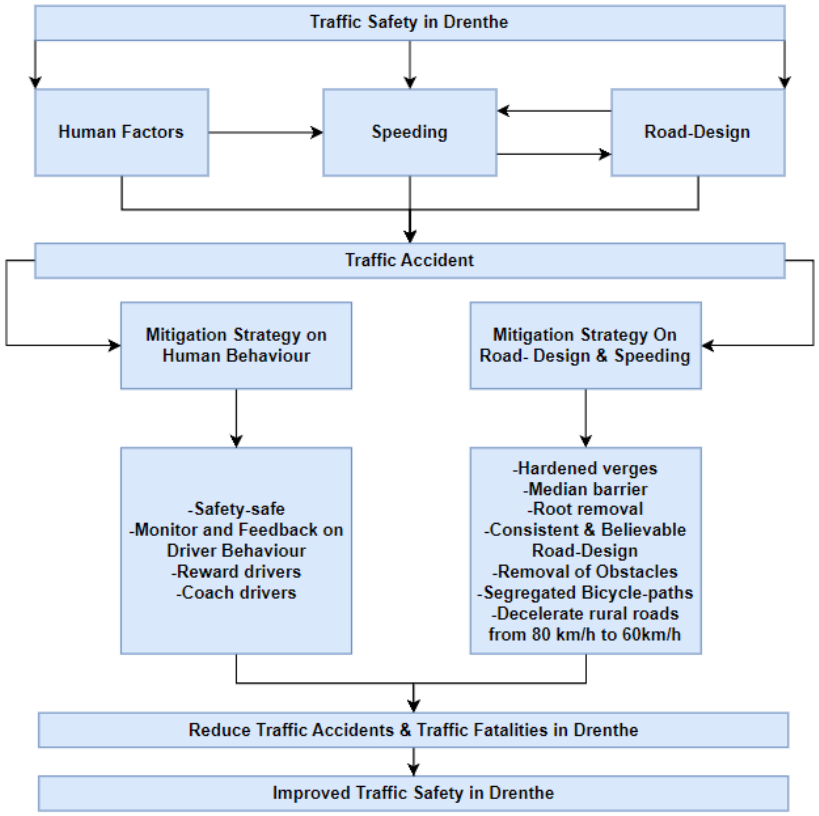

Figure 24: Conceptual Framework

2.11 Hypothesis

Harwood et al. (2013) suggested that higher traffic volume increases the chances of material damage rather than crash severity. This trend is attributed to reduced speeds in congested conditions and the known correlation between speed and crash severity (Elvik et al., 2019). For instance, median-divided roads, typically experiencing high volumes, tend to have fewer severe crashes on average compared to undivided roads with lower volumes. This aligned with Dickerson et al. (2000), who suggested that with more traffic volume, the average traffic speed is lower, and thus the driving behaviour is safer. For the case of Drenthe, when looking at Figure 10 and Figure 11, it can be seen that there are more traffic accidents in urban areas than in rural areas. However, when looking at the traffic fatality rate, the rural area yields more traffic fatality than the urban area. Therefore, it is suggested that traffic accidents on rural roads tend to be a lot more severe than traffic accidents in urban areas. To confirm these suspicions, the following null hypotheses are formulated:

H0: There is no association between the location and the severity of traffic accidents.

By confirming this suspicion, policy interventions can be tailor-made for rural areas in Drenthe.

Because there is a debate in the literature regarding traffic volume and traffic safety, this study checks if there is a correlation between kilometres driven and traffic fatality in Drenthe.

H0: There is no significant linear relationship between traffic fatalities per 1 billion kilometres driven and the average distance to facilities in kilometres in Drenthe.

By confirming this suspicion, it becomes insightful for policymakers to consider the placement of facilities.

3. Methodology

This Chapter explains the research methodologies and data acquisition strategies implemented within this thesis. It encompasses a detailed exposition of the research techniques employed, the selection criteria for interview participants, and the adherence to ethical standards throughout this study. Table 1 illustrates which research strategy was utilised per research question.

Table 1: Research strategies concerning research questions

Research Question	Research Strategy
Main RQ	**Literature Review, Interviews, Statistical Tests**
SQ1	**Literature Review, Interviews**
SQ2	**Literature Review, Interviews**
SQ3	**Literature Review, Interviews, Statistical Tests**

3.1 Research Method

This research used differing research methods to collect and analyse both primary and secondary data. This mixed methods approach utilised both qualitative data and quantitative data. This is a fitting approach for traffic safety research because topics such as traffic accidents are easily quantified in numbers. Moreover, expert interviews provided in-depth insights on traffic safety, which data cannot provide, as the experts can also contextualize, and know existing policies of Drenthe. The results derived from the analysis can be based on a variation of qualitative and quantitative evidence (Yin, 2003), also known as triangulation. Literature research was conducted first to develop a comprehensive overview of traffic safety. Additionally, semi-structured qualitative interviews were conducted with experts on the topic of traffic safety. The expert knew either the traffic situation in the municipality of AA en Hunze or Midden-Drenthe because as per Figure 14, these two municipalities have the worst traffic fatality rate per inhabitant. It is these experts who provided information regarding what goes wrong in their municipality. The output of this interview was qualitative data. This data is analysed using ATLAS.-ti, providing a coding of the most frequent answers. The code book is located in Appendix B. Moreover, existing data collected from the SWOV is used to provide insight into the location and types of crashes in Drenthe. This dataset can be found in Appendix C.

3.2 Unit of Analysis

The unit of analysis is defined by the spatial boundaries, timeframe and theoretical scope of the research project (Yin, 2014). The spatial boundary of this research is within the provincial borders of the province of Drenthe. The geographical proximity of the province to the researcher engenders a degree of personal familiarity with the region and facilitates, where necessary, direct on-site observation of specific locales. The time frame of this study is mainly from the year 2018 up until 2022. In these 5 years, trends can be identified and analysed. Data for 2023 is not available yet at the time of writing this thesis, which was in the period January until June 2024. Sometimes, the data reaches back to 2010 to grasp a broader perspective. Regarding the theoretical scope, this thesis analyses which combinations of road-design and traffic calming measures get the best out of specific driver behaviour, to reduce traffic fatalities in Drenthe.

3.3 Quantitative Data

The use of quantitative data in this research offers several distinct advantages, paramount among which is the ability to facilitate objective analysis and derive statistically significant conclusions. Quantitative

data, by its very nature, allows for the measurement and analysis of variables in a manner that is not only precise but also quantifiable, enabling the establishment of patterns, relationships, and causations within the data (Creswell & Creswell, 2009). This form of data is instrumental in the validation of research hypotheses through empirical evidence, thereby enhancing the reliability and validity of the research findings (Bryman, 2015). Furthermore, quantitative data supports the generalisation of findings to a larger population, given that the data collection and analysis methods are standardised, allowing for replication and verification of the research by other scholars (Trochim & Donnelly, 2015). The statistical analysis facilitated by quantitative data also permits the application of mathematical models to predict outcomes, offering a robust framework for decision-making and policy formulation (Black, 1999). Thus, the strategic employment of quantitative data significantly enriches the scientific rigour and credibility of research endeavours. All data used in this thesis is based on accidents on public roads, provided by SWOV and CBS.

3.3.1 SWOV Data

The National Scientific Institute on Traffic Data (SWOV) provided secondary quantitative data regarding fatal traffic accidents per municipality in Drenthe from the year 2018 onwards. This study analysed this secondary quantitative data to identify trends or significant patterns. This study aimed to seek explanatory value based on the selected variables derived from the literature review to understand the causes of traffic accidents and traffic fatalities. Once insight into the causation of the accidents occurs, fitting policies can be created and implemented to reduce traffic accidents in Drenthe. With the aid of this data, an analysis of the distribution and frequency of traffic accidents and injuries in Drenthe, including identifying crash types and locations is conducted. The SWOV (2023a) collected this data by combining insurance companies' data, police reports and data from hospitals on traffic-related injuries and fatalities. It should however be noted that, since not all accidents are reported, the real number of accidents is likely higher. The variables are listed and explained concisely below:

Year: The year in which the traffic accident took place
Accident severity: divided into fatal, injured and material damage.
Municipality: Divided into all Drentse municipalities.
Town: Determines which city or town where the accident took place.
1st mode of transport: This means the first mode of transport involved in the traffic accident. For example, a motorcycle, car or bicycle.
2nd mode of transport: The second mode of transport involved in the accident. For example, an agricultural vehicle, train or pedestrian. Trees and animals are also included in this variable.
Inside/outside built-up area: Divides the location of the accident in rural and urban sections. It has to be noted that the variable 'urban' means within the borders of a village or city. The variable 'Rural' means outside the borders of a village or city.
Light condition: Divided into darkness, daylight and twilight.
Location (road section): Divided into an intersection and road section.
Road condition: States if the road was wet/damp or dry during the accident.
Road Type: Determines whether the crash was on an N-road, Motorway or no-state road.
Situation (road): Determines if the accidents happened on a bend, intersection (3 or 4 arms), roundabout, or straight road (with or without a separated carriageway).
Speed limit (road): Determines what the actual speed limit at the crash site is.
Street: Determines which street the accident took place.
Type of crash: Determines if the crash was lateral, single vehicle, frontal, or on a fixed object.

3.3.2 Recoding of Data

The variable 'road condition' provides inaccurate data, as not all accidents that happened on an N-road are labelled as 'state N-road. For fatal accidents, this thesis manually checked whether the 'street' variable indicated if the accident happened on an N-road. Of all the 122 fatal traffic accidents in Drenthe between 2018 and 2022, 37 happened on N-roads, meaning a total of 30.3%. According to the variable 'road condition', a mere 2 fatal accidents happened on an N-road. Thus, in the variable 'road type', 35 cases were recoded to 'state N-road', making the total number of fatal crashes on N-roads 37.

3.3.3 Pearson Correlation

Hakkert et al. (2002) stated that more vehicle kilometres travelled is associated with an escalation in the frequency of crashes. To investigate the potential relationship between traffic fatalities per 1 billion kilometres driven (Figure 22) and the average distance to facilities in kilometres (Figure 19) in Drenthe, the Pearson correlation coefficient was used. The Pearson correlation coefficient, denoted as 'r, measures the strength and direction of the linear relationship between two continuous variables. The Pearson correlation coefficient r ranges from -1 to 1, where a value close to 1 indicates a strong positive linear relationship. However, a value close to -1 shows a strong negative linear relationship and a value close to 0 shows no linear relationship.

Referring back to the previously mentioned hypothesis, the following null hypothesis can be formulated:

H0: There is no significant linear relationship between traffic fatalities per 1 billion kilometres driven and the average distance to facilities in kilometres in Drenthe.

The significance level is set at 0.05 for hypothesis testing. If the p-value obtained from the correlation analysis is less than 0.05, the null hypothesis is rejected.

3.3.4 Chi-square Test of Independence

A chi-square test of independence is used to test whether there is a significant association between the location (inside/outside built-up area) and the severity of accidents (fatal, material damage only, injured), as the data pointed out that there is a discrepancy in traffic fatalities between the urban and rural areas.

Referring back to the previously mentioned hypothesis, the following null hypothesis can be formulated:

H0: There is no association between the location and the severity of traffic accidents.

The significance level is set at 0.05 for hypothesis testing. If the p-value obtained from the correlation analysis is less than 0.05, the null hypothesis is rejected.

3.4 Qualitative Data

The employment of qualitative data in this research offers profound insights into the complex dimensions of human behaviour and social phenomena, which quantitative methods may not fully capture. One of the primary advantages of qualitative data is its ability to provide depth and detail through direct quotations and narratives that bring to light the participants' perspectives, experiences, and emotions (Luckman, 2016). This depth enables researchers to understand the context and the subjective realities of the study subjects, thereby facilitating a richer and more nuanced interpretation of the data (Denzin et al., 2024). Qualitative methods are particularly adept at exploring new areas of research where established theories and hypotheses may not exist. Through the application of qualitative research methodologies, this study seeks to determine potential connections and strategies that could efficiently bridge the current research gap and address prevailing challenges in traffic safety in Drenthe to achieve safer traffic conditions.

3.4.1 Semi-structured Interviews

Two expert semi-structured interviews were conducted with experts on mobility and traffic of the municipality of Midden-Drenthe and AA en Hunze. These municipalities were chosen because they had the most traffic fatalities in 2018-2022 per inhabitant of all the Drentse municipalities. In terms of traffic fatalities per driven kilometre, Midden-Drenthe also has the worst (most) fatality rate per inhabitant, as shown in Figure 22. Additionally, these municipalities also score badly in terms of proximity to facilities. The interview with the traffic expert of the municipality of AA en Hunze was conducted on

the 8th of May 2024. The interview with the traffic expert of the municipality of Midden-Drenthe was conducted on 22 May 2024. The interview guide is located in Appendix A. The coding of the interviewee's responses can be found in Appendix B. The transcribed interviews can be found in Appendix E.

3.5 Ethical Considerations

The qualitative nature and contextual framework of this study necessitate adherence to the principles delineated by the Netherlands Code of Conduct for Research Integrity (NWO, 2018). These principles encompass transparency, informed consent, confidentiality, appropriate data handling and storage, as well as the consideration of potential risks and benefits associated with the research. Ethical considerations predominantly emerge during the data collection phase, particularly due to the utilisation of semi-structured interviews involving various experts. With participants' consent, the interviews are recorded using a recording application on the researcher's telephone and subsequently translated into English and transcribed. The transcribed interviews can be found in Appendix E. The consent form of the interviewee of the municipality of AA en Hunze can be found in Appendix G. The interviewees of the municipality of Midden-Drenthe gave verbal permission, so their consent form is absent.

Transparency constitutes a fundamental aspect of this research endeavour and has been meticulously upheld throughout all phases to ensure the integrity of the findings. Before conducting interviews and making observations during site visits, participants were provided with comprehensive explanations regarding the research objectives, methodologies, and potential advantages. Participation in this study affords individuals the opportunity to articulate their viewpoints, share insights, and contribute to the comprehension of the research topic.

Additionally, obtaining consent was a prerequisite before each interview, with participants duly informed of their right to refrain from answering questions or withdraw from the study at any juncture. Furthermore, stringent measures have been implemented to safeguard confidentiality and anonymity, thereby respecting the privacy of participants. Pseudonyms have been assigned to all participants during data analysis, and all collected data are securely handled. The data collected is securely stored on a computer protected by a password and is solely used for this research. Data will be retained until the conclusion of the study and permanently deleted thereafter.

As a researcher, the student occupies a pivotal role in advancing knowledge within the field of traffic safety. The primary responsibility is to design and conduct rigorous research that addresses key questions and gaps identified through a thorough literature review. This involves formulating research aims and hypotheses, selecting appropriate methodologies, collecting and analysing data, and drawing evidence-based conclusions. The student's work contributes to both academic understanding and practical applications, such as informing policy and improving traffic safety measures. Their position requires critical thinking, methodological precision, and a commitment to ethical research practices.

The expert interview outed qualitative data, which yielded detailed and descriptive information without numerical quantification. Such data are open to interpretation by the researcher and inherently possess a subjective nature. It is crucial to acknowledge that researchers are not entirely impartial, as their interpretations may be influenced by prior experiences, academic background, and personal biases. In this instance, the researcher has strived to maintain objectivity and independence from any affiliations or personal interests, concentrating solely on the study's objectives. Moreover, interviewees may introduce bias based on their interests and perspectives. No funds were received to create this research.

Finally, the study is constrained by a specific timeframe and word limit, potentially resulting in the exclusion of certain details. Despite these limitations, efforts were undertaken to enhance objectivity by immersing oneself in the study's environmental and theoretical context, while minimising preconceived notions as much as possible (Yin, 2014).

4. Results

This Chapter aims to answer the main research question on how to improve traffic safety in Drenthe. A literature review was conducted, and data provided by SWOV (2023a) was analysed and interpreted. Finally, the collected data includes conducted interviews with traffic and mobility experts from the municipalities of Midden-Drenthe and AA en Hunze. This Chapter will determine the key factors in traffic safety in Drenthe (SQ1), and what policy and infrastructural changes could be made to improve traffic safety in Drenthe (SQ2). Finally, this Chapter provides insight into how road-design can reduce the frequency and severity of traffic accidents in Drenthe (SQ3).

4.1 Key Factors Contributing to Unsafe Traffic in Drenthe

During the interviews and literature review, as well as the data provided by SWOV (2023a), the following factors contributed to unsafe traffic in Drenthe:

4.1.1 Driver Behaviour

Both the interviewees agreed that impaired driving is a huge problem for traffic safety in Drenthe. This aligns with the data in Figures 8 and 9, showing that more and more people are caught drink-driving amidst the rising trend of traffic fatalities as a result of drink-driving. A local rural phenomenon is a 'drinking shack' where young adults go drinking nowadays instead of bars and pubs. As their location is not mapped out, the police find it difficult where to check for drink-driving, as demonstrated in the quote below.

'Back in the day, there were a lot of discos, the cops could stand outside. But nowadays, the younger people are in these drinking shacks, a club of around 10-15 people. Back in the day, big discos or village parties existed. Then the cops know where the chance of drink-driving is high.'
– Mobility expert Midden-Drenthe.

This added to the fact that in urban areas, more people got fined for drink-driving than in rural areas, presumably because the police concentrated on a denser area. However, it must be noted that this remains a logical presumption because of a lack of data. Furthermore, both experts underlined the increase of mobile phone usage in traffic for cyclists and drivers and its negative consequences on traffic safety due to distraction. Another behavioural aspect contributing to unsafe traffic is drug usage as a driver according to the experts. An explanation of why traffic fatality is higher in Midden-Drenthe than in adjacent municipalities can be attributed that Midden-Drenthe has a lot of trees near the roads, as per the following quote:

'With municipalities with fewer trees, the same happens, drink-driving and driving with drugs, but there, it often has a better ending because there are no trees adjacent to the road.'
– Traffic expert Midden-Drenthe.

4.1.2 Speeding

One of the main factors contributing to unsafe traffic is speeding, both experts agreed. Jaarsma et al. (2011) found that the implementation of 60 km/h speed zones in a former 80km/h led to a decrease in the number of fatal and injury accidents after the implementation of 60 km/h speed zones. However, not a lot of people tend to adhere to a deceleration of a road, as can be derived from the following quotes.

'The road between Assen and Rolde was even 100km/h after to 80km/h and nowadays it's 60km/h. But nearly nobody drives 60km/h there.'
- Traffic expert AA en Hunze.

'Not that people actually drive 60km/h then.'
- Traffic expert AA en Hunze.

4.1.3 Age

The experts agreed that age is a significant factor in traffic safety in Drenthe on both sides. On one side, young people are inexperienced in traffic and are more error-prone, aligning with Chen & Terken (2022) who stated that males drive more recklessly and angrily. Additionally, one expert argued that young males tend to overestimate their driving skills, attributing to one-sided traffic accidents in Drenthe, as can be seen in the quotes below:

'We also know that young males really tend to overestimate their driving skills. If you look at one-sided traffic accidents, the most are young males.'
- Traffic expert AA en Hunze.

'We know that young drivers are a higher risk in traffic, they are less experienced, have lesser quality cars, fewer gadgets in the car and fewer crumple zones. For younger people on the bicycle, the same goes; for starting cyclists, going from elementary to high school, the distance to school increases a lot. In the first months of the schoolyear, a peak of traffic accidents in this group can be seen.'
- Traffic expert AA en Hunze.

On the other side, the experts attributed the high amount of traffic fatalities in Drenthe to elderly people as well. In Figure 6, the overrepresentation of elderly people injured fatally in traffic is confirmed. A reason for this overrepresentation could be because of the lower reaction times for braking (Economou et al., 2021), which was also mentioned in the quote below.

'You can say that these elderly people have a lot of experience in traffic. However, their reaction time decreases. They take longer to take decisions and perhaps have worse vision. Their movements are also stiffer and cannot even turn their heads on the bicycle sometimes. The mirror does not always help them out, and the distance is harder to estimate in a mirror. They are also more vulnerable, weaker bones, makes them more vulnerable than younger people. This is surely a cause for the higher number of traffic fatalities in Drenthe.'
- Traffic expert AA en Hunze.

This quote also aligned with Owsley (2016), who suggested that elderly drivers who experience reduced visual processing speeds are at a heightened risk of being involved in traffic accidents.

'The amount of elderly people in Drenthe is a lot higher than in the other provinces. Just as young people that have to bridge longer distances to facilities as well. Furthermore, like I said, the 18-year-old boys are also a weak group.'
- Traffic expert AA en Hunze.

Almost a quarter of the population in Drenthe is aged 65+, with another quarter being in the age cohort of 45-65, as can be seen in Figure 25, confirming that Drenthe has a high number of elderly residents in comparison to other provinces.

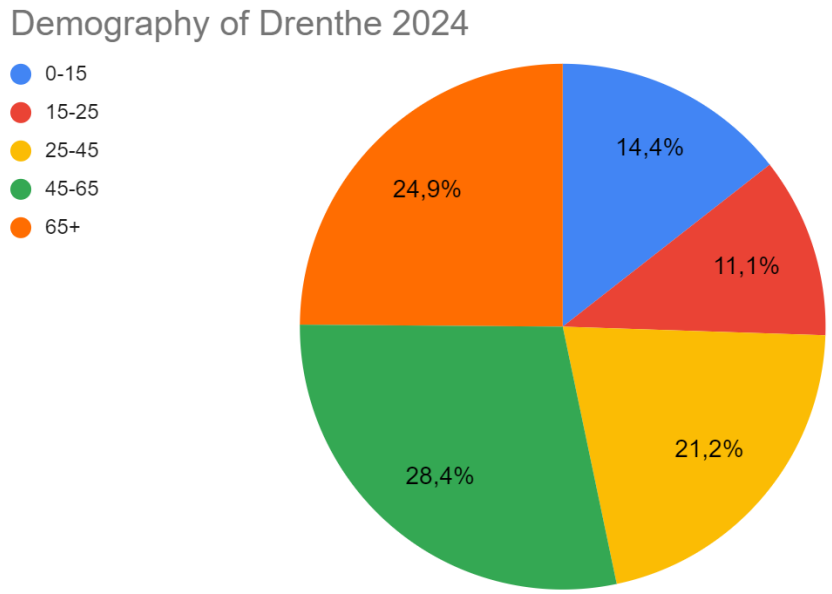

Figure 25: Demography of Drenthe at the start of 2024 (Allecijfers, 2023)

4.1.4 Cyclists

Another factor contributing to unsafe traffic situations in Drenthe regards cyclists. A large problem is that cyclists still have to cycle on the road segment of cars, where also large AVs drive. Moreover, an issue is that cyclists still have to cross large roads, with sometimes not even a safe-haven in the middle of the road.

'I think so yes, in Drenthe, of course, we have cyclists that have to cross 80km/h or 50km/h roads.'
- Traffic expert Midden-Drenthe.

Additionally, it was also found that the rise of e-bikes is a concern for traffic safety, as the average speed of e-bikes is around 25km/h, which makes a crash more severe than a crash on a normal bicycle, where the speed is slower.

'Another possibility for this is that elderly people cycle a lot more because of the e-bikes. On a normal bike, they cycle around 12km/h. But now, race at around 25km/h. If something happens with these elderly, like running off the road or crashing into something, the chance of a severe injury or fatality is a lot higher than back in the day, because they couldn't'
- Mobility expert Midden-Drenthe

4.1.5 Trees

In response to the question as to why the traffic fatality rate in the rural municipalities of Midden-Drenthe and AA en Hunze is so high, both interviewees indicated that they perceive trees, adjacent to rural roads in Drenthe, to be the main obstacle. This confirms data presented in Figure 26, showing that nearly a fifth of all traffic fatalities in Drenthe occurred because drivers crashed into a tree from 2018 to 2022. This amounts to nearly as many fatalities as in car-on-car crashes. Additionally, nearly half of all traffic fatalities in Drenthe are one-sided. The experts agree that the trees are a negative amplifying factor in traffic safety, as trees are not forgiving upon crashing into them.

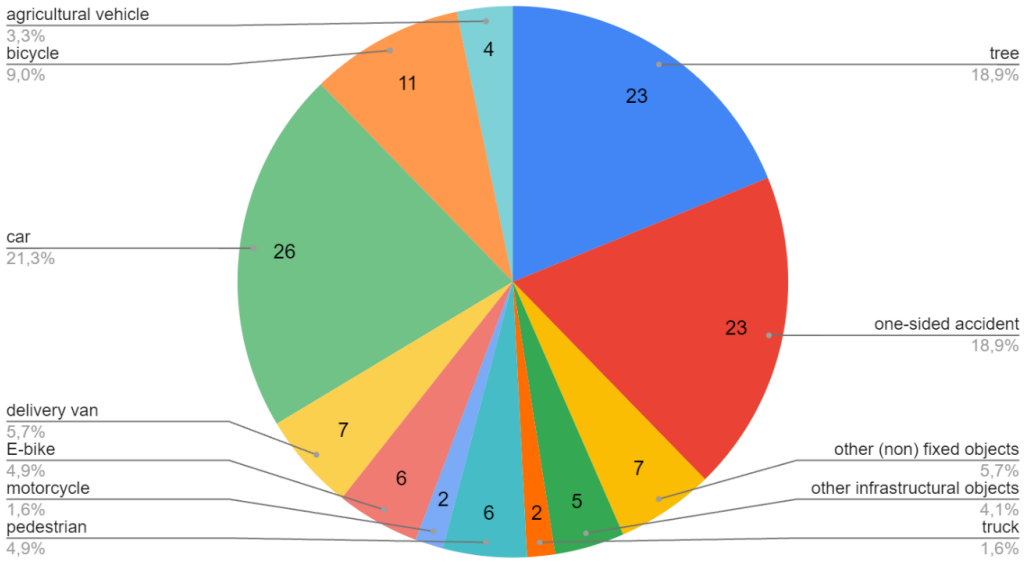

Figure 26: Cause of traffic fatality in Drenthe 2018-2022 (SWOV, 2023a)

4.1.6 Rural Roads

A commonality in the interviews, SWOV data and literature review was the notion that rural roads tend to be more fatal than urban roads. In Figure 14, it is shown that most urban municipalities score vastly fewer traffic fatalities per inhabitant than rural municipalities. In Figures 19 and 20, it can be observed that in the rural municipalities, facilities are further away than in the urban municipalities of Emmen, Meppel, Hoogeveen and Assen. These 4 urban municipalities also score the best (least) in terms of traffic fatalities per inhabitant, and traffic fatality per 1 billion kilometres driven, as shown in Figures 21 and 22. The experts linked the higher average speed in rural areas as a reason for this discrepancy.

'The more urban an area, the lesser the average speed is. If you look at a rural area, where a lot of 80/60km/h roads are, cyclists at connector roads, many crossings, then you get that (more fatality rate). So, more traffic speed, more severe injuries, not perse more accidents, but more severe.'
- Traffic expert AA en Hunze.

Moreover, the experts suggested that the road is better designed in urban areas for more vulnerable road users than in rural areas, as the quote below demonstrates.

'In urban areas, with cycle paths, it cycles safer than when you have to cross 60km/h roads in the rural areas on your own.'
- Traffic expert AA en Hunze.

'If you look at the west, or Groningen, you see more segregated cycling lanes, and more urban areas'
– **Traffic expert Midden-Drenthe.**

The experts concluded that there is a correlation between traffic fatality per inhabitant, distance to facilities and a discrepancy in terms of traffic safety in rural and urban areas.

'Well, if you overlay this map with your traffic fatality table, I think it overlaps. It can be seen that Assen, Hoogeveen, and Meppel, which were the safest in terms of traffic fatality per inhabitant have the lowest average distance to facilities. Emmen, which was un safer than these 3 municipalities before, is now also ranked better. It can be said that there is a correlation between average distance to facilities and traffic fatalities per inhabitant.'
- Traffic expert AA en Hunze.

This study aimed to determine if traffic is safer inside the urban area than in the rural area. Based on the literature, this study identified this by looking for a correlation between traffic fatalities in Drenthe per 1 billion kilometres driven, and the average distance to facilities in kilometres. Thus, this study conducted a Pearson correlation between these variables, visible in Table 2. The calculations can be found in Appendix H.

Table 2: Data for the Pearson correlation (CROW Databank, 2024a; 2024d)

Municipality	Traffic fatality per 1 billion kilometres driven	Average distance to facilities in km
Aa en Hunze	11.62	3.9
Assen	4.65	1.6
Borger-Odoorn	11.99	4.1
Coevorden	7.74	3.7
de Wolden	13.09	3.5
Emmen	5.64	2.7
Hoogeveen	7.55	2
Meppel	1.37	1.7
Midden-Drenthe	15.21	4.5
Noordenveld	11.05	3.7
Tynaarlo	6.94	3.5
Westerveld	12.82	4.9

Based on the Pearson correlation test, the null hypothesis stating that there is no significant linear relationship between traffic fatalities per 1 billion kilometres driven and the average distance to facilities in kilometres in Drenthe was rejected. The Pearson correlation coefficient (r) was calculated to be 0.851, indicating a strong positive correlation between the two variables. With a sample size (N) of 12, the test yielded a t-value of 5.144 and a corresponding p-value of 0.0004. Given that the p-value is significantly less than the commonly used alpha level of 0.05, there is strong evidence to reject the null hypothesis. The calculations can be found in Appendix G. This suggests that there is a statistically significant linear relationship between traffic fatalities per 1 billion kilometres driven and the average distance to facilities in kilometres in the region of Drenthe. Given the strength of the correlation and the extremely low p-value, it is statistically evident that the average distance to facilities is significantly related to the rate of traffic fatalities in Drenthe. Thus, the null hypothesis is rejected and the alternative hypothesis stating that there is a significant linear relationship between these two variables was accepted.

This finding was an indicator of a difference in traffic safety between urban and rural areas, as urban municipalities such as Assen, Emmen, Meppel and Hoogeveen have on average closer proximity to facilities. Additionally, as shown in Figure 10, more accidents happened in the urban areas, according to SWOV (2023a). However, when looking at traffic fatalities, it can be seen in Figure 11 that nearly three-quarters (73%) of the traffic fatalities in Drenthe happened in rural areas.

Based on the data, a chi-square test of independence was conducted to determine whether there is no association between the location and the severity of traffic accidents. The crash locations were

categorized into urban and rural areas, and the severity of traffic accidents was classified into three categories: fatal, injured, and material damage. The Chi-Square Test of Independence was used to evaluate the relationship between these two categorical variables. The observed frequencies for each combination of location and severity are displayed in Table 3. The calculations can be found in Appendix G

Table 3: Contingency table for the Chi-square test of Independence (data from SWOV, 2023a)

Accident severity Location	Fatality	Injured	Material Damage only	Total
Urban area	27	1183	3610	4820
Rural Area	89	974	3098	4161
Total	116	2157	6708	8981

The calculated chi-square statistic was 44.35. The p-value associated with this chi-square statistic is less than 0.05. Thus, the null hypothesis, stating that there is no association between the location and the severity of traffic accidents, is rejected. Thus, there is an association between the location and the severity of a traffic accident. This result is statistically significant, indicating that there is an association between the accident severity and crash location.
These findings suggested that urban areas have a lower number of fatal accidents compared to rural areas but a higher number of accidents involving injuries and material damage. This could be due to various factors such as differences in traffic density, speed limits, road conditions, and emergency response times. This aligned with the quote below.

'Thus, I think in urban areas, the space is a lot tighter, but the speeds are a lot lower. The chance that you hit each other is larger, but the chance of an injury should be much smaller.'
- Mobility expert Midden-Drenthe.

4.1.7 N-Roads

As shown in Figure 27, nearly a third of the traffic fatalities in Drenthe happened on N-roads (SWOV, 2023a). Both experts agreed that N-roads are the most dangerous roads in Drenthe, as stated in the quotes below.

'The N-roads, like the N381, are the most dangerous roads that exist because you drive 100km/h, without a median barrier.'
- Mobility expert Midden-Drenthe.

'In terms of traffic accidents and fatalities, the N-roads play a huge part for sure.'
- Traffic expert AA en Hunze.

Thus, this study confirmed the notion that N-roads are the un safest type of roads in Drenthe. Particularly the ones with a speed limit of 100km/h, without a median barrier. However, the experts argued for a different approach for different types of N-roads. Some N-roads have a speed limit of 100 km/h, while others have a speed limit of 80 km/h. Some N-roads allow agricultural vehicles on them, whereas they are prohibited on other N-roads. Some N-roads are double-laned, others are not. Therefore, the experts

were critical of the idea of having one-size-fits-all solutions for N-roads. Instead, they suggested a tailor-made approach for N-roads, due to their aforementioned differences, as the quote below illustrates.

'So, if measures are applicable on all these roads, I'm unsure. The N-roads where 100km/h is the speed limit, it might be a good idea.'
- Mobility expert Midden-Drenthe.

Both experts agreed that a median barrier on N-roads with a speed limit of 100km/h is a good idea. Moreover, the quote below underlined the issue a one-size-fits-all solution brings. Thus, the experts suggested sub-dividing the different N-roads and creating tailor-made solutions for each situation.

'In Smilde you have the N371. Between Beilen and Westerbork you have the N856. So, the N-road N381 is vastly different than the one between Beilen and Westerbork where agricultural vehicles are allowed. If you implement a prohibition at overtaking there or median barriers, you cannot overtake them.'
- Mobility expert Midden-Drenthe.

The data did not determine on which N-road the accident happened. Therefore, it is beyond the scope of this research to determine whether the accident happened on a single-lane or double-lane N-road, or what the speed limit was.

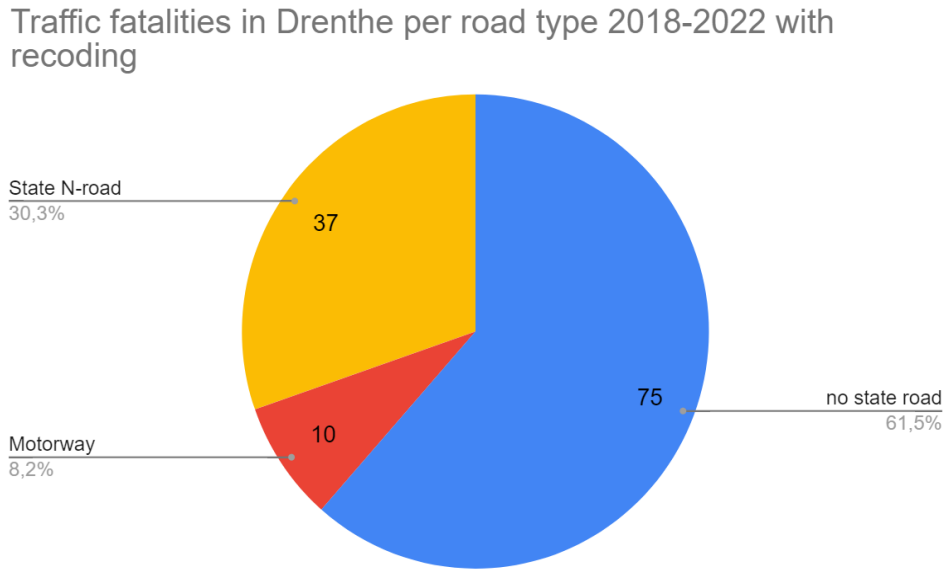

Figure 27: Traffic fatalities in Drenthe per road type in the period of 2018-2022, recoded variable 'road type' (SWOV, 2023a)

4.1.8 Alternative Factors

The experts brought forward some alternative factors contributing to traffic safety in Drenthe that are not mentioned in the literature. Among these alternative factors influencing traffic safety were budget constraints for road maintenance, a lack of workforce capacity, data constraints, politics going against traffic-expert advice, and not having a blank canvas to create the ideal desired traffic situation. This means that whenever an existing situation is decent, it is too costly to alter the situation, as can be read in the quote below.

'We are really looking at whenever maintenance is happening on the road, to lift along with the traffic measures, because it is costly to alter a road that is in decent shape to decelerate it from 60km/h to 80km/h.'

- Traffic expert Midden-Drenthe.

Moreover, the mobility expert of Midden-Drenthe stated that there are too many speed limits, enabling doubt for road users on the speed limit. The expert from the municipality of AA en Hunze did not mention this issue.

'There is a speed limit of 30km/h, 50km/h, 60km/h, 70km/h, 80km/h, 90km/h. 100km/h, 120km/h, and soon 130km/h. In my own stupidity, I tend to think, why haven't we thought of making it 30km/h, 60km/h, 90km/h, 120km/h? Steps of 30km/h, aligning with each other. So, whenever you leave the built-up area, you know that you may drive twice as fast from 30km/h to 60km/h. Like this, it becomes a lot more unambiguously. If you can drive 50km/h or 60km/h, it matters nothing at all, or does it? But that is my interpretation. Anyway, just create 4 base speeds instead of 30/50/60/70/80/90/100/120km/h. Those are 9 speed limits. If you count in neighbourhood speeds, walking pace at 15km/h, then we have 10 speed limits! Then nobody knows where he stands anymore.'
- Mobility expert Midden-Drenthe.

The expert suggested implementing 4 base speeds to keep it simple for the road user, as quoted above. The effect and feasibility of this suggestion are subject to future research as it is beyond the scope of this research.

The final alternative factor regarding traffic safety that became apparent during the interviews is the need for tailor-made solutions to safeguard the village unique identities of the Drentse villages.

'We also do not want uniform generic VINEX areas everywhere where everything looks the same. Because that's the charm of the Drentse villages.'
- Mobility expert Midden-Drenthe.

The experts underlined the need for tailor-made solutions for each village, balancing the need to keep the road-design safe, whilst not losing the village's own unique identity.

4.2 Proposed Solutions to Improve Traffic Safety

Both experts proposed some solutions to improve traffic safety in Drenthe. The main focus of improving traffic safety in Drenthe is the deceleration of rural roads, improving road-design, segregating cyclists from the road and creating tailor-made solutions. These options are discussed more comprehensively below:

4.2.1 Decelerating Rural Roads

When asked what the main solution to improve traffic safety in Drenthe is, the experts agreed that decelerating rural roads from a speed limit of 80 km/h to 60 km/h would see an improvement in traffic safety. Decelerating rural roads was the most given answer whenever asked what more can be done to improve traffic safety even more in Drenthe. An effect of deceleration is that road users have more time to make a good decision, instead of making a rushed dangerous decision. This aligned with the findings of Jaarsma et al. (2011) who suggested that the implementation of 60 km/h speed zones on former 80km/h roads resulted in a significant decrease in both driving speed and traffic volume, alongside an increase in road safety measures, such as road markings and signage. Furthermore, Jaarsma et al. (2011) observed a reduction in the number of fatal and injury accidents following the implementation of the 60 km/h speed zones.

'I think that one of the few things that work is to reduce the speed limit and enforce it as much as possible.'
- Traffic expert AA en Hunze.

'I think decelerating from 80km/h to 60km/h and consistency in road-design'.
- Mobility expert Midden-Drenthe

4.2.2 Consistency & Believable Road-Design

The mobility expert of Midden-Drenthe stated deceleration and consistency in road-design are the biggest points of improvement in Midden-Drenthe. However, he underlined that the identity of the villages must be kept whenever a change to the infrastructure happens. The traffic expert of the municipality of Midden-Drenthe added that whenever consistency in road-design is achieved, drivers can read the road situation better. If the situation is unclear, the risk of a traffic accident increases. The traffic expert of the municipality of AA en Hunze adds that driver behaviour can be steered through road-design, aligning with the notion of Patten et al. (2006) that consistency in road-design helps drivers anticipate road conditions better, reducing cognitive load and accident risk as well as the findings of Theeuwes & Godthelp (1995) stating that consistent road-design enhances the predictability of the road environment for drivers.

4.2.3 Segregate Cyclists and Creating Safe-Havens

The experts agreed that on rural roads where the speed limit is 60km/h or more, there is an absolute need to segregate cyclists from the road segment onto a dedicated cycling path. The only roads where cyclists on the road segment would be acceptable is at a 30km/h village road, conform the GOW30. However, an issue that arises when planning segregated bicycle paths in rural areas is land parcels belonging to farmers, unwilling to sell their land to the road authority. The dream of the municipality is there, as can be seen in the quote below. However, budget constraints are also a hindrance towards realisation.

'Our ultimate wish is a safe cycling path everywhere.'
– ***Mobility expert Midden-Drenthe.***

Moreover, the traffic expert of AA en Hunze argued in favour of a safe-haven for cyclists on rural roads, stating this is still a point of improvement in AA en Hunze. This way, cyclists make better decisions in traffic, because they face simpler decisions to make, as they only have to think about one road segment at once, again aligning with Patten et al. (2006). Another advantage is that the road segment becomes narrower if a cyclist safe-haven is built, as the road narrows, lowering the speed of cars. A safe-haven was also advised and slowly getting integrated more and more on rural roads for cars to wait on AVs approaching, for a safe passage.

'Furthermore, you also have bicycle crossings. Now, they have to cross the entire road at once. In rush hour, sometimes it's impossible to wiggle through. It would be nice to have a middle safe-haven, so they can cross in two times. On multiple roads, this can be implemented still.'
– **Traffic expert AA en Hunze.**

5. Discussion

This chapter aims to answer the research questions aided by synthesizing the findings from the literature review with the empirical results obtained through statistical analysis and expert interviews. By comparing and combining these insights, a better understanding of the key factors influencing traffic safety in Drenthe is gained and recommendations to improve traffic safety in Drenthe were made.

5.1 How do key factors in traffic safety contribute to and influence traffic safety in Drenthe?

5.1.1 Driver Behaviour

The literature consistently identified driver behaviour, particularly drink-driving and mobile phone usage as significant contributors to traffic accidents (Behnood & Mannering, 2017; Pawowski et al., 2019). Alcohol represents a substantial risk factor that not only increases the probability of road traffic collisions but also exacerbates the severity of injuries incurred in such incidents (Pawowski et al., 2019) This is corroborated by the empirical findings and expert interviews in Drenthe. Both experts highlighted drink-driving as a severe issue, exacerbated by the rural phenomenon of "drinking shacks" which are difficult for police to monitor. The impact of the national awareness campaign "Bob" is unclear due to the absence of an evaluation of its effect on accidents (SWOV, 2023b). Moreover, increasing penalties, such as higher fines, more frequent or longer driving disqualifications, or revoking driving licences, appeared to have little effect on serious alcohol offenders (SWOV, 2023b). For this group, more prevention-oriented measures need to be developed, with a broader approach to the underlying problem of alcohol violation, possibly in combination with an alcohol interlock device or an ankle monitor (SWOV, 2023b). According to Dijcks (2024b), the amount of fined impaired drivers has increased by 32% nationally since 2019. During the most recent assessments in 2022, it was observed that 2.6% of motorists were driving under the influence of alcohol during weekend nights, representing nearly a doubling from the lowest recorded violation rate of 1.4% in 2017 (SWOV, 2023b). In Figure 8, a rising trend is visible in the national fatality rate due to impaired driving. In 2022, nearly 10% of the total traffic fatalities in the Netherlands were attributed to impaired driving, indicating a serious issue (NOS, 2023). The experts' insights suggested that traditional enforcement methods, like monitoring discos, are less effective nowadays due to dispersedly located drinking shacks. The rise in mobile phone usage among both drivers and cyclists causing them to be distracted in traffic was also noted as a growing concern. Due to a lack of data, this falls out of the scope of this thesis. These issues call for innovative policing strategies and public awareness campaigns to address these evolving behaviours. An example could be targeted education programs; enhancing driver education programs, particularly for young drivers, to reduce risky driving behaviours.

5.1.2 Age and Gender

Age and gender significantly influence driving behaviours and traffic safety outcomes. Younger drivers were more prone to distracted driving, and risk-taking, and were more likely to be involved in accidents (Chen & Terken, 2022). Data from Drenthe showed that drivers aged 20-29 account for 14.8% of traffic fatalities, highlighting the vulnerability of this age group. Conversely, older drivers exhibited more cautious behaviours, slower speeds, lower accelerations, and longer brake reaction times (Economou et al., 2021). In Drenthe, 33.2% of traffic fatalities involved individuals aged 70+, indicating the need for targeted interventions, as shown in Figure 6 (SWOV, 2023c). The quote below illustrates the danger of elders in traffic:

'You can say that these elderly people have a lot of experience in traffic. However, their reaction time decreases. They take longer to take decisions and perhaps have worse vision. Their movements are also stiffer and cannot even turn their heads on the bicycle sometimes. The mirror does not always help them out, and the distance is harder to estimate in a mirror. They are also more vulnerable, weaker bones, makes them more vulnerable than younger people. This is surely a cause for the higher number of traffic fatalities in Drenthe.'

- Traffic expert AA en Hunze.

Additionally, it was also found that the rise of e-bikes is a concern for traffic safety, as the average speed of e-bikes is around 25km/h, which makes a crash more severe than a crash on a normal bicycle, where the speed is slower.

'Another possibility for this is that elderly people cycle a lot more because of the e-bikes. On a normal bike, they cycle around 12km/h. But now, race at around 25km/h. If something happens with these elderly, like running off the road or crashing into something, the chance of a severe injury or fatality is a lot higher than back in the day, because they couldn't'.
- Mobility expert Midden-Drenthe

Moreover, gender differences in driving styles impact traffic safety. Men are more likely to drive recklessly and angrily, while women tend to drive more anxiously and carefully (Taubman-Ben-Ari & Yehiel, 2012; Chen & Terken, 2022). In Drenthe, the male traffic fatality rate was double that of females, reflecting higher risk-taking among male drivers, as shown in Figure 7, and acknowledged in the quote below. Men also drove more kilometres on average, correlating with higher accident involvement.

'We also know that young males really tend to overestimate their driving skills. If you look at one-sided traffic accidents, the most are young males.'
- Traffic expert AA en Hunze.

5.1.3 Speeding

Speeding continues to be a significant risk factor for both the incidence of traffic accidents and the severity of injuries (Elvik et al., 2019; Jaarsma et al., 2011). The literature consistently demonstrated a strong association between speeding and the severity of road traffic injuries and fatalities. Viallon and Laumon (2013) suggested that speeding is a contributing factor in approximately 30% of fatal collisions in Europe. A key issue is adherence to speed limits according to the interviewees. Furthermore, Charly and Mathew (2023) identified a positive correlation between speeding, jerk events, and the occurrence of crashes. Additionally, Pérez-Zuriaga et al. (2013) identified risky driver behaviour, such as excessive speed, unsafe overtaking, and sudden braking as the main causes of accidents. Moreover, Nilsson (2004) highlighted that increased speed variability is particularly dangerous in rural contexts, characterized by high-speed limits and expansive road networks. This aligned with the statement of SWOV (2021) implying that vehicles operating at velocities exceeding the average speed of road traffic are associated with an elevated risk of involvement in traffic accidents. An increase in speed limits is correlated with elevated travel speeds on roadways, which subsequently lead to an augmentation in traffic fatality rates. (Farmer, 2016).

5.1.4 Urban vs. Rural Discrepancy

A Pearson correlation test confirmed a strong positive relationship ($r = 0.851$) between the distance to facilities and traffic fatalities in Drenthe, indicating that rural roads with longer distances to amenities were more fatal than urban roads, which are closer to facilities. Thus, this confirmed the notion of Hakkert et al. (2002) who suggested that more vehicle kilometres travelled is associated with an escalation in the frequency of crashes.

A chi-square test of independence was conducted to determine whether there is no association between the location and the severity of traffic accidents. The calculated chi-square statistic was 44.35. Given that the p-value associated with this chi-square statistic was less than 0.05, the null hypothesis was rejected. Thus, there is an association between the location and the severity of traffic accidents. This result is statistically significant, indicating that the distribution of accident severity differs significantly between urban and rural areas. These findings suggested that urban areas have a lower number of fatal accidents compared to rural areas but a higher number of accidents involving injuries and material

damage. This aligned with the notion of Elvik et al., (2019) that congested conditions in urban areas yielded lower speed, and thus less severe accidents. This also confirmed that higher traffic volume increases the chance of material damage, rather than crash severity (Chang & Xiang, 2003; Harwood et al., 2013; SWOV, 2010; Zhou & Sisiopiku, 1997). Moreover, this also confirmed Gonzalez et al. (2007) findings that traffic fatalities for car drivers are significantly higher in rural areas than in urban areas, as can be seen in Figure 11. This discrepancy is attributed to higher rates of speeding on rural roads compared to urban areas. Thus, this thesis supports Clark and Cushing's (2004) notion, demonstrating that rural-urban disparities significantly influence the relationship between traffic mortality rates and other contributing factors. Specifically in rural areas, an inverse relationship exists between population density and traffic mortality rates, a correlation that is absent in urban settings. This conclusion is also supported by the traffic fatalities per inhabitant, as shown in Figure 14, showing that the urban municipalities of Hoogeveen, Emmen, Assen and Meppel had the lowest number of traffic fatalities per inhabitant. Moreover, Figure 16 demonstrated the low percentage of traffic fatalities per traffic accident. It can be seen that these 4 urban municipalities score best (lowest traffic fatality rate), again showing the discrepancies between urban and rural traffic safety. This notion was supported by the experts, as demonstrated in the quote below. Finally, De Waard et al. (1995) discovered that driving in an urban environment induces higher physiological arousal and a greater appreciation of the road compared to driving in a rural environment. Consequently, this can also be an argument that the municipalities with the lowest fatality rates were Assen, Meppel, Hoogeveen, and Emmen, as these are the four most urban municipalities in Drenthe.

'Thus, I think in urban areas, the space is a lot tighter, but the speeds are a lot lower. The chance that you hit each other is larger, but the chance of an injury should be much smaller.'
- **Mobility expert Midden-Drenthe.**

Finally, Figure 26 shows that 18.9% of traffic fatalities consisted of drivers driving into a tree, and a further 18.9% of traffic fatalities in Drenthe were one-sided crashes. Explanations for this are factors such as monotony and boredom, prevalent on roads with low traffic volumes, which are commonly associated with single-vehicle crashes (Armstrong et al., 2008; Candappa et al., 2013). Another reason for the distribution of single-vehicle and multiple-vehicle crashes differs among different road categories (Martensen and Dupont, 2013). Single-vehicle crashes tend to be more prevalent on low-volume rural roads, whereas multiple-vehicle crashes are more frequently observed on high-volume, multilane roads.

Additionally, 18.9% of all traffic fatalities in Drenthe between 2018 and 2022 were due to road users colliding with trees (SWOV, 2023a), as shown in Figure 26. This is one of the core reasons the experts gave why the fatality rate is so high in their municipalities.

To underscore the dangers faced by cyclists in traffic, Farah et al. (2015) discovered that drivers tend to overestimate the lateral distance between their vehicle and a cyclist during overtaking manoeuvres on rural roads. Furthermore, they found that drivers maintain shorter lateral distances when overtaking faster cyclists. Additionally, Farah et al. (2015) identified that drivers' overtaking strategies are influenced by factors such as cyclist speed, oncoming traffic, and road characteristics. As illustrated in Figure 12, cyclists represented the mode of transport with the highest traffic fatality rate in the Netherlands (SWOV, 2024a). The experts agreed that cyclists have some dangerous crossings, especially on rural roads.

5.1.5 Road-design

The synthesis of the expert interviews with the literature review highlighted a cohesive narrative on the importance of tailored and consistent road-design, compatible with each other, to enhance traffic safety in Drenthe. De Waard et al. (1995) and Milton and Mannering (1998) state that driving on roads with slopes, bends and curvatures tends to be safer due to drivers having more psychological arousal. When looking at Figure 28, it can be seen that the majority of traffic fatalities in Drenthe happen on straight roads. The results showed that drivers had a higher likelihood of exceeding speed limits and overtaking

other vehicles on road sections with straighter alignments and better visibility. These are exactly the factors N-roads possess. Moreover, sections of the road where drivers frequently need to engage in hard braking are associated with a higher incidence of crashes and can therefore be considered unsafe (Charly & Mathew, 2023).

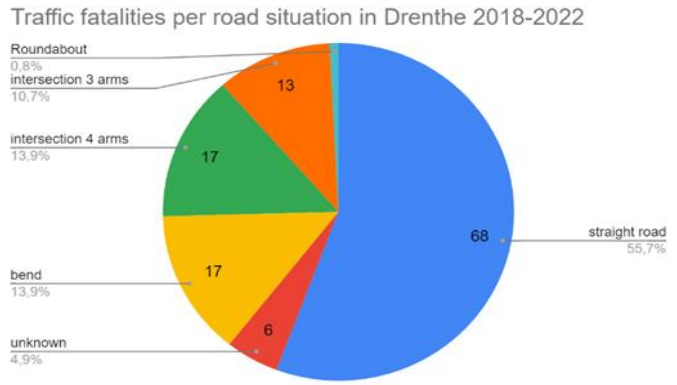

Figure 28: Traffic fatalities per road situation in Drenthe 2018-2022 (SWOV, 2023a)

Yu, Chen, and Bao (2019), who investigated two-lane rural roads, stated that open fields presented less of a deterrent to speeding, while built-up areas exerted a particularly pronounced inhibitory effect on the occurrence of speeding. This could be a possible explanation for the high amount of traffic fatalities on N-roads, which are often located near boring fields in Drenthe. The expert interviews reinforced findings from the literature review, underscoring the critical need for targeted interventions on N-roads, which are identified as the most hazardous roads in Drenthe due to their high-speed limits and lack of median barriers (SWOV, 2023a; Visser, 2021). However, for these types of roads, experts argued for a subdivision in N-roads, as not all N-roads have the same speed limit, as exhibited in the quote below. On some N-roads, AVs are permitted whereas on other N-roads they are prohibited. For the N-roads with a speed limit of 100 km/h, they are in favour of installing a median barrier or doubling the road, aligning with Kennisnetwerk SPV (2023) that a secure shielding structure is a crucial measure to prevent vehicles from crossing into the opposite lane and thus reduce collisions, exhibiting a lower probability of fatal crashes.

'So, if measures are applicable on all these roads, I'm unsure'.
- Mobility Expert, Midden-Drenthe.

Moreover, both the experts and literature underscored the necessity of consistent and predictable road-design. Such consistency helps reduce driver uncertainty and improves decision-making (Patten et al., 2006; Rosén & Sander, 2000; Theeuwes & Godthelp, 1995), as also highlighted by the quote below, enhancing safety for all. Experts reiterated this by highlighting that consistent road-design reduces cognitive load on drivers, which in turn can lower accident rates. Another way to reduce the workload on road users is proposed by the expert of the municipality of AA en Hunze. She proposes to add more safe-havens on segments where cyclists have to cross the rural road. This way, the cyclist only has to cross one road segment at a time, enhancing their decisions. In turn, the installation of such a safe-haven narrows down the road, reducing the speed of the car. Gichaga (2017) suggested that interventions like this diminish the likelihood of accidents and thus improve road safety.

'If the situation is unclear, the risk of a traffic accident increases.
- Traffic Expert, Midden-Drenthe.

The experts and the literature agreed that consistency and believability in road-design are key for traffic safety, stating that driver behaviour can be steered through road-design. Adhering to the CROW guidelines is something that the municipalities are actively pursuing. However, often the money or capacity is currently lacking. Therefore, they have to make choices on what roads get priority.

Regarding the priority for cyclists on roundabouts in the built-up area; the municipalities are all debating the matter again. The experts agreed that segregating cyclists from rural roads that have a speed limit higher than 60km/h is key to improving traffic safety, aligning with the findings of Jaarsma & de Vries (2013). An issue with this implementation is that parcel owners near the road could be unwilling to sell their parcels, hindering the development of segregated cycle paths.

5.2 What policy and infrastructure changes could be made to improve traffic safety in Drenthe, and what are the potential benefits and drawbacks of these changes?

This section examines the potential policy and infrastructure changes that could enhance traffic safety in Drenthe, as well as the associated benefits and drawbacks. The analysis integrated findings from both the literature review and expert interviews to provide a comprehensive understanding of the proposed interventions.

5.2.1 Deceleration of Rural Roads

Reducing speed limits, especially on rural roads, and enhancing enforcement could decrease the incidence and severity of accidents. Jaarsma et al. (2011) analysed changes in driving speed, traffic volume, and road safety measures before and after the implementation of 60 km/h speed zones in areas previously designated as 80 km/h zones. The implementation of 60 km/h speed zones resulted in a significant decrease in both driving speed and traffic volume, alongside an increase in road safety measures, such as road markings and signage. Furthermore, Jaarsma et al. (2011) observed a reduction in the number of fatal and injury accidents following the implementation of the 60 km/h speed zones. The benefits of this policy change are that there will be a reduction in traffic fatalities and a reduction in accident severity. However, the drawback would be the adherence to the new speed limit and potential resistance from drivers who may find lower speed limits inconvenient, as demonstrated in the quote below.

'Not that people actually drive 60km/h then.'
- Traffic expert AA en Hunze.

'The speed limit has to be believable'.
- Mobility expert Midden-Drenthe

However, to achieve the desired speed reduction, it is necessary to not only change the speed limit signage but also to modify the spatial design of the road, as quoted above. This can be accomplished through the implementation of traffic calming measures such as speed bumps, alterations to the type of road surface, or road narrowing.

5.2.2 Reward Good Behaviour

Cameron and Pierce (2002) found that intrinsic motivation can be bolstered by incentivizing people with rewards. Thus, the idea of rewarding drivers to incentivize positive driver behaviour has merit. A way to encourage good drivers' behaviour is the so-called 'safety-safe'. According to Safetysafe (2023), since the installation of the safety-safe, a reduction of 25% in speeding could be observed. Another example of rewarding drivers for good behaviour is to reduce their insurance fees. This approach not only promotes safer driving but also provides a tangible benefit to the drivers, creating a win-win situation.
Regarding impaired driving, increasing penalties, such as higher fines, more frequent or longer driving disqualifications, or revoking driving licences, appear to have little effect on serious alcohol offenders (SWOV, 2023b). For this group, more prevention-oriented measures need to be developed, adopting a broader approach to address the underlying problem of alcohol violations. This could potentially involve the use of an alcohol interlock device or an ankle monitor (SWOV, 2023b).

5.2.3 Infrastructural Changes

Implementing consistent and intuitive road-design changes, such as widening or narrowing roads with clear markings and segregating vulnerable road users from the road segment will improve traffic safety (Patten et al., 2006; Theeuwes & Godthelp, 1995), especially for cyclists. The drawback is the high initial costs and possible traffic disruptions during construction. Developing dedicated cycling paths segregated from vehicular traffic on rural roads with speed limits of 60 km/h or higher and creating safe-havens at intersections will improve traffic safety. Separate cycling paths reduce collision risks between cyclists and vehicles, enhancing cyclist safety (Rosén & Sander, 2009). The drawbacks are land acquisition for cycling paths can be costly and contentious in rural areas. Budget constraints and resistance from landowners may also pose significant challenges.

Regarding the tree issue: Although Kloeden et al. (1999) proposed installing a guard-rail near the road if an object is within 9 meters of the road, it is not feasible, according to both experts, to install that on the rural roads in Drenthe due to budget and space constraints. From a traffic safety perspective, the traffic experts advocated in favour of cutting down trees that pose a risk and potentially contribute to the number and severity of road accidents. However, landscape architects will likely not agree with cutting. A proposed solution is to remove the roots of trees that damage the asphalt after a consultation with a tree expert to check for feasibility.

Implementing no-overtaking zones or, even better, the installation of difficult or non-traversable median barriers will reduce traffic accidents on N-roads significantly in Drenthe (SWOV, 2013). Installing median barriers on N-roads where the speed limit is 100 km/h reduces the risk of head-on collisions on these roads, which are often fatal on high-speed roads (Kennisnetwerk SPV, 2023; SWOV, 2023a). Experts identified N-roads like the N381 as particularly dangerous without such barriers, as quoted below. High installation and maintenance costs and complicated road maintenance and emergency responses are possible drawbacks. Although this method is being implemented in certain regions, it is not universally feasible due to financial, spatial and environmental, limitations. Additionally, not all N-roads are homogeneous; some N-roads permit the use of agricultural vehicles (AVs). In such cases, the implementation of no-overtaking zones would prevent faster vehicles from overtaking slower ones, thereby potentially impeding traffic flow. Median-divided roads, with high volumes, tend to have fewer severe crashes on average compared to undivided roads with lower volumes. This aligns with Dickerson et al. (2000), who state that with more traffic volume, the average traffic speed is lower, and thus the driving behaviour is safer.

'The N-roads, like the N381, are the most dangerous roads that exist because you drive 100km/h, without a median barrier.'
- **Mobility expert Midden-Drenthe**.

5.3: How can road-design reduce the frequency and severity of traffic accidents?

Road-design plays a pivotal role in mitigating the frequency and severity of traffic accidents. Well-designed roads not only enhance driver comprehension and behaviour but also create an environment that naturally enforces safer driving practices. Consistency in road-design helps drivers anticipate road conditions better, reducing cognitive load and accident risk (Patten et al., 2006). Experts stress that predictable road-design improves driver decision-making, as the quote below demonstrates. This aids better decision-making, aligning with the findings of Theeuwes & Godthelp (1995), stating that consistent road-design enhances the predictability of the road environment for drivers. Standardizing road-designs across varied environments can be challenging and expensive. Redesigning existing roads to meet new standards would require substantial investment. When drivers are presented with a road environment that consistently communicates the appropriate speed, through both explicit signage and implicit design cues, they are more likely to adhere to speed limits, reducing the incidence of speeding-related accidents (Montella, 2010). Rosén & Sander (2009) state that with consistent usage of crosswalks and cycling paths, drivers expect and respect these users, enhancing safety. SWOV proposes a new sub-category in road-design to combat the issue when a segregated cycling path is not feasible.

The ‘GOW30’. This means that they alter the speed limit of a distributor road from 50km/h to 30km/h inside the built-up area. GOW30 should be implemented in places where creating a separate bicycle lane is not possible or feasible (Dijkstra & Van Petegem, 2019).

"If the situation is unclear, the risk of a traffic accident increases."
– Traffic Expert, Midden-Drenthe.

The maintenance of verges is of paramount importance to traffic safety in Drenthe. The effect of (semi) hardening the verges is estimated to eliminate around 20% of traffic accidents in the Netherlands (Schoon, 2003). The expert of Midden-Drenthe repeatedly discussed budget constraints. However, Schoon (2003) noted that when conducting a cost-benefit analysis on constructing (semi-hardened) verges are best implemented during great maintenance, which most municipalities do once every 15 years. However, when implementing (semi) hardened verges outside of the great maintenance period, the benefits still outweigh the costs significantly.

6. Conclusion

This study aimed to identify the key factors contributing to traffic safety issues in Drenthe and propose effective solutions based on a comprehensive analysis of interview data, literature review, and statistical findings. To improve traffic safety and reduce traffic fatalities in Drenthe, it is suggested that policymakers and transportation planners adopt a multi-faceted approach that addresses human behaviour, road-design, and speed management. This conclusion is derived from empirical data analysis and aligns with established traffic safety theories and practices. The following conclusions can be drawn from the research and help answer the main research question: '*How can policymakers and transportation planners improve traffic safety and reduce traffic fatalities in Drenthe?*'

Implementing programs that monitor and provide feedback on driver behaviour can significantly influence safer driving behaviour. Initiatives such as the "Safety-Safe Program," which rewards safe driving and coaches drivers, can lead to a reduction of 25% in speeding (Safetysafe, 2023). This approach is supported by behavioural theories by Cameron and Pierce (2002) which emphasize positive reinforcement and continuous feedback as effective tools for behavioural improvement.

This study suggests driver behaviour, speeding, age, cyclists, trees and N-roads as the main factors contributing to traffic accidents in Drenthe. Issues such as drink-driving, mobile phone use, and drug use also impact negatively on traffic safety (Pawowski et al., 2019). In 2022, nearly 10% of the total traffic fatalities in the Netherlands were attributed to impaired driving, indicating a serious issue (NOS, 2023). Despite efforts to reduce speed limits, adherence remains a challenge, particularly on rural roads according to the interviewees. It is suggested that young and elderly drivers were at higher risk of a crash, the former due to inexperience and overconfidence, and the latter due to slower reaction times and increased physical vulnerability (Chen & Terken, 2022; Economou et al., 2021). It was also suggested that the rising use of e-bikes and the lack of dedicated cycling paths and dangerous crossings in rural areas pose significant risks. The proximity of trees near rural roads contributed to nearly 20% fatal one-sided traffic fatalities in Drenthe (SWOV, 2023a). Finally, N-roads are particularly dangerous due to high average speeds and the lack of median barriers, amounting to 30.3% of traffic fatalities from 2018-2022 (SWOV, 2023a).

Consistent findings across interviews, data analysis, and literature review were the higher rate of traffic fatalities in rural areas compared to urban areas in Drenthe. Experts agreed that decelerating rural roads from 80 km/h to 60 km/ is an effective measure to improve traffic safety (Jaarsma et al., 2011). Lower speed limits give drivers more time to react to potential hazards, thereby reducing the likelihood and severity of accidents. The Pearson correlation test revealed a strong positive correlation between traffic fatalities per billion kilometres driven and the average distance to facilities, confirming the significant impact of rural road characteristics on traffic safety. The Chi-Square test indicated a statistically significant association between the location (urban vs. rural) and the severity of traffic accidents. Urban areas experience more frequent but less severe accidents, while rural areas see fewer but more fatal accidents. This confirms that higher traffic volume increases the chance of material damage, rather than crash severity (Chang & Xiang, 2003; Harwood et al., 2013; SWOV, 2010; Zhou & Sisiopiku, 1997). Moreover, this also confirmed Gonzalez et al. (2007) findings that the traffic fatality rate for car drivers is higher in rural areas than in urban areas, as shown in Figure 11. This discrepancy is because of higher rates of speeding on rural roads compared to urban areas. Thus, this thesis supports Clark and Cushing's (2004) notion that rural-urban disparities significantly influence the relationship between traffic mortality rates and other contributing factors.

Road-design plays a crucial role in traffic safety. The installation of hardened verges, median barriers, consistent and believable road-designs, and the removal of roadside obstacles are essential measures to improve traffic safety. When drivers encounter familiar road characteristics, they expend less mental effort interpreting these features, which can decrease driver fatigue and improve concentration (Patten et al., 2006). According to the experts, Tailor-made solutions for N-roads should be considered, depending on the speed limit and other rules that apply to them to check if doubling or installing a median barrier is feasible. The installation of difficult or non-traversable median barriers will reduce

traffic accidents significantly in Drenthe (SWOV, 2013).

Both the experts and Jaarsma & de Vries (2013) agreed that segregating cyclists from high-speed traffic by creating dedicated bicycle paths is crucial for protecting vulnerable road users. This strategy reduces conflicts between cyclists and motor vehicles, which is consistent with the principles of traffic safety engineering that advocate for the separation of different modes of traffic to reduce crash rates. Moreover, creating more safe-havens at rural cyclist crossings aids cyclists in decision-making (Patten et al., 2006), whilst narrowing the road, and decreasing the cars' speed. Passing zones for cars on rural roads for passing AVs will also improve traffic safety. To safeguard the uniqueness of Drenthe's identity tailored safety measures per situation are required.

The findings of this study not only address traffic safety issues specific to Drenthe but also contribute to broader traffic safety theories and practices. Societally, the proposed measures address public concerns about road safety and the high incidence of traffic fatalities on rural roads. Academically, this research supports and extends existing theories on traffic safety by providing empirical evidence from Drenthe. By integrating human behaviour, road-design, and speed management, this study provides a holistic approach to enhancing traffic safety. These recommendations, backed by empirical data and statistical evidence, offer actionable insights for policymakers and transportation planners aiming to improve traffic safety and reduce fatalities in Drenthe.

7. Reflection

7.1 Limitations of the Study

7.1.1 Insufficient Focus on Driver Behaviour

One notable limitation of this study was the inadequate exploration of driver behaviour during the expert interviews. Human factors are crucial in understanding traffic safety, and detailed insights into behaviours such as distraction, fatigue, and impaired driving were not sufficiently gathered. Future studies should place a greater emphasis on these aspects, employing comprehensive surveys or behavioural studies to capture a broader range of driver-related data.

7.1.2. Lack of Data

Another significant limitation was the absence of recent specific data on drink-driving in Drenthe. Alcohol impairment is a well-documented risk factor in traffic safety literature. The omission of this data restricted the ability to fully understand its impact on traffic fatalities and accidents in the region. Future research should strive to include detailed statistics on drink-driving incidences and their correlation with traffic accidents. Moreover, this study contacted a large data manager on time regarding hard breaking and hard accelerating zones in Drenthe, but the data manager did not provide the requested data, limiting the spatial side of this research partly. Therefore, this research supports an open data model regarding traffic safety, as it concerns everyone in the physical world. Ideally, data regarding the traffic accident/fatality per N-road would have been insightful, but the SWOV data did not always state which N-road an accident happened. Thus, the author was unable to subdivide the N-roads into roads that could be doubled or need a median barrier.

7.2 Future Research Recommendations

7.2.1 Simplification of Speed Limits

During the interview, the mobility expert of the municipality of Midden-Drenthe stated that instead of the 10-speed limits the Netherlands currently uses, he wondered what the potential impact of simplifying speed limits to four distinct speed limits (e.g., 30 km/h, 60 km/h, 90 km/h, and 120 km/h) would mean. The current multiplicity of speed limits in the Netherlands can create confusion among drivers, leading to unintentional speeding and increased accident risks, he argued. A systematic study could investigate whether a streamlined approach would enhance compliance, reduce speeding incidents, and improve overall traffic safety. Possible future research could involve simulations, pilot studies in select regions, and analysis of traffic data pre- and post-implementation.

7.2.2 Enhanced Behavioural Interventions

Given the identified gap in driver behaviour analysis, future studies should develop and test targeted behavioural interventions. These could include educational campaigns, behavioural monitoring systems, and reward-based programs for safe driving. Evaluating the effectiveness of such interventions through longitudinal studies could provide robust evidence for policy implementation.

7.2.3 Technological Integration in Traffic Management

The integration of advanced technologies such as automated speed enforcement, intelligent traffic management systems, and vehicle-to-infrastructure communication offers promising avenues for enhancing traffic safety. Possible future research could focus on the deployment and efficacy of these technologies in reducing accidents and fatalities, particularly in rural settings where traditional enforcement may be challenging.

7.2.4. Comprehensive Data Collection

Future research must address the gaps in data collection, especially concerning drink-driving and other high-risk behaviours. Collaborating with local law enforcement and health agencies to gather comprehensive, accurate data will be essential. Additionally, employing advanced data analytics and

machine learning techniques can uncover hidden patterns and correlations, leading to more effective interventions.

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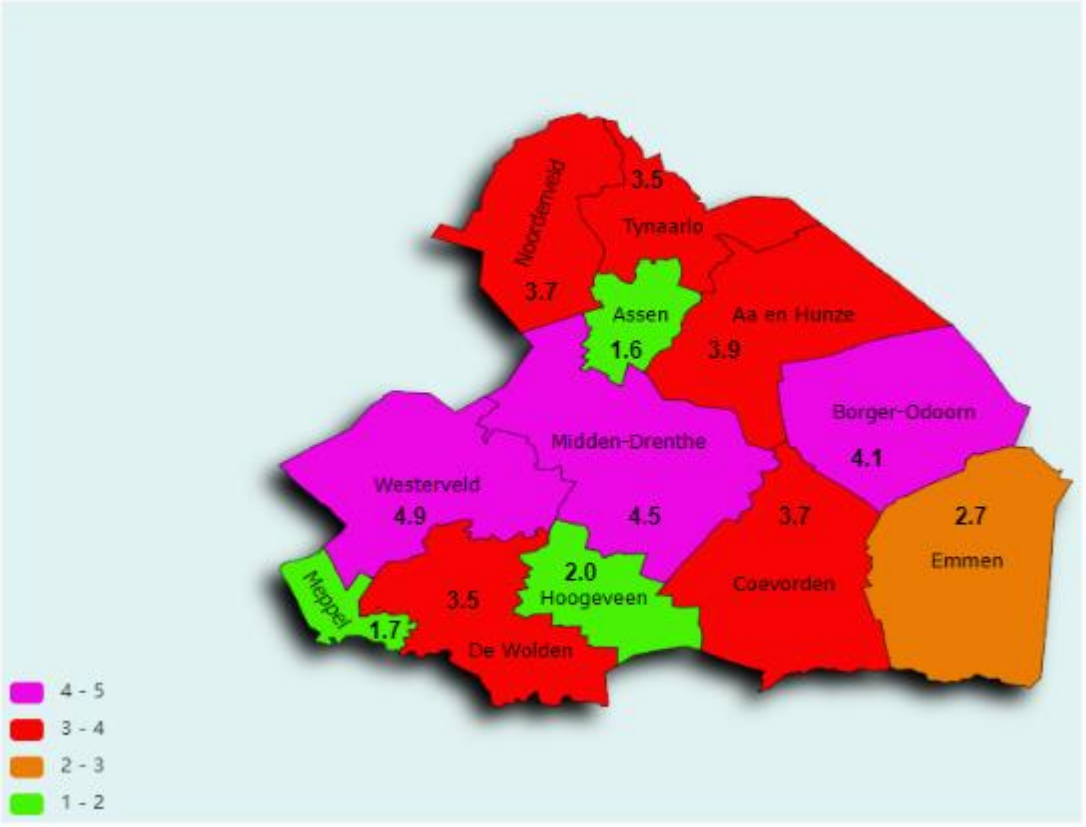
Appendix A - Interview Guide

1. The municipality of Midden-Drenthe and AA en Hunze score the worst or second to worst in terms of traffic fatalities per 10,000 inhabitants, and the amount increased significantly in 2018-2022 compared to 2014-2018. Why do you think that is?

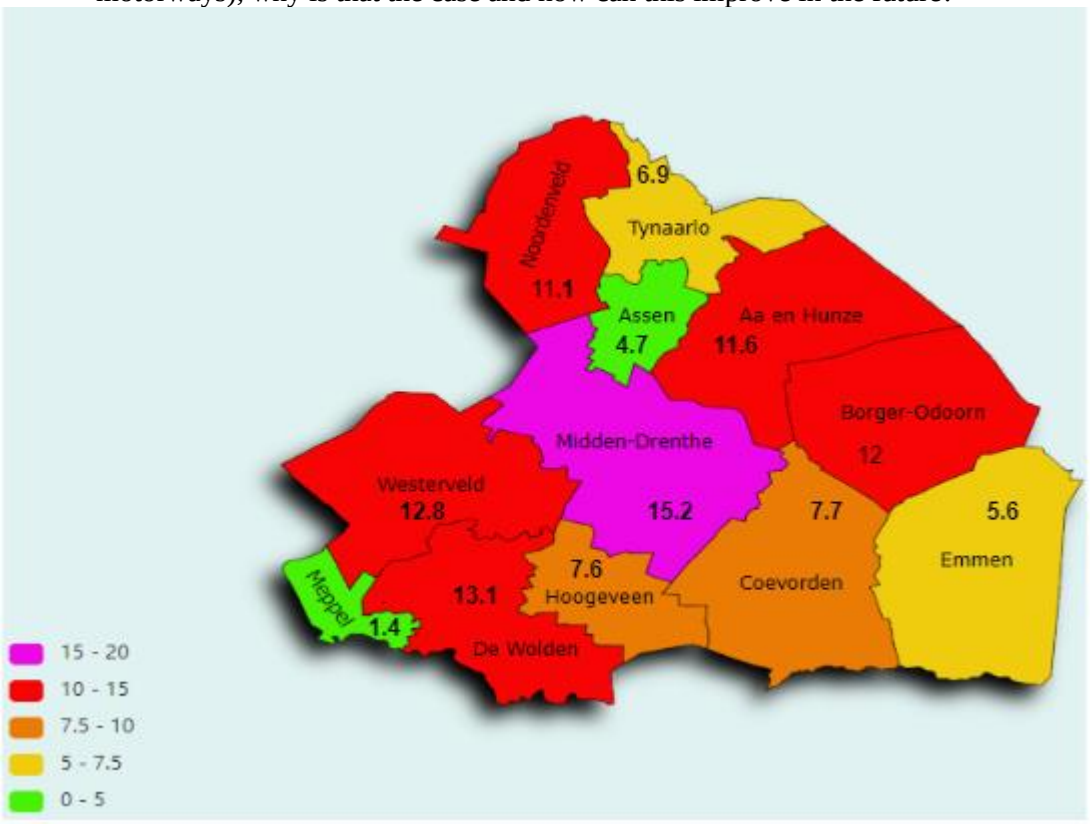
Municipality	Traffic fatalities in 2014-2018 per 10,000 inhabitants	Traffic fatalities in 2018-2022 per 10,000 inhabitants	Change
Midden-Drenthe	3.3	5.4	+63.64%
AA en Hunze	2.7	5.1	+88.89%
de Wolden	4.2	4.9	+16.67%
Westerveld	3.6	4.6	+27.78%
Borger - Odoorn	5.5	3.9	-29.09%
Noordenveld	1.5	3.2	+113.33%
Coevorden	3.1	2.8	-9.68%
Tynaarlo	1.8	2.1	+16.67%
Emmen	1.5	1.5	0%
Hoogeveen	2.0	1.3	-35%
Assen	1.5	1.3	-13.34%
Meppel	0.6	0.3	-50%

2. Midden-Drenthe scores 2nd worst in terms of distance to amenities like schools, general practitioners, kindergarten etc, with an average of 4,5 km, and AA en Hunze is also amongst the worse scores at 3,9 km, are measures being planned to be implemented to mitigate the negative effects of the traffic to these frequently visited places? And if so, what are they? (and then what apart from planned, are there also more measure that could be considered?)



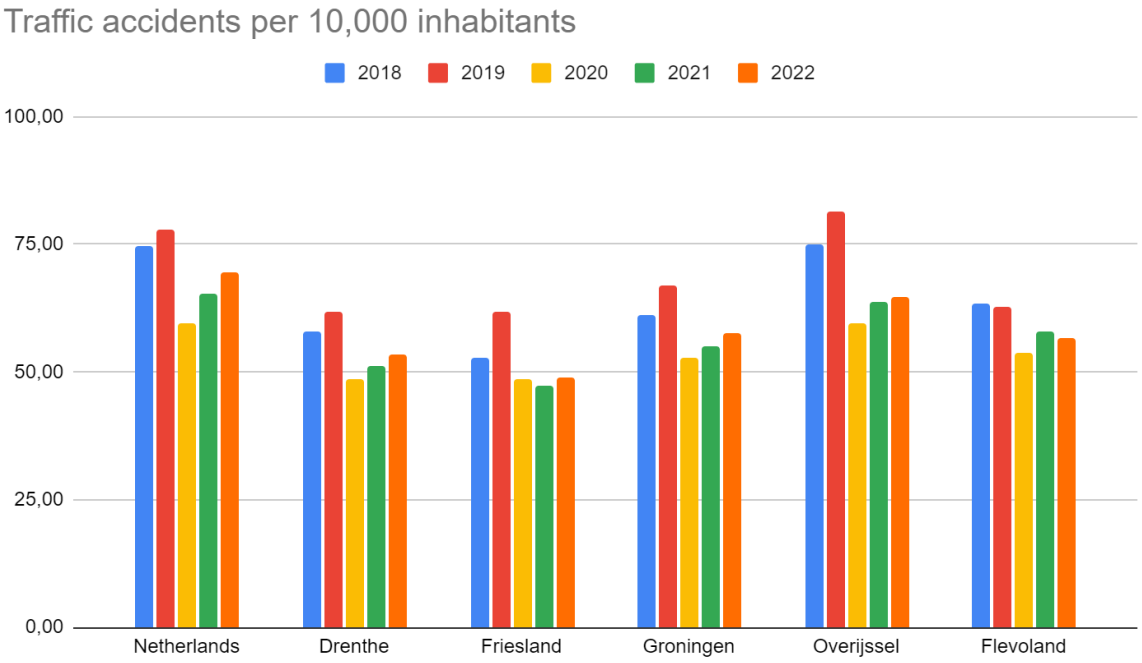
3. Midden-Drenthe scores worst at traffic fatalities per 1 billion travelled kilometres (excluding

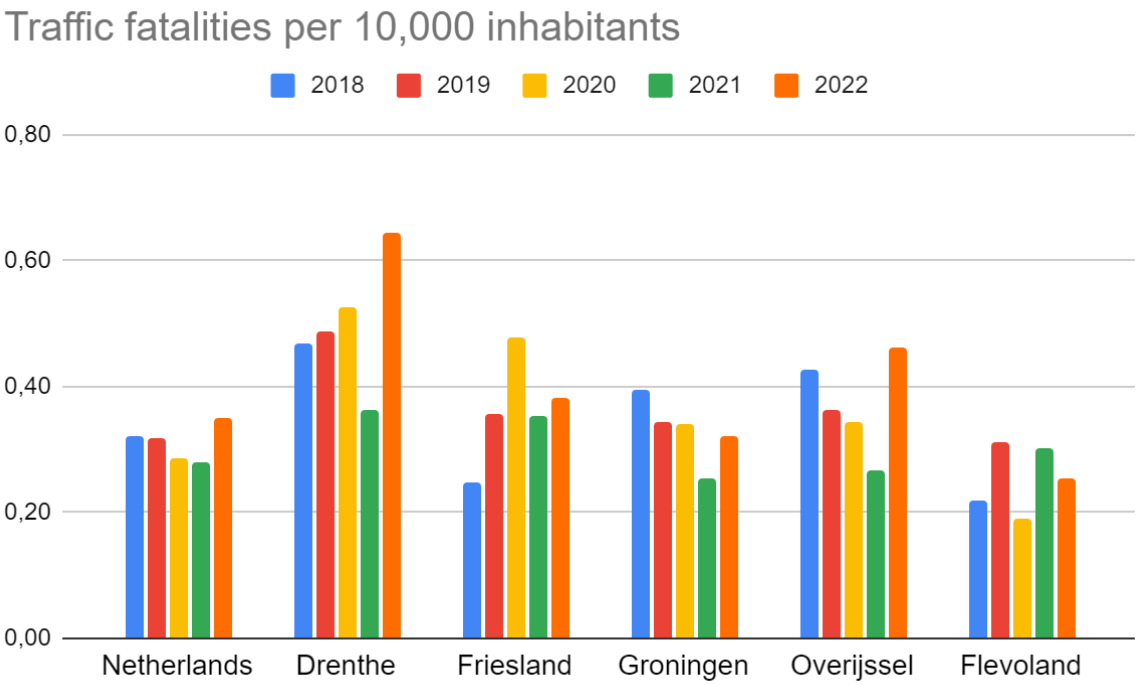
motorways), why is that the case and how can this improve in the future?



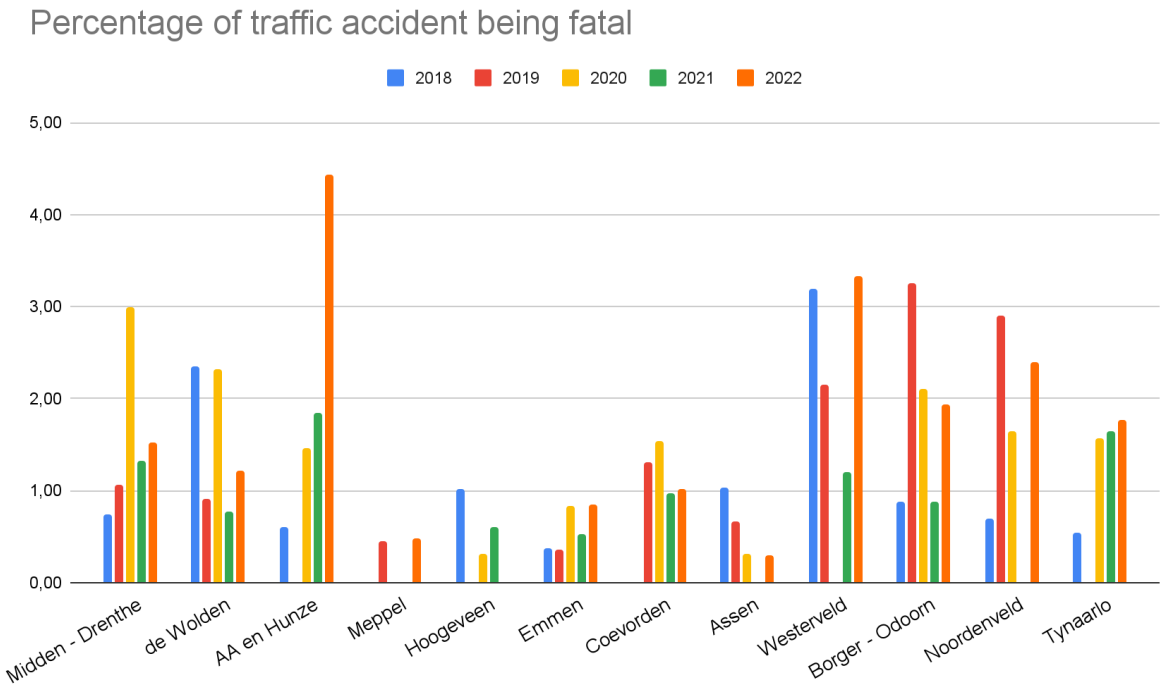
4. A vast majority of fatal crashes occur on N-roads, which are also often found in Drenthe. Theory suggests putting up verges in the middle of the road, or hardening the verges. How would you solve the many traffic accidents and traffic fatalities on N-roads?
5. The theory suggests that lowering rural roads from 80km/h to 60km/h improves the amount and severity of traffic accidents, why isn't this implemented more in your municipality?
6. Regarding trees adjacent to the rural roads: Do they pose a risk? And if so, what would be the most effective way to combat the negative consequences of them being next to the road (in terms of crashes and roots destroying the asphalt)
7. A lot of rural roads have bad verges, and trees adjacent to them. With lots of agricultural vehicles on these narrow roads, why isn't the municipality maintaining them better? The same applies for signage.
8. Where do you think the biggest point of improvement can be made regarding traffic safety in your municipality?
9. About consistency in traffic regulation the CROW knowledge institutes advices giving cyclists priority on roundabouts, and Drenthe proclaims to be the province of cyclists, Noordenveld only gives priority to cyclists currently, with Meppel thinking about it. Why don't cyclists get priority in your municipality at roundabouts?
10. How can the municipality of Midden-Drenthe or AA en Hunze improve traffic safety and reduce traffic fatalities in Drenthe?
11. What policy and infrastructure changes could be made to improve traffic safety in Drenthe, and what are the potential benefits and drawbacks of these changes?

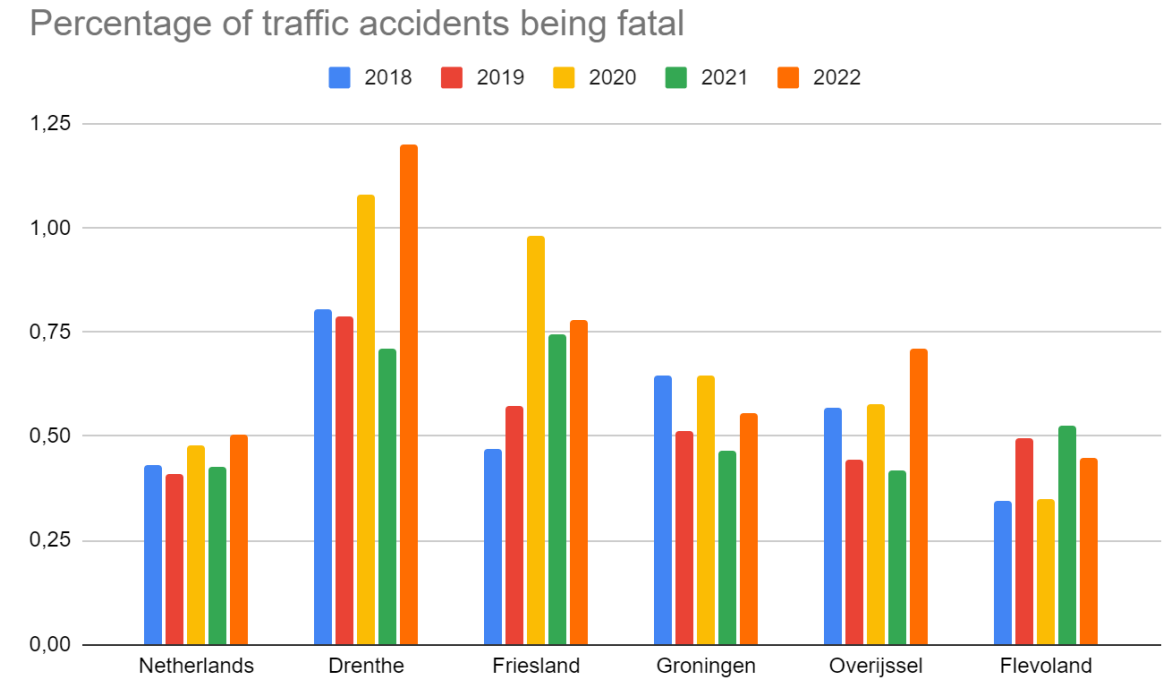
12. According to you, what factors influence the causation and/or severity of a traffic accident in Drenthe?
13. How can road-design reduce the frequency and severity of traffic accidents?
14. Drenthe has fewer traffic accidents per 10,000 inhabitants than the Netherlands, as well as Friesland and Groningen but yet has a lot more traffic fatalities per 10,000, why do you think that is?



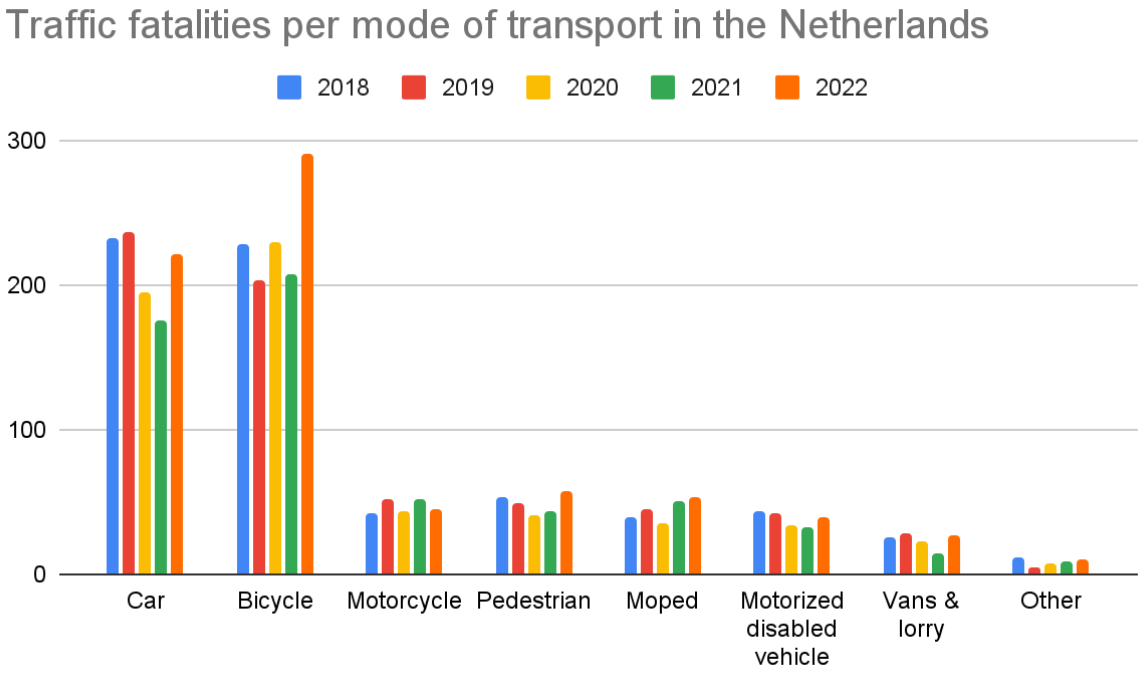


15. The data shows that the urban municipalities in Drenthe have more traffic accidents per capita but also less traffic fatalities per inhabitants. Why do you think that is?





16. The chart below states that cars and bicycles are ever present among the traffic fatalities in the Netherlands. Does this trend apply for your municipality as well? How can we protect cyclists better?


Traffic fatalities per mode of transport in the Netherlands
2018
2019
2020
2021
2022
300
200
100
0
Car
Bicycle
Motorcycle
Pedestrian
Moped
Motorized disabled vehicle
Vans & lorry
Other

Appendix B - Code Book

Table BA: Codebook of the conducted interviews

Theme	Code
Traffic volume & speed	More traffic more accidents More speed more severe accident
Factors leading to traffic accidents	Rural roads Trees Drink-driving Drugs 80km/h rural road Cyclist crossing the road Elderly people on e-bike Mobile phone usage in traffic Overestimation of own driving skills Distraction Age Speeding Decelerating
Factors to decrease traffic accidents	Road-Design Safe passing havens Move side-stripe Shield the trees Consistency in road-design Separated cycling lane Tailor made solution
N-roads	Median barrier Difference N-roads Widening N-road without median barrier Tailor made solution
Differences urban and rural areas	Distance to facility Urban vs rural
Alternative factors regarding traffic safety in Drenthe	Budget constraint Politics Blank canvas Too many speed limits Capacity Alternative way to look at traffic safety Data constraint Village unique identity

Appendix C - Raw Data Table

This data based on the traffic data of SWOV (2023a; 2023b; 2023c) and inhabitant numbers of Allecijfers (2023)

Table CA: Accidents in the municipalities of Drenthe (SWOV, 2023a; 2023b)

Municipality	accidents in 2018	accidents in 2019	accidents in 2020	accidents in 2021	accidents in 2022
Midden-Drenthe	270	280	200	227	263
de Wolden	170	221	129	130	165
AA en Hunze	167	135	137	162	158
Meppel	200	219	173	169	206
Hoogeveen	391	411	318	333	327
Emmen	540	554	482	562	593
Coevorden	194	230	194	205	196
Assen	387	446	321	311	328
Westerveld	94	93	104	83	90
Borger - Odoorn	113	123	95	113	103
Noordenveld	144	138	122	123	125
Tynaarlo	183	197	128	121	113
Average of Drenthe's municipalities	238	254	200	212	222
Netherlands	128225	134617	103578	114219	122036
Drenthe	2853	3047	2403	2539	2667
Friesland	3417	4009	3154	3092	3205
Groningen	3566	3902	3087	3222	3408
Overijssel	8637	9434	6933	7418	7580
Flevoland	2604	2618	2277	2481	2462

Table CB: Inhabitants of the Netherlands, other provinces and the Netherlands (Allecijfers, 2023)

Municipality	Inhabitants in 2018	Inhabitants in 2019	Inhabitants in 2020	Inhabitants in 2021	Inhabitants in 2022
Midden-Drenthe	33172	33178	33185	33381	33689

Municipality	Inhabitants in 2018	Inhabitants in 2019	Inhabitants in 2020	Inhabitants in 2021	Inhabitants in 2022
de Wolden	23917	24110	24330	24374	24511
AA en Hunze	25399	25386	25445	25399	25579
Meppel	33410	33564	33920	34386	34761
Hoogeveen	55677	55662	55699	55603	55857
Emmen	107192	107113	107048	107024	107856
Coevorden	35299	35483	35297	35317	35517
Assen	67708	67963	68599	68836	68979
Westerveld	19152	19348	19460	19661	19854
Borger - Odoorn	25351	25372	25559	25598	25681
Noordenveld	32370	31290	31253	31214	31238
Tynaarlo	33462	33698	33887	33978	34221
Average of Drenthe's municipalities	41009	41014	41140	41231	41479
Netherlands	17181084	17282163	17407585	17475415	17590672
Drenthe	492109	492167	493682	494771	497743
Friesland	647268	647672	649957	651435	654019
Groningen	582944	583990	585866	586937	590170
Overijssel	1151501	1156431	1162406	1166533	1171910
Flevoland	411670	416546	423021	428226	434771

Table CC: Traffic accidents per 10,000 inhabitants (SWOV, 2023a; Allecijfers, 2023)

Municipality	Accidents per 10,000 inhabitants in 2018	Accidents per 10,000 inhabitants in 2019	Accidents per 10,000 inhabitants in 2020	Accidents per 10,000 inhabitants in 2021	Accidents per 10,000 inhabitants in 2022
Midden-Drenthe	81,39	84,39	60,27	68,00	78,07
de Wolden	71,08	91,66	53,02	53,34	67,32
AA en Hunze	65,75	53,18	53,84	63,78	61,77
Meppel	59,86	65,25	51,00	49,15	59,26
Hoogeveen	70,23	73,84	57,09	59,89	58,54
Emmen	50,38	51,72	45,03	52,51	54,98

Municipality	Accidents per 10,000 inhabitants in 2018	Accidents per 10,000 inhabitants in 2019	Accidents per 10,000 inhabitants in 2020	Accidents per 10,000 inhabitants in 2021	Accidents per 10,000 inhabitants in 2022
Coevorden	54,96	64,82	54,96	58,05	55,18
Assen	57,16	65,62	46,79	45,18	47,55
Westerveld	49,08	48,07	53,44	42,22	45,33
Borger - Odoorn	44,57	48,48	37,17	44,14	40,11
Noordenveld	44,49	44,10	39,04	39,41	40,02
Tynaarlo	54,69	58,46	37,77	35,61	33,02
Average of Drenthe's municipalities	57,97	61,91	48,68	51,32	53,58
Netherlands	74,63	77,89	59,50	65,36	69,38
Drenthe	57,97	61,91	48,68	51,32	53,58
Friesland	52,79	61,90	48,53	47,46	49,00
Groningen	61,17	66,82	52,69	54,90	57,75
Overijssel	75,01	81,58	59,64	63,59	64,68
Flevoland	63,25	62,85	53,83	57,94	56,63

Table CD: Traffic fatalities (SWOV, 2023a)

Municipality	Traffic fatalities in 2018	Traffic fatalities in 2019	Traffic fatalities in 2020	Traffic fatalities in 2021	Traffic fatalities in 2022
Midden-Drenthe	2	3	6	3	4
de Wolden	4	2	3	1	2
AA en Hunze	1	0	2	3	7
Meppel	0	1	0	0	1
Hoogeveen	4	0	1	2	0
Emmen	2	2	4	3	5
Coevorden	0	3	3	2	2
Assen	4	3	1	0	1
Westerveld	3	2	0	1	3
Borger - Odoorn	1	4	2	1	2

Noordenveld	1	4	2	0	3
Tynaarlo	1	0	2	2	2
Average of Drenthe's municipalities	1,92	2,00	2,17	1,50	2,67
Netherlands	554	552	496	486	615
Drenthe	23	24	26	18	32
Friesland	16	23	31	23	25
Groningen	23	20	20	15	19
Overijssel	49	42	40	31	54
Flevoland	9	13	8	13	11

Table CE: Traffic fatalities per 10,000 inhabitants (SWOV, 2023a; Allecijfers, 2023)

Municipality	Traffic fatalities per 10,000 inhabitants in 2018	Traffic fatalities per 10,000 inhabitants in 2019	Traffic fatalities per 10,000 inhabitants in 2020	Traffic fatalities per 10,000 inhabitants in 2021	Traffic fatalities per 10,000 inhabitants in 2022
Midden-Drenthe	0,60	0,90	1,81	0,90	1,19
de Wolden	1,67	0,83	1,23	0,41	0,82
AA en Hunze	0,39	0,00	0,79	1,18	2,74
Meppel	0,00	0,30	0,00	0,00	0,29
Hoogeveen	0,72	0,00	0,18	0,36	0,00
Emmen	0,19	0,19	0,37	0,28	0,46
Coevorden	0,00	0,85	0,85	0,57	0,56
Assen	0,59	0,44	0,15	0,00	0,14
Westerveld	1,57	1,03	0,00	0,51	1,51
Borger - Odoorn	0,39	1,58	0,78	0,39	0,78
Noordenveld	0,31	1,28	0,64	0,00	0,96
Tynaarlo	0,30	0,00	0,59	0,59	0,58
Average of Drenthe's municipalities	0,47	0,49	0,53	0,36	0,64
Netherlands	0,32	0,32	0,28	0,28	0,35

Municipality	Traffic fatalities per 10,000 inhabitants in 2018	Traffic fatalities per 10,000 inhabitants in 2019	Traffic fatalities per 10,000 inhabitants in 2020	Traffic fatalities per 10,000 inhabitants in 2021	Traffic fatalities per 10,000 inhabitants in 2022
Drenthe	0,47	0,49	0,53	0,36	0,64
Friesland	0,25	0,36	0,48	0,35	0,38
Groningen	0,39	0,34	0,34	0,26	0,32
Overijssel	0,43	0,36	0,34	0,27	0,46
Flevoland	0,22	0,31	0,19	0,30	0,25

Table CF: Percentage of traffic accidents being fatal (SWOV, 2023a)

Municipality	% of traffic accidents being fatal in 2018	% of traffic accidents being fatal in 2019	% of traffic accidents being fatal in 2020	% of traffic accidents being fatal in 2021	% of traffic accidents being fatal in 2022
Midden-Drenthe	0,74	1,07	3,00	1,32	1,52
de Wolden	2,35	0,90	2,33	0,77	1,21
AA en Hunze	0,60	0,00	1,46	1,85	4,43
Meppel	0,00	0,46	0,00	0,00	0,49
Hoogeveen	1,02	0,00	0,31	0,60	0,00
Emmen	0,37	0,36	0,83	0,53	0,84
Coevorden	0,00	1,30	1,55	0,98	1,02
Assen	1,03	0,67	0,31	0,00	0,30
Westerveld	3,19	2,15	0,00	1,20	3,33
Borger - Odoorn	0,88	3,25	2,11	0,88	1,94
Noordenveld	0,69	2,90	1,64	0,00	2,40
Tynaarlo	0,55	0,00	1,56	1,65	1,77
Average of Drenthe's municipalities	0,81	0,79	1,08	0,71	1,20
Netherlands	0,43	0,41	0,48	0,43	0,50
Drenthe	0,81	0,79	1,08	0,71	1,20
Friesland	0,47	0,57	0,98	0,74	0,78

Municipality	% of traffic accidents being fatal in 2018	% of traffic accidents being fatal in 2019	% of traffic accidents being fatal in 2020	% of traffic accidents being fatal in 2021	% of traffic accidents being fatal in 2022
Groningen	0,64	0,51	0,65	0,47	0,56
Overijssel	0,57	0,45	0,58	0,42	0,71
Flevoland	0,35	0,50	0,35	0,52	0,45

Table CG: Male/female traffic fatality distribution (SWOV, 2023c)

Year	Male	Female
2010	24	6
2011	21	9
2012	21	12
2013	23	12
2014	19	7
2015	21	10
2016	21	8
2017	16	4
2018	15	11
2019	26	3
2020	19	10
2021	15	5
2022	29	10

Table CH: Traffic fatalities per mode of transport in the Netherlands (SWOV, 2024a)

Year	2018	2019	2020	2021	2022
Car	233	237	195	175	221
Bicycle	228	203	229	207	290
Motorcycle	42	52	44	52	45
Pedestrian	54	49	41	43	58
Moped	39	45	36	50	54
Motorized disabled vehicle	44	42	34	32	40
Vans & lorry	26	28	23	14	27

Other	12	5	8	9	10

Table CI: Traffic fatalities per 10,000 inhabitants per province (SWOV, 2023a; Allecijfers, 2023)

Year	Drenthe	Friesland	Groningen	Flevoland	Overijssel
2018	0,5283478968	0,417137878	0,3773947412	0,2429130129	0,4255315453
2019	0,5892308911	0,4477575069	0,3253480368	0,3841112386	0,4928958148
2020	0,5874226729	0,5384971621	0,4608562368	0,2363948835	0,4043337698
2021	0,4042274103	0,3684174169	0,3577896776	0,3969866379	0,2914619646
2022	0,7835368855	0,4587022701	0,4236067574	0,39101044	0,5546501011

Appendix D - Transcribed interview with traffic expert from the municipality of AA en Hunze

R= Remco
E = Traffic expert of the municipality of AA en Hunze

R: ‘’Hello and welcome, can you tell something about yourself and experiences?’’

E= ‘’My name is (anonymous) and I’m the traffic and transportation expert since 3,5 years, I started off at the PABO and was a teacher, after a few years I went into traffic education. I used to teach traffic education to kids. Afterwards, I had a traffic education company up until the covid crisis, because than teachers weren’t allowed to give guest colleges. Before corona, it got boring, so I started a post-HBO traffic which I completed in June and joined this job in september, cause they were looking for some time already. They didn’t require any experience, and so I got hired. At the start it was a bit of swimming, but now the job really suits me. Before me, a year long 2 people worked here as traffic expert for 12 hours per week. My predecessor left in 2019, I started here in November 2020, so a lot of old work was still laying around. ‘’

R: ‘’Yeah I reckon there was still so much to do’’

E: ‘’Exactly, if no one is there to do it it doesn’t get done. So yeah, enough work to do here’’

R: ‘’Good to hear, Let me tell a little about the research. I study the master Infrastructure and environmental planning, born in Drenthe, you might know it. Always I had passion for traffic safety, and I wanted to pick something that would intrigue me for the coming half year, so therefore I picked how to get traffic safety in Drenthe, thats how we got here at this interview. I sent the questions beforehand, did you see them?

E ‘’Yes, I saw them ‘’

R: ‘’Let’s go to the first question: As you can see in the table, traffic fatality per inhabitant is looked at to keep it fair. in Drenthe. The questions are also for Midden-Drenthe, cause they score the worst as well, just as AA en Hunze. As you can see, the traffic fatalities per inhabitant nearly doubled in 2018-2022 in comparison to 2014-2018. Why do you think that is?

E: ‘’Well if youlook at the most urban municipalities, they score best in these termst: Assen, Meppel and Hoogeveen.’’

R: ‘’ Not Emmen?’’

E: ‘’Yes Emmen also yeah, so the top 4 most urban municipalities’’ Often Hoogeveen isn’t in, but they are in this case. The more urban an area, the lesser the average speed is. If you look at a rural area, where a lot of 80/60km/h roads are, cyclists at connector roads, much crossings, then you get that (more fatality rate). So more traffic speed, more severe injuries, not perse more accidents, but more severe. If you get hit at 30kmh, it’s a lot better than if you get hit with 60/50 kmh. All hits above 50km/h are deadly, basically you are chanceless

than. Humans can't stand these hits above 50km/h according to myth busters. '' So, this is not a surprising statistic. Ofcourse, the road-design and driver behaviour are important parts of traffic safety. As well as driver behaviour, you also have the mood aspect of people, something that is out of a persons control. Tired driving is just as bad as driving with alcohol. So, mobile phone use also increased a lot lately in the car and bicycle. Especially in combination with an e-bike and cars with safety gadgets, drivers feel much safer than before. Steer assistance is so strong these days, Have you ever driven in a car without steer assistance?

R: ''Yeah I did, you can really feel the difference''

E: ''yeah you really feel it. Driving the car has become much easier nowadays so the drivers get distracted earlier. So, people overestimate their own driving abilities in traffic more. We also know that young males really tend to overestimate their driving skills. If you look at one-sided traffic accidents, the most are young males. In Hoogeveen, 1 male dies per year at the road beyond the Alfa college.

R: ''That a lot''

E: ''Lots of them are students going there. In rural areas, young people often get a car sooner, and not in the urban areas. We know that young drivers are a higher risk in traffic, they are less experienced, lesser quality of cars, less gadgets in the car, less crumple zones. For younger people on the bicycle the same goes; for starting cyclists, going from elementary to high school, the distance to school increases a lot. The first months of the schoolyear, a peak of traffic accidents in this group can be seen. In urban areas, with cycle paths, it cycles safer than when you have to cross 60km/h roads in the rural areas on your own.

R: '' that's also something that I picked up. You have the rural areas in Drenthe with not a lot of high schools, the kids from the village often have to cycle around 10km to high school.

E: ''You see these kids have more experience than their peers in the urban areas, or kids that get brought to school by their parents with the car, or kids that don't cycle a lot. You can ask yourself; if you live in a village, and the little kid is brought to a elementary school with the car, it matters it the kid cycled with their parents, which makes the kids more skillful. The habit of parents to bring their kids to school with the car and then going to their jobs brings lesser skill to the kids, something that doesn't help this negative trend of a lot traffic accidents. Additionally, a lot of senior inhabitants, AA en hunze has a large proportion of elederly people, with e-bikes as well. if an elderly falls, they have a larger chance to be fatally injured. This has impact on the numbers of the fatalities of AA en Hunze. Thus, there are so muc factors contributing to traffic fatalities, you can't put it down to 1 factor really. Besides, in urban areas, more inhabitants are present so more money is available for less roads basically. If you see what budget we have, or requestable subsidy, our budget is often the same as an urban area, but with more roads! A new subsidy from the state is coming, all 374 municipalities are ranked We're at place 304. So, there's 70 municipalities with more roads in length than us. Our little municipality, at the back of Assen. It tells a lot really. We have to do it with so many inhabitants with their WOZ value, who bring in so much tourist tax. We have to lowest tourist tax of the Netherlands. Only 1 euro 30 or something. Whereas

in Amsterdam, around 16 euro per night is paid by tourist. This money comes in the municipal budget pot. So, I don't think that there is one factor responsible. In this municipality, for years there was only 1 traffic expert. Assen has 5! + 2 on policy.

R: ''Okay, so there's differences in how many people work on these things.''

E: ''yeah, and I only have 2 hands, and 1 head. You have to go with the flow. All these villages I am responsible for. So a few factors are attributed to the municipalities, but there are also chances and challenges to reconfigure a lot of these municipalities. There are subsidies, so money shouldnt be the main concern. Capacity is a concern! I can't overview 20 villages at the same time and look at their road-design, and keep track of other rural stuff as well. These subsidies have to be formally requested as well to the state, and a plan has to be written, which also costs time, so yeah, thats a lot of work. So, a part at the municipality, a part because only so few people work as traffic expert, a part that the population is the way it is. Driver behaviour as well. These are the main factors in traffic safety in Drenthe

R: ''Good, lets go to the next question. Let's see: There might be some overlap because the answer was pretty long, which is good, so if we think we already treated the question we might be able to skip it. Onto question 2, facilities, with some maps. you can see the average distance to facilities such as GP elementaries, kindergartens… Does this also play a role in traffic safety?

E: ''Well, if you overlay this map with your traffic fatality table, I think it overlaps. you can see assen, hoogeveen, and meppel, which were the safest per 10,000 inhabitants have the lowest average distance to facilities. Emmen, which was a bit unsafer than these 3 is now also ranked pretty good. you can say about this that there is correlation between average distance to facilities and traffic fatalities per 10,000 inhabitants.

R: ''I reckon that'll happen yeah''

E: ''About road length, it are the smallest municipalities with the least distance to facilities. The largest municipalities score worst in average distance to facilities. Tynaarlo looks a bit like an outier.

R:'Okay, so distance to facilities where people need to go daily, that it means that there are more traffic volume, more fatalities, more accidents?

E: Well ,if you can cycle or walk to the local bakery, I can walk to the stores myself. such as dominos or Hema or the barber. everything is a walkable distance to my house. In AA en Hunze, like Gasseltenijveensemond.

R: 'I reckon that's not gonna be easy''

E:'' Or Anloo, they have a restaurant, but not a supermarket, you have to go to annen or assen. Or Loon, but even there it is hard. The tourism is present here, the restaurants etc, but, the daily amenities are not really present here. So I reckon that you get into the car

quickly to go to these facilities which causes traffic volume. Also, in Aa en Hunze, the N33 and the N34 pass through AA en Hunze and Borger-Odoorn.

R: ‘’N34 is the Hunebed highway right?’’

E: ‘’Yes, a lot of accidents happen there’’ Do you know the average speed there? The v85 is above the 115 km/h.

R:’’ Wow, on average?

E:’’’No, on average even higher, at 128 km/h. The v85 is the speec that 85% of traffic doesn’t exceed is around 114/115 km/h. On a 100km/h road!.

R: ‘’Okay, that’s too high’’ I’ve read theory about how speeding gives so much chance on traffic accidents?

E: ‘’ That’s right, hence why its so stupid that the government proposes the speed to 130 km/h on motorways. Whereas 100km/h is proven to decrease severity in accidents. Not perse traffic accidents but severity of the accidents. So yeah…’’

R: ‘’Okay that’s crystal clear.’’

E: ‘’ In terms of traffic accidents and fatalities the N-roads play a huge part for sure. They count for the municipality, but we aren’t the owners of the road.

R:’’ I know, there will be a question about these roads, I know the province is the manager of these roads, but as an expert I’m curious about your opinion on N-roads.

E:’’ The ing. van veelenweg in 2022 a boy, in december or so, a schoolboy had a fatal accident there. You have to cross the road at once. This is an 80km/h road, they also drive 100km/h here. So that’s rough. If you have no experience with estimating distances in traffic, which experience learns, than such bad things can happen.

R:’’ I’ve read that only once you turn 26, you gain the skill of estimating traffic distances.’’

E: ‘’ And also if you never practice it, ur brains only finish once you turn 25, after, it only gets worse. Additionally, under the age of 9, a child can’t estimate traffic speed at all, you cant expect it. Estimating speed is anyways a very difficult thing humans aren’t good at at all. People usually say that everyone drives like crazy in the street, but once we start measuring it usually isn’t that bad. People tend to overestimate that. Often they only look out of their windows, so people are bad at estimating speeds. If you are annoyed, everything looks worse. If someone moves physically, you can see the movement of the object. A car is a square box that getsgradually bigger, it’s tough to estimate the speed. At most you can say that cars are way overspeeding or underspeeding with a huge margin. Learning happens by frequently visiting the same places, and look at where the car is, so you know at which tree crossing the road is still safe. you don’t learn to estimate traffic speed, you learn where a car is to still safely cross the road. In a new area, drivers drive slower. If then the traffic situation

is unclear, than the risk of a traffic accident increases. In AA en hunze, we have 25000 inhabitants, but also 22000 recreative beds. In tourist season, our population thus doubles.

R:''Okay, I didnt know that.''

E:'' This means that potentially if you are with 3 persons in a car, around 8/9000 cars are added on these roads with people that don't know the roads here, and estimate traffic worse than the locals, adding to the risks.

R:'' Okay, i'm just checking if it's still recording.''

R: '' Okay, so moving onto the next question. Traffic fatalities per 1 billion driven kilometer (excluding motorways), you can again see as well..

E: '' So excluding motorways, but also N-roads?

R: ''No they're included. When looking at motorways, motorways tend to be pretty safe regarding traffic fatalities. ''

E: '' yeah that is correct.''

R: This was more of a question for the municipality of Midden-Drenthe, but AA en Hunze scores averagely, okaish.''

E: ''Midden-Drenthe only has a piece of A28, and that's it regarding motorways. ''

R: ''So, my guess is that we can look at the answers for question 2 regarding distances to facilities for this question?''

E: '' presumably yes. Certainly if you see Meppel, they have a car-free city centre, paid parking as well.

R:'' Yeah Meppel tends to score pretty well in all these statistics.''

E: ''Yeah, but Meppel is a very tiny municipality in surface ofcourse.''

R: '' A third of the traffic fatalities in Drenthe happen on N-roads lately,

E: (nods)

R: ''I came here by car, on the N33, 2 lanes on both sides with a good verge and a median barrier segregating the opposing lanes, other N-roads don't have these.''

E:''No, but not all of them are 2 lanes wide''

R: '' So are you in favour of making them 2 laned, or adding median barriers, or better verges?

E: ‘’ We must ensure that taking over becomes impossible whilst crossing into the opposing lane. This makes the 80km/h roads so dangerous. People just start to overtake whenever behind a lorry. you get retarted takeover maneauvores which are very dangerous.

R: ‘’I see them often enough, regardless if there is an overtake prohibition, they still do it.

E: ‘’ Indeed, they dont care, they think they are good drivers, it always ends well, so yeah.

R: ‘’So, these single lane N-roads, what would be the solution to make them safer according to you?’’

Ë:’’ Widening, or make it impossible to take over via the opposing lane. But in the Netherlands, hardening all the verges is impossible everywhere. But with the traffic volume crossing the N34, there is a good case to double the lanes just as the N33 got. Also to install a median barrier, in my opinion, if this road was in the west of the netherlands, it would have already be done.

R: ‘’ Yeah, I suppose indeed.’’ I also often see that the verges aren’t hardened on N-roads, which in my opinion is pretty dangerous, with speeds of 100km/h it can be really dangerous if you run-off road. I’ve read that verge hardening is often delayed until big road maintenance for it to be more cost efficient.’’

E:’’ yeah, also we do that, but also sometimes it isnt feasible to the soil subsidising. If you look at the Gieterstraat, which isn’t an N-road, a little distance of verges got grass pebbles, but also a large part didnt. These verges are really soft. The road just received large maintenance, it was a bumpy road. People thought this was because of the roots of the trees. This was false after all. It was actually bumpy because the soil was sand/peat sand/peat sand/peat, making the soil inconsistent. The peat was rally soft. So the road got rebuilt on stones, and the soil got thickened. Old asphalt was dumped in it, and thereon lays the road. This didn’t happen for the verges. A reason that this didn’t happen, is because the trees near the road weren’t allowed to be removed. If they don’t need to be removed, than why remove it? So, hardening verges is sometimes really difficult. If a tree is present, there is no space for hardening the verge without tree removal. A tree doesn’t begin with the trunk, but the roots go under the verge and road-surface. And to put grass pebbles at random in the verges doesnt work, because they would subside. Than you get crooked grass pebbles near the verges.

R: ‘’That would be dangerous.’’

E:’’ So, sometimes nature is in the way. Does the nature have to be removed for the road, or not? That’s the discussion.’’

R: ‘’Politics decide this?

E:’’ Together with specialists that advice. From a traffic point of view, I say, remove the trees, it’s safer. But my infra colleague will get worried about the maintenance costs. The green people don’t want the nature to be removed for a road, why not go slower there, or stay

behind the tractor, why do people need to overtake? That's the power spectrum we are in. The board has to decide.

R:'' Okay, clear.'' Moving onto question 5. I've read some papers. They state that when rural roads get their speed limit changed from 80km/h to 60km/h, they become safer.

E: '' But these roads aren't ours.''
R: ''Those inbetween villages neither?''

E: The most rural roads that we manage are already moved from 80km/h to 60km/h. The zandvoort road between Gieten and … in direction to Eext, there is one piece of road that's still 80km/h, but is nominated to be lowered to 60km/h. The Borgerderstraat to Papenvoort is not ours, but from the province.

R: "Okay, and they don't lower them to 60 km/h?

E:'' No they have their own policy wether or not to do it.'' The road between anderen and Gasteren and Loon, yeah that one is also decelerated.''

R:'' And that is because it's proven that these roads from 80 km/h to 60 kn/h are considered to be safer?''

E:'' Yeah. Not that people actually drive 60km/h then.

R:'' Yeah that's also a thing.''

E:'' The road between Assen and Rolde was even 100km/h after to 80km/h and nowadays it's 60km/h. But nearly no one drives 60km/h there.

R:'' I know the road indeed. ''

E:'' you know the road Hooghalen I presume, that one is also still 80km/h

R:'' Yup still 80 indeed. Now, let's talk about the famous trees adjacent to the roads. Do they form a risk?

E: '' Like I said, does the world needs to be asphaltised to pass safely, or do you say you want green? Seeing the climate goals, and liveability, do you want to keep the trees? Adjacent to the most 60/80 roads, you have this lane structured near the road, with trees, a historical looking road. Thus, the trees belong there historically. Do you want to throw that away yes or no? That's the consideration.''

R: ''This answer was expected, hence I have a subquestion. If the trees can't be removed, how to deal in the best way with trees adjacent to the road?

E:'''AA en hunze is decently safe, it would be nice if people adhered to the speed limit. Don't speed! Driving safely on roads with trees next to it is behavioural. On the 80/60 km/h roads, if you just adhere to the speed limit, dont use ur mobile phone, consume alcohol or other

stuff, and don't drive while tired, than you should be able to drive safely on roads next to trees. But, an accident is an accident. Stuff like a seizure in traffic can happpen. But I you just do these thing, most single vehicle crashes on these roads can be prevented.

R: ''So, regarding trees, driver behvaviour is the most important?''

E:'' Yes, this is most important on these roads. Use the N-roads if it rains.
R: In Sweden, they tested with a bar near the roads with trees. Like a barrier against the trees. Did the municipality ever think of such thing?

E:'' no, and I dont know if that would be effective.

R;" it was proven to be effective, the idea is that the bar catches the car, and not the tree. So the bonnet doesn't crash into the tree directly. Sort of a bounce is the idea from the bar.'' Like a rail, but I can imagine the people won't like it visually, because these roads are aesthethically pleasing with their lane structure.''

E:'' Maybe we can place bushes near these roads. But my cityplanner or landscape architect would maybe not agree with this, or if that belongs there. With crossing the roads it would also be more challenging than. But it is nice to read such researches.''

R:'' Surely, because traffic is more or less in Europe decently comparable. About the verges, sometimes you can see roots of trees that destroy the asphalt. So whenover, a tractor comes by on these roads, you have to go off-road, and specially once these verges are soft, it gets dangerous whilst steering back, bringing risksk.

E:'' Partly, but these roads aren't that busy. There are escape havens near the road. If you drive on these roads, and you have to be somewhere, and you might have left the house too late, and if you encounter a tractor on the road, than you must make the choice to stop somewhere, resulting in time-loss. This is safer. Or you can squeeze past the tractor at a high speed and hope that they move aside abit. Have you ever driven a tractor?.

R:'' Yes.''

E:'' Than you know that if you steer one of these wheels into the verge, it becomes very uncomfortable on such big machine. Hence they dont go into the verge. This is also driver behaviour. People net to be conscious that if you choose to drive on such touristy roads, that you have to have a touristy driving style on these roads, decelerating and anticipating tractors ahead, and perhaps move ahead into the escape havens near the road to let the tractor pass.

R:'' So again, driver behaviour basically.

E:'' Yeah, up until a certain point you can steer driver behaviour through road-design. But some roads, it is what it is. We have long straight roads in Drenthe, we didn't want meandering roads back in the day, because we wanted to get from a to b quickly. Straight roads are faster. We chose that back in the day, and now we must deal with that. Some

villages are connected through 1 road. If person A has to go to village 3, he races through village 1 and 2. Also this is attributed to driver behaviour.

R:'' you cant prevent all stuff with road-design ofcourse. So: where is the biggest improvement to be made in your municipality?

E: In sustainable safe planning. We still have 50km/h roads with priority to traffic from the right hand side. We started in some villages, from start of the village up until the end of the village to arrange a 30km/h zone. We want to make this on more places. To put more areas in the GOW 30 plan.

R:'' GOW 30 plan?

E:'' a connector road, but at 30km/h. Here it is ''alllowed'' to make a cyclist path next to it. A sort of in between form between the ETW50 and ETW30.'' Actually, a connector road is usually 50km/h or 70km/h. but in a village, you want the cars to go slower, but traditionally, there already is a cyclist path present. Die GOW 30 enables us, with some trademarks signalise to drivers wether drivers drive to fast, without the cyclists on the same road, if done correctly. Same applies to the 60km/h roads. The lining now is on the side of the roads, this can be moved more to the middle, so the road looks smaller, and then the people drive slower because optically, the road looks smaller. Furthermore, you als have the bicycle crossings. Now, they have to cross the entire road at once. In rush hour, sometimes it's impossible to wiggle through. It would be nice to have a middle haven, so they can cross in two times. On multiple roads, this can be implemented still. This depends on buying land parcels as well. We try to do this next to 60km/h roads and make a segregated bicycle path. But on some routes, people don't want to sell their parcels. What do you do if that happens? Sometimes, a whole route bar 1 parcel this works. Either you cancel the plan, or the cyclists have to cross multiple times and go along the road on the other side of the road. Does this make the road safer for the cyclist? Not indefinitely.

R:'' Indeed, this adds risks.''

E:'' This are the tough sides. But, these are the 3 things that can still improve. GOW30, not just a sign of 30km/h, but the road-design as well. At some places we placed a sign that stated 30km/h but didn't change the road-design. We should still do this. We also made a risk analysis for traffic for the municipality. We're also writing a mobility plan. In this plan, a top 20 of roads that need to be changed are written down.

R: Okay, another thing: the CROW knowledge institute advises that cyclists get priority on roundabouts. Drenthe calls themselves the cyclist province. Currently, only Noordenveld gives cyclists priority on roundabouts, with Meppel contemplating the idea. The other municipalities give cars priority on roundabouts. Thus, the rule is not consistent, making it harder for the drivers, because consistency would aid the drivers. So, why dont the cyclists get priority on roundabouts here?

E:'' That is all down to research of 25 years ago, they concluded that there was no significant difference between giving cyclists priority or not within the built up area. Like I said, i've been in the traffic industry for some time, I started when I was 16/17 years old. This was because

my ex-father in law was in the industry as well. I recall we had this discussion at the dinner table. Hence I still remember. Back than, it was a conscious choice wether or not to give the cyclists priority. Because it didn't matter that much, the choice was made to not give them priority. The rest of the Netherlands thought differently. Groningen for example. Throughout the years, more research occurred. But once the roundabout is built, you can really change that. To give cyclists priority at a roundabout properly, certain distances between each other are needed. The bicycle path needs to be atleast 10 meters distance from the road to not give them priority. If you want to give the cyclists priority, the roundings of the roundabout have to be installed properly. Many of our current roundabouts are too small to change this. Hence you can't change this easily. Do you know the roundabout in Haren?

R:'" The one if you get off the motorway?''

E:''yes, heading towards the city center.''the small one with the cyclists on the roundabout. Technically, the cyclists have the priority.''

R: ''But this one is too tight for cyclists to get priority?

E:'' Yes, and dangerous. The most recent SWOV researches, I had a presentation about it last month, because we are having this discussion again. Do we switch or not? and how? .Research turns out: a wrong designed roundabout which gives cyclists priority brings more damage and risks to cyclists, than if you don't give them priority. If the roundabout is too tight for cyclist priority, than you are better off to not give them priority. Otherwise the driver can't spot the cyclists good enough with dead angles. So, that's the challenge.So, if you standardise all roundabouts inside the built up area to give priority to the cyclists, than we need someone who looks at all the roundabouts, draws the new designs, talk to locals, because participation you know.

R: ''Yes, I know all about it.''

E: ''That's some tasks to be done. Is that achievable? for such a small municipality? is there space for it? When looking at these roundabouts and when you conclude, no this isn't feasible for this roundabout, what are you going to do? Do we remove the roundabout? Make a crossroads? Don't give the cyclists priority, and disregard the uniformity? And also there needs to be money for this, editing a roundabout costs tonnes of money.

R:'' That was a big factor for safety, the consistency in the road-design, but when I hear these struggles about cyclist priority regarding roundabouts, it's quite the hassle.

E:'' Yup, but if you have a blank space, if you can choose between giving them priority or not, the costs aren't that much of an issue. But whenever a roundabout already exists, it gets complicated to edit it. Even more so if the roundabout is made just recently.

R:'' Okay, that's clear. Moving onto question 10:

E:'' Sadly, I didn't have a black and white answer.''

R:'' No, I get that, as often is the case in traffic, right? How can the municipality improve the traffic safety? I think we already discussed that?

E: ''Yes we talked about that. And about decreasing the traffic fatalities as well.

R:'' Okay, lets see: Are there still changes in policy and infrastructure…?

E:'' Yes they are ongoing, the spv 2030 from the state and province as well. Our own SPV ''strategisch plan verkeersveiligheid'' with the risk analysis instead of looking at traffic fatalities. We're now focussed on risks, what groups of traffic, or vulnerable traffic participants, the road-design. 6 themes, such as are large vehicles passing by, are cyclists present. 6 themes give a certain scores, if you don't score as well on any theme, you get points. In lesser way, a score of 0.33 or 0.66 or 0.5 can be attributed to one's own insights. This way, you get a score for a road, and than you know wether to take action in such a road. This is another way to look at traffic safety instead of looking at the traffic accidents. Whereas, a traffic accident is not a black and white event, but tonnes of variables are present at a traffic accident. In the risk analyis we are trying to get these variables mapped in this 6 themes. This is something we are currently doing, and are busy with the mobility plan, which is based on this risk analysis. What we want in policy, is seated on the research we've done on the roads.

R:'' So, a risk analysis is being conducted on these roads, considering these 6 themes, where points are being given to roads

E:'' Officially, there are 9 themes, but alcohol consumed driving is also one of the themes. We've picked 6 themes that are measurable, whereas the 3 others are less measurable. If lots of elderly people live somewhere is difficult to measure in traffic. However, a school route or cyclist travel patterns are measurable.

R:'' Okay, question 12 we've touched upon in terms of factors.

E:'' Yes.''

R: ''Road-design, i've heard that narrowing a road, theoretically, that people tend to drive slower, and more careful, thus creating a safer road.

E:'' Yes. This makes the road safer. Just as consistency in road-design. For example, there was a crossroads here in Gasselte, at the borgerweg and sodemarserweg, you might be able to find on google maps how it looked before after and now. It is a hugely touristic road, Indeed, the whole area here is pretty touristy, but Gasselte is by far the most touristy. Lots of cyclists, school go-ers, regular car traffic, and no separated cycling path. One side is going out of the village, onto a separated cycling path, next to a 50km/h zone, and outside of the built up area it became a 60km/h road. On the crossroad, as a cyclist, cross from a 30km/h road to the other side of the road to the cycle path, across the crossroad onto the cyclist path, and then it got 50km/h to follow the way. But, on the crossroads, the cyclist had to watch 4 different directions for cars and cyclists. I've some videos of this situation. Cyclists had about 7 directions which they chose to pass this point. This illustrates that this situation was thus completely unclear, because when you arrive at this crossroad, you have to check

the traffic, cross the road and make it across the cycling path, but also check the ongoing traffic and other cyclists, too much choices in a square meter. Moreover, advertisement boards were also present at this crossroads. Thus, next to the difficult situation, and the advertisements and also the end of the 30km/h zone, the cyclist had a lot to digest. So we took these factors apart. This is an example that we can lessen the burden on a traffic participant through road-design by segregating these choices and directions from eachother, prioritise the right hand side. This way, cyclists could cross the road later, at a better spot, and lengthen the 30km/h speed limit zone further, and not only a short space in front of the crossroads, becausewhen it was only a short length of road where the drivers had to drive 30, none of them did. So, we made choices to lessen the choices of the traffic participants in one area and spread them out more, so they make safer choices.

R:'' So, ensuring the driver to not multitask all at once.

E: '' Yes, we can't do it all at once, it has been known for some time that we cant multitask. We can switch between a lot of tasks real quick, but we can only do one at a time. Everytime you switch task, you lose, power and attention. We reconstructed that crossroad so that instead of 6 tasks at once, now the traffic participant only has to do 2 at once.

R:'' So less distraction for the driver.

E:'' Yes, the same goes for wether a cyclist has to cross a road in one go or has a safe-haven. They have to drive on the road, check both directions, estimate the speed , which we can't as I said, and then cross the road, which potentially has another street, you dont know. By facilitating a safe-haven, you only have to check one direction and the distance you need to cover is less. Choices are thus made easier, and better.

R: ''Okay, now comparing Friesland Groningen and Drenthe, and the Netherlands even.

E:'' Can you show me the questions once more?

R:'' Sure, Drenthe has less traffic accidents than the others,

E:'' yeeej''

R:'' Which is good ofcourse. However, there are more traffic fatalities per inhabitant, as the graph shows. Even Overijssel scores better. As you can see, Drenthe scores lowish in terms of total traffic accidents, just as Friesland. But if you look at traffic fatalities, it can be seen that Drenthe scores worse than the others.

E:'' I think less accidents… hmmmm,, less busy roads in the other areas. The data calculates in per inhabitant but not in terms of road surface. In Drenthe, the amount of elderly people is a lot higher than in the other provinces. Just as young people that have to bridge longer distances to facilities as well. Furthermore, like I said, the 18 year old boys is also a weak group.

R:''' But, it can be said that the group of 18 year olds are also present in the other provinces.

E:'' They are there, but, in AA en Hunze, the percent of seniors is 54%. I have it in the mobility plan, I don't know it by heart. But it's higher than in the other provinces.

R:'' I indeed have written down in my thesis that the percentage of elderly people indeed is higher than in the other provinces.

E:'' you can say that these elderly people have a lot of experience in traffic. However, their reaction time decreases. They take longer to take decisions and perhaps have worse vision. Their movements are also stiffer, and can't even turn their heads on the bicycle sometimes. The mirror doesn't always help them out, and the distance is harder to estimate in a mirror. They are also more vulnerable, weaker bones, makes them more vulnerable than younger people. This is surely a cause for the higher number of traffic fatalities in Drenthe.

R:'' I really found this interesting indeed.''

E:'' Yes you can see that in every.. Oh no, not Flevoland. But you can see in the chart that all traffic fatality numbers go up.''

R:'' Yes indeed, that's one of the reasons that i'm writing this thesis is that the trend of traffic fatalities is at an increase.

E:'' That's why I really can't understand that our new cabinets parties, one of the few agreements they have is that we're going back to 130, or even 140 km/h. Whereas the government wants the traffic fatality number to go to 0. Guys, we are heading into the wrong direction this way.

R: ''0 traffic fatalities in 2050 was the idea right?

E:'' Yes, the reason behind the 0 was that everything above 0 is in theory unacceptable. I can't say, 50 is also okay. Than we get weird discussions. A friend of mine his job is to calculate how many fatalities in a fire are acceptable in a building regarding square meters and height etc. There is an acceptable amount of fatalities, to calculate how safe a building is.

R:'' Yeah that's bizarre.''

E:'' What is enough, the only acceptable should be 0 right? But how realistic is that? In this discussion also. We've said 0, but in anyway not a rising trend in traffic fatalities!

R:'' Yes, but it looks like it is going that direction currently.

E:'' Less is better, but this is not good right now. you would say that Geert Wilders is behind ''less''…

R:'' Moving onto the rural and urban municipalities, as you can see here, the percentages of accidents that turn out to be traffic fatalities, you can see that AA en Hunze doesn't score greatly, and you can see that the more urban municipalities have relatively many accidents, but not so much traffic fatalities.''

E:'' I know one of the cases in AA en Hunze in 2022 was because of a heart attack

R:'' That's something you can't do much against.''

E:'' No, if you subtract that case, it goes more to the amount of Westerveld,
R:'' Yeah, as ever I have to work with the data I have,

E:'' the boy is also in these cases, 22, yes. Meppel has none at all sometimes.

R:'' The different data sources didn't always align with each other. I used the BRON, and also the SWOV, and the CBS, and they did align. But sometimes they didn't all align their statistics.

E:'' These statistics about the traffic accidents isn't complete, and thus not reliable. This month, a dashboard the numbers about first-aid and general practicioners is being launched. Because thhre are lots of accidents where no ambulance or police is involved at all.

R: ''That's right, the data I used stated that they based their numbers on police reports and insurance claims. That's all their data is based on.

E:'' So, if you have vehicle damage, or if a person requires an ambulance, than they are recorded. However, if a persons has to brake on a bicycle, and fell and injured his knee, and later that evening goes to the general practitioner, they don't come in the data.

R: ''nope indeed, they dont show up.

E:'' Thus, we hope for a better picture of the situation, but I reckon that an explosive increase in cases is to be expected if more is reported, but also a better picture of the real cause of al the traffic accidents. THis than again leads to a better risk analysis and thus also a better policy plan. yes. In my opinion it would help if the press would release an article that the e-bikes are dangerous, that people think, lets set the speed of my e-bike at 18km/h instead of 25 km/h. Peddle assist is one thing, but why do they need to go so fast?

R:'' Their speed limit is 25km/h right?

E:'' Yup.'' It would be best if the users of the E-bikes can decide for themselves up until which speed the e-bike gives them peddle assist, that would be best.

R:'' Just as before, the percentage of traffic accident with a fatal ending, Drenthe again scores more fatalities than the other provinces and Dutch average. Is his attributed to the same reasons you just mentioned? like elderly people in Drenthe, etc.?

E:'' Yes.

R:'' Alright, onto the last question now. Cars and bicycles are the most frequent modes of transport involved in traffic fatalities in the Netherlands. Note, this is focussed on the

Neterherlands as a whole, as you can see, overrepresented. How can we protect cyclists better in traffic?

E:'' By not allowing cars and bicycles to be on the same roads.

R: ''So separate cycling lanes?''

E:'' well, yeah. Cars have become bigger larger stronger heavier, etc.''

R:'' SUV'S these days indeed have become large etc.

E: As a cyclist or pedestrian it basically leaves you chanceless against a car when run-over. The cyclist hasn't changed. Still a human on the bicycle. you can put on a helmet, or even fall protection gear with some kind of inflatable thingy. But now one uses it ofcourse of course. Helmets slowly getting more used, yeah, cars should alter their speeds a lot more to accommodate bicycles and the road-design should be more catered towards the cyclist rather than for the cars. When looking at Haren, it is clear that the car is a guest there. The other modalities are: does the car have priority ? - which isn't helpful for speeding e-bikes. I think that one of the few things that work is to reduce the speedlimit and enforce it as much as possible. This way, the connectorroads become such uncomfortable experiences for the car drivers that they prefer the N-roads more. Anyway, this might relocate the problem, as the N-roads would get more congested.

R:'' Okay, when you said making the drive uncomfortable for the car drivers, do you mean speed bumps? How should I envisage this?

E:'' Crossroads, speedbumps, lots of corners. One of the tools to do this is to make the border of the built up area that small that only one car can pass at a time.

R:'' Yes, I've seen those measures around.''

E:'' That is a very evil one, terribly annoying. But it makes people think that they take a detour elsewhere. As long people don't detour through other villages, because that would relocate the issue. But if everywhere is equally, annoying, it works appeasing. yes.

R:'' So the trend that, I live in the city of Groningen myself, the urban city centers, i's everywhere hostile towards the car, 'car as guest', one way streets, etc. Is that the idea to implement in rural villages as well?

E:'' Surely in the villages. That you make it in such a way that you get the idea that the car doesn't belong there. Let's drive slowly, yeah.

R:'' Okay, so that would also be in the form of a ''car is guest'' format like at the trainstation in assen? Like you may know?

E:'' Cycling street you mean?

R:'' Hmm yes, it says cycling street, and near it the sign says auto is guest'.

E:'' That's the short space in front of the …house. yeah, that is basically a one way road for destination traffic. The possibility is still there, but actually it is a cycling path. But because there have always been building there, the choice must be made, and in this case, they gave the cyclists the priority. But yeah, in Rolde, a shared space was tried. However, a shared space in a city, no tractors pass by, and in a village, they are present. So whenever constructing a shared space, but you have to take into account the agricultural traffic, its difficult. As well as, when taking a lot of traffic calming measures, the public transport sector will notfind that funny. The longer their journey, the more costly. This way, it's safer for traffic, but the bus can't pass this road anymore. Whereas we want to move the people into the buses of public transport. Now we see again, that we are in this power matrix in terms of traffic. Any choice has negative impacts on other sectors, making your choice a consideration of multiple factors. It's not a mathematical formula, where if you put in one thing, you can see what happens. There are so many factors in play, and they are not always influenceable, even though you might have unlimited money. Even than, traffic is not malleable.

R;'' And that is what makes traffic policy so hard.

E:'' And because traffic is not malleable, we have to change our behaviour. influencing one's behaviour is very difficult.''

R:'' Okay, that sounds like a nice closure. That was it. I Would like to thank you!''

Appendix E - Transcribed interview with traffic expert from the municipality of Midden-Drenthe

R= Remco
E1 = Mobility expert of the municipality of Midden-Drenthe
E2= Traffic expert of the municipality of Midden-Drenthe

R: As you can see in the provided Table, the municipality of Midden-Drenthe scores the worst in terms of traffic fatality per inhabitant in the period of 2018-2022, the first question is why do you think that is the case?

E1: I think that we have a lot of rural areas. Lots of rural roads with trees alongside it, and some roads with the speedlimit of 80 km/h, which we want to amend to 60km/h, those are some factors that make Midden-Drenthe less safe in terms of traffic safety. I can't proof this, but it could also be the case that lots of people go drinkingshacks, are you familiar?

R: I know them yes

E1: Lots of partying is going on there, and then the people are getting in the car drunk, whilst very drunk, which unfortunaly happens a lot with younger people, and then they run off-road or out of the corner, You have lived for some time in Hooghalen I heard? A few years ago at de Streek a car went off road against a tree, but was drunk at the wheel. This gets us a high traffic fatality number which we can't do anything against.

R: Indeed

E2: Indeed, like E1 says, we're a rural municipality with a lot of straight rural roads with trees adjacent to the roads. As can be seen in the data, a lot of one-sided traffic accidents happen here, people crashing in trees. you also see that cyclists get hit when crossing the roads between trees, you see this a lot. This has to do with that we're a rural municipality. We have more straighter roads, the low sun shining through the trees, and also, like E1 said, individualism, drunk drivers and drugs are stuff that play a role. And then the tree is easily hittable. With municipalities with less trees, the same happens, drink-driving and driving with drugs, but there it often has a better ending because there are no trees adjacent to the road.

R: Okay,

E1: If you have less rural areas, Emmen has the most roads, but they have a clear centre and is the largest, but after that, Midden-Drenthe has the most road-surface of all drentse municipalities, approximately 850 kilometre. So, that's from Hooghalen to the top of Switzerland laid out.

R: That's some distance indeed, yeah. I also found something, which isn't included in the questions, as I also dived into the drink-driving case. The only proof currently available is the amount of fines per inhabitants for drink-driving. Drenthe scores the best out of all of the Netherlands. So, in Drenthe, in terms of fines, the least drink-driving happens. Do you think that is distorted?

E1: Less chance of fines I think. I believe, but i'm unsure, maybe cynical, on a Saturday night there is about 1,5 cop for the whole of Drenthe or a few municipalities. Look, Drenthe is pretty large, so ofcourse, hmm, it's difficult to know where those people are. Back in the day, there were a lot of discos, the cops could stand outside. But nowadays, the younger people are in these drinking shacks, a club of around 10-15 people, and a club over there. Back in the day big disco's or village parties existed. Than the cops know where the chance of drink-driving is high.
R: Exactly, okay.

E1: But it's nice to hear that we are scoring good on that. But i expected differently

R; Indeed. So moving onto the second question, which i made a nice map. We can see the average distance to facilities in the map. We can see that Midden-Drenthe, bar Westerveld, is averagely the furthest away from facilities as general practitioners, kindergartens and elementary schools etc. The question is: Do you think this contributes to the negative effect on traffic? That the most facilities are far away.

E2: Yes, hmm,

E1: You mean that people have to travel more distance before they are at a facility? ehh yes. That's right. The more kilometres travelled per inhabitant, the more chance there is at a traffic accident. That is a fact. But, if we look at the amount of inhabitants, could the facilities be closer? I think the answer would be no, that people want that.

E2: If you look at the map, does E1 also have it in front of him?

E1: Yes

E2: Than you can see that all rural municipalities and small centres Westerveld, Midden-Drenthe, Borger-Odoorn and AA en Hunze are all around the 4km. Urban municipalities Hoogeveen, Meppel and Assen, where the population density is a lot denser, these municipalities average around or under the 2km. So, what you can see is that according to me, a municipality with a lot of small villages, seeing you resided in Hooghalen, there is an elementary. But in Zwiggelt, there was an elementary, in Oranje, there was a school, but it's gone now. Because, in these places there aren't enough students to keep the school alive. If the school is gone, than maybe also the schooldoctor, the general practitioner or the bibliotheque bus that came once a week disappear. This is all related. Because we have so much small villages, the facilities disappear.

R:And thus this contributes to more traffic, thus also more chance at a traffic accident?

E2: Yes, definitely. More traffic, and other traffic flows, if something is resided in your own village, you perhaps take the bicycle. Outside your village, you take the car. Thats the reality.

R: Okay, clear. Moving to map 3 and question 3. We can see that Midden-Drenthe has, in terms of traffic fatalities per 1 billion kilometres excluding highways like the A28 I must sidenote.

E2: But provincial roads are included?

R: Yes those are included

E2: In ur research, have you excluded national roads and provincial roads?

R: For this map,
E2: As a municipality, we got the A28, going straight through our municipality and also the N381. Those are pretty busy roads, where within our municipality, lots of accidents happened. The A28 as well as the N381. So in your research, lots of traffic flow through these roads are included.

R: That's right. For this map, i excluded the highways, but not the provincial roads, because i want to demonstrate that these roads a very traffic accident prone.

E2: The n-roads are ofcourse managed provincially.

R: I know, you are not the road authority there, but I still wanted to gather your opinions and thoughts about them

E1: The n-roads, like the N381 are the most dangerous roads that exist because you drive 100km/h, without a median barrier. There's only the green line. The chance that something goes wrong is the greatest. And when it goes wrong, it goes very wrong. The safest roads are either the motorways or the 30km/h roads. All inbetween are safe in general. Your question concerns 1 billion traveled kilometres. For municipal roads interventions can mean that we still have some roads with a maximum of 80km/h. But we want to change that to 60km/h. The places where we have great-maintenance, we are going to apply road measures to make these roads 60km/h.

R: I understood that indeed, yes. the road from assen to Hooghalen, is currently set at a speedlimit of 80km/h. But is the road from your municipality or from the province?

E1: Thats ours.

R: So with the next great-maintenance, this would be an example of a road to be scaled down to 60km/h.

E1: That's a possibility, but with the road near Hooghalen there is more in play. Hooghalen has a village vision. They want to see what's possible in the village. One of the things for our concern is that we have to look good at certain things. For instance, you have the Oude Provincialeweg, or Asserweg, there's also a paralelroad adjacent. Can we decelerate the roads? But it also depends on the plans of the village. But, yeah, traffic wise the nicest would be to make the paralelroad a proper segregated bicycle road or path. So that all car traffic can be on the other road. Factually, Hooghalen has luxury facilities, because you have the motorway on the one side, with the entrance at the TT, there is the paralelroad and the regular road.

R: Choice aplenty indeed

E1: So yeah, maybe from a point of view from traffic flow from the past this situation was logical, but now it's very illogical. But, as I said, if you have 850km road surface, you can't from one side change everything. If we tackle 1km of road surface without anything else. That costs us 300.000 euros. For solely replacing the top layer.

R: Okay

E1: some traffic measures are also needed than, so if we tackle 1 kilometre of road, it costs us about 400.000 euros or half a million. That's gonna hit hard when you have much roads. So we have to make choices what we have to do, and look smartly how to use our money. Otherwise it's impossible.

R: So, for you it's more of an issue of money or a matter of capacity? Because I spoke with another expert in the field of another municipality. She said if I write a correct plan, there is always money available. but I'm the only person approximately working here in this job. Thus, it's more of a capacity issue. But that isn;t the case here?

E1: Partly, ofcourse if there is a good plan, money usually comes available, but the money isn't unlimited. Often we try to combine with smart stuff, because otherwise the money is thrown away.

E2: Ofcourse we always try to make estimates. Which roads are in the worst conditions, which ones really need maintenance? WHich ones are the most dangerous, where are the cyclists still on the road? These are the roads that we think about earlier to decelerate to 60km/h than for example the road from hooghalen to assen. The structure is different there, and there is a separated cycling path. This is how we look at this from a traffic perspective. If there is great-maintenance somewhere, than we must look if there is money available to amend the road and decelerate the road.

E1: I dont know if you know smalbroek? If you drive behind Beilen to Spier?

R: No, less known there

E1: That's a parelelroad near the motorway. This is a road that we are gonna alter. We are going to decelerate. At one point, cyclists don't have the priority. So with the maintenance, we are going to decelerate this one as well immediately.

R: Okay, that brings us to, we already discussed question 4 partly, about dangerous N-roads. It appears that a third of the traffic fatalities happen on N-roads. The theory suggests that a median barrier or a mid verge, I know you aren't the road authority at the municipality. Would you think this would solve the problematic N-roads? Or perhaps something else like a prohibition for taking over etc?

E2: I don't know the correct solution. These are rigorous measures on roads where you can drive 100km/h to put a median barrier there, it's a costly measure.

E1: And also, I find this question difficult because N-roads are for example the N381, which you know, with a speed limit of 100km/h. But along Nieuw-Balinge there's another N-road which meanders to Sleen and Elp etc.

E2: n371

E1: Yes hmm no it's another. In Smilde you have the N371. Between Beilen and westerbork you have the N856. So, the N-road N381 is vastly different than the one between Beilen and Westerbork where agricultural vehicles are allowed. If you implement a prohibition at overtaking there, or a median barriers, you can't overtake them. So, a highway is very clear. But n-roads are a big collection of different roads basically, they all call it distributor roads (gebiedsontsluitende wegen), and it's provincial. But there's lots of types of N-roads. So, if measures are applicable on all these roads, I'm unsure. The N-roads where 100km/h is the speedlimit it might be a good idea.

R: As for the rest, your conclusion would be that these roads cannot be generalised under 1 size fits all?

E2: No, it really needs tailor-made solutions. Some n-roads for example still have trees alongside them. So per road tailor-made solutions are required on how to make them the safest.

R: Okay, we just briefly touched upon it. The theory I found is, that decelerating the rural roads from 80km/h to 60km/h is effective, and better perhaps. We discussed it briefly, but why isn't this applied more in your municipality?

E2; We are working on it, especially with great-maintenance, we try to create work during works. We are really looking at whenever maintenance is happening on the road, to lift along with the traffic measures, because it's costly to alter a road that's in decent shape to decelerate it from 60km/h to 80km/h. The speed limit has to be believable, so wer are trying to lift along with maintenance works at that moment.

E1: From the past, they made political choices for speed limits concerning 80km/h or 60km/h, and as a civil servant, you have to adhere to that. We make proposals ofcourse, but within the context of the law, because 80km/h on rural roads is legal, the politics sometimes choose differently sometimes. Right now, their policy focusses on making the rural roads 60km/h. However, when looing at provincial or N-roads, I would suggest keeping these at 80km/h. motorways are 100km/h. perhaps they go to 130km/h. But, right now I have the opinion that the difference in speed between 60km/h and 80km/h and 100km/h is rather small, only 20 km/h. Even more so when you are driving faster than 80km/h on an 80km/h road. Our roads are usually the smallest of the municipality, and if the speeds are aligned more closely, than you get a lot of unwanted traffic on all sorts of roads. If you allow 80km/h or 100km/h on provincial roads, but on our road only 60km/h, than it serves as a motivation to take the provincial road rather where you can drive faster than the rural road for a certain group of road-users.

R: Okay, logical, that's something the other expert also said that the municipality wanted to move the fast drivers to the provincial roads, and demotivate them to drive on the rural roads.

E2: And later on you can drive 130km/h again, so that saves time.

E1: I want to see it first

R: If they can find the signs again.

E1: yes. But in principle, they can remove the 100km/h signs and than it would always be 130km/h right?

R: That could also work I guess. Regarding the trees, adjacent to the rural roads, which we discussed. What does the municipality do regarding maintenance? Could it be improved?

E1: Regarding road-maintenance or tree maintenance?

R: The effect that the trees have on the roads. I'm talking about the roots of trees damaging the road surface for example. These roads tend to be narrow. Whenever a tractor comes along you have to detour into the verges, and often you can see that the verges are pointing upwards, or badly maintained, not very pleasant when driving there.

E1: For example at de Streek?

R: For example at de Streek, yes.

E1: cutting down trees is difficuly. It's only possible with a good plan. If we don;t have damaged verges, there's nothing to be done. If there is verge damage, we have 3 solutions. if there needs to be moved into the verges, the verges get filled with rubble and stuff. That is small-maintenance. We have 850km road surface. If half is in rural areas, that's more than 400km, but ⅔'s is also 800km verge. I calculate verge hardening, with concrete in the verges. i calculate 1 meter concrete strip is 50 euros. Thus, both sides is 100 euros. If you have a road of 1km, it costs you a tonne. That's a lot of money. So, 400km road surface, than it would cost 400 million if we want to make the roads like that? Hence why we discussed that on lesser visited roads, we make safe passing havens. These are stelconplates of 24/26 meters long where road users can wait on each other. This means that verges can be pretty bad, but there is a safe location to wait on incoming traffic, so you can pass each other safely.

E2: If we look at CROW, some roadmap exists regarding trees in the obstacle free zone, you first look at decelerating the road, this means creating a piece of safety. Another measure is to relay the side-stripe a little, or whenever possible, shield the trees, and when that all isn't possible than we cut down the trees. There is a road map for this to check the possibilities before cutting down the trees.

R: I heard from the other traffic expert as well that the landscape architect and or the tree hugging people might be angry when cutting the,

E2: Very well possible, but sometimes it is really needed from a traffic safety perspective to remove a tree, than there is no choice.

E1: Sometimes indeed, but is is hard to remove trees. What they did in the past, is plant trees at 6 meter distance from the road. When they were grown, they cut down every tree inbetween.

R: Okay,

E1: Otherwise, these trees got too little space. But nowadays this isn't possible anymore, or at least, protests or anything, and thus than the tree remains. Some roads have multiple rows of trees behind eachother. Sometimes, 1 row is planted, or 2, and that the first row of trees is sawn for the lumber production. That way, wood provision was present. But nowadays, when sawing 1 row of trees away, everyone finds it difficult. Ofcourse we have a tree challenge, but sometimes there are choices made in the past, that are very hard nowadays.

R: Okay. Now a more general question is coming: Where do you think the biggest improvement in terms of traffic safety can be made right now in your municipality?

E1: i think decelrating from 80km/h to 60km/h and consistency in road-design. You also see this in different years, you know duurzaam veilig probably? iN the start, these measures were pretty general, and sometimes very extreme, for example, in the built up area, every 150 meter a speed bump was advised. So at one point, these measures and guidlenes were amended. Nowadays, you see alot more that clarity and consistency in road-design should be visible. it remains difficult. If you have a blank canvas, and you create a neighbourhood, everything can be created perfectly as it is prescribed. But, when dealing with existing situations. you have lived in Hooghalen yourself, but Hooghalen is way different than Smilde, or Oranje. So, a village wants to keep its own identity. There we must see that within the consistency in road-design that we keep the identity of the villages are kept alive. This is quite a puzzle. We also don't want uniform generic VINEX areas everywhere where everything looks the same. Because that's the charm of the Drentse villages.

R: Absolutely, I think we can all agree on that

E2: Like E1 says, a lot of stakeholders are involved in road-design. Farmers, inhabitants, bus-companies. There is a large scala in stakeholders involved. We don't want to plant a village full with speed bumps. A balance should be found. There is through passing traffic, recreative traffic. There's so many facets, so we are looking for consistency in road-design so that traffic participants can read the road-situation. For example in a 30km//h zone to put level-floored junctions, or to create intersection surface of the same material, to try and address that. But we have to keep the village vision in mind also.

R: So that is also a case of tailor-made solutions

E2: Surely, all concerns regarding traffic and such, like E1 said, if you have a blank canvas for a new area, you can perfectly design the traffic situation adhering to the best safety

standards from the CROW, like separated cycling lanes, parelelroads, 50km/h roads. Than we have the perfect roads. But right now we simply have to deal with limited space.

E1: There is also a different origins of the roads, in smilde you have the canals etc. Thats very different than hooghalen, and hooghalen looks very different than westerbork. So the origins of a village also matters. Herein we have to look at consistency in the road-design. For example in the calm side of the canal in Smilde, if you want to achieve a speedlimit of 30km/h, other measures are needed than in the laaghalerstraat or the stengelinstraat in hooghalen for example.

R: Okay. Regarding the consistency in road-design. The CROW, which I heard mentioned just before, write in their guidelines that they want the cyclists to get the priority on roundabouts in the built-up areas. Right now, in the cyclist province of Drenthe, as the province calls themselves, only the municipality of Noordenveld has implemented this. Meppel is considering it, the rest is not doing this as of yet.

E1: This can be nuanced a little, all municipalities are thinking about it at the moment. Lately, there was a meeting with all the municipal councilors, where they discussed the idea. Right now, there are exceptions, but in the political world some movement has happened to see if something can be done. Imagine if we give the cyclists priority on roundabouts, what does this mean regarding modifications or costs, or execution and such. But a lot of municipalities are thinking about it. All councilors have met eachother regarding this topic.

E2: If you look historically, the SWOV did a lot of research in this topic, but it was a long time ago, so it isn't relevant anymore,

E1: I'm off to the toilet for a moment

E2 and Remco: Okay

E2: Actually, that research has to be redone again in the current times again. What can be seen, is that not giving the cyclists priority on roundabouts, was proved to be safer than giving them priority. Back then, it was decided to keep it the way it was because it was extremely expensive to modify 3 quarters of the Netherlands to accommodate cyclist priority. But, for consistency in road-design, we in Drenthe are contemplating the idea. However, with designing the roundabouts it's very difficult. to prioritise, or not prioritese. We're currently working on a project through beilen and the discussion is alive ofcourse right now at the roundabouts that we are going to install in these plans. If we do it now, the rest of beilen also has to be looked at. Than we also have to look at all the other roundabouts in Midden-Drenthe. This would also be very costly. It's an ongoing discussion. If all councillors decide tomorrow that we are going for it, than there is a strong incentive for everyone to say we're also going to do it ,as the surroundings will also do it. The municipality of Noordenveld has done this, they are adjacent to Groningen, making it easier of course because of the overflowing effect of Groningen.Besides a little piece of Noordenveld, we don't have adjacent municipalities whom also do it. Everyone is in the waiting phase.

R: I get it indeed, it's the consistency in road-design that makes traffic for the traffic participants more pleasant, because something is always the same. But indeed, the other

expert said that certain angles of existing roundabouts have to be modified, so that drivers can see cyclists in their blind spots better.Thus, the priority signs cannot be simply modified for the new priority on roundabouts to work.

E2:Modiciations will be needed here and there. Sometimes, modifications cannot be done immediately. Harshly said, than we have to deal with the situation at that given moment. If we now look at road that we decelerate from 80km/h to 60km/h, one has great-maintenance, so we can design it perfectly according to the guidelines. But on other roads, we cannot modify that yet because there isn't any money available to design the road for it to comply to the design principles of a 60km/h road. At such a moment, we can say, we change the signage, because the whole surroundings are amended to 60km/h roads. But the design principles are than to be done when there becomes money available. In this way, in all the surroundings, there is a consistency in road-design and uniformity in the speed limit of 60km/h is achieved. But i's an ongoing discussion that has been going on for a few years. To be continued. I hope I can still experience it one day.

R: Okay, we spoke about this, which factors influence the cause traffic accidents and severity of accidents the most according to you in Drenthe?

E1: The question above, you skip question 11? regarding policy and infrastructure?

R: Yes, I reckoned we discussed that topic sufficiently already.

E1: Okay, but I have a nationwide addition. If I look purely at speeds, in my opinion, usually it was 80 km/h, and those still are the normally appicable speeds. But, actually there should be a decision at national level that, whenever a speedlimit sign is not present within the built up area, 30km/h should be the speedlimit. Outside the built-up area 60km/h. That would be really helpful. In my opinion. Additionally, I find there to be too many speed limits in the Netherlands.

R: I can imagine that thought.

E1: Because, there is a speedlimit of 30km/h, 40 not, 50km/h, 60km/h, 70km/h, 80km/h, 90km/h. 100km/h, 120km/h, and soon 130km/h. In my own stupidity, I tend to think, why haven't we thought of making it 30km/h, 60km/h, 90km/h, 120km/h? Steps of 30km/h, aligning with each other. So whenever you leave the built-up area, you know that you may drive twice as fast from 30km/h to 60km/h. Like this, it becomes a lot more unambiguously. If you can drive 50km/h or 60km/h, it matters nothing at all or doest it? But that is my interpretation. Anyway, just create 4 base-speeds instead of 30/50/60/70/80/90/100/120. Those are 9 speedlimits. If you count in neighbourhoodspeeds, walking pace at 15km/h, than we have 10 speedlimits! Than nobody knows where he stands anymore.

R: That's a good point.

E1: How much consistency in speedlimits are there to be achieved with this many speedlimits? If there are 4 speedlimits,than it is more clear which speed belongs where.

R: And than there is less possibility of doubt among the drivers I think.

E2: Exactly.

R:Returning to factors again. Which factors contribute the most to accident severity or the cause of traffic accidents in Drenthe?

E2: a lot of rural roads, trees adjacent to the roads, low sun. These are the factors. Also driver behaviour Individualism such as impaired driving like drink-driving or drugged driving.

R: Okay, that's in line with stuff I've read. Concerning road-design, I think we talked sufficiently about it. You need to design the road in a manner that the speedlimits are believable and thus force the driver to adhere to the speedlimit, that they can see it. So, we got to question 14, which has a graph. We can see that Drenthe has less traffic accidents than the Dutch average and Friesland and Groningen. However, when we check the graph below, which is the graph of traffic fatalities per inhabitant. We can see that Drenthe sscores worse than the Netherlands, Groningen and Friesland. Shortly said, Drenthe has less traffic accidents but more traffic fatalities than these. Can you explain why?

E1: Or, if AA traffic accident occurs, at least, this is the way i interpret it. If an accidents happens here, because of all the factors that we've just discussed, the severit of the accident is is often pretty hefty. If you drive in te polder, where there is only meadows, and you have a traffic accident, you run off-road in a meadow. THat is less severe than whenever you run into a tree. Perhaps in Flevoland, a traffic accidents results in no injuries, and in Drenthe, you do get an injury.

R: Okay, you can see indeed that Flevoland scores remarkebly better than the rest.

E1: Yes, but ofcourse that's a very newly designed area. Have you ever been there? Broad roads, broad verges, segregated cycling paths and such. I think that if we look at speeds, we have a colleague, he worked in marknesse and surroundings for a while, He loves to drive quickly, he gets high average speeds there. he states that a lot of speeding happens there as well, because of the long straight roads. It used to be canals of course. Perhaps the verges are broad, the trees further away from the road. For cars a tree is a nuisance. But back in the day, with horse and wagon, or the bicycle, you would be happy there are trees, as they shield the wind.

R: Indeed, Flevoland has been more of a blank canvas where you talked about before. Moving onto question 15. There are some graphs again. The urban municipalities, as was also shown in the table of question 1, have more traffic accidents, but less traffic fatalities. Perhaps this is an open door, but can you tell me why this is? E2 is on mute I think.

E2: I was talking to my son, who doesn't have a shirt on, you can't be doing that.

E1: Because speeds are low, what you can see in Beilen as well. The location where the most accidents tend to happen is at the supermarket.

R: you mean in Drenthe, or midden-Drenthe?

E1: In Beilen, shopping carts crash into cars, or people driving at the back of a line crash into other cars, or whatever, but rarely these crashes yield injuries. Thus, I think in urban areas, the space is a lot tighter, but the speeds are a lot lower. The chance that you hit each other is larger, but the chance on an injury should be much smaller.

E2: That's right.

R: Than we move onto the last question: The last graph shows that nationally, because i couldn't find good data about Drenthe, in terms of traffic fatalities, cars and bicycles are overrepresented. Is this trend also visible in your municipality?

E1: I think so, you can do a difficult analysis on this, but I think that in terms of mode of transport, most people use cars and bicycles. There aren't as many lorries or mopeds. Thus, it's logical that these are most present in traffic accidents because they are on the roads the most.

R: Than it's also logical, as you can see in 2022, that in the Netherlands almost 300 traffic fatalities on the bicycle happened, whereas car traffic fatalities stood at 220, so you can see that more cyclists were injured fatally in traffic than car drivers. This can be attributed to vulnerability?

E2: I think so yes, in Drenthe ofcourse we have cyclists that have to cross 80km/h or 50km/h roads. But also lots of mixed traffic, such as cyclists in combination with agricultural vehicles on the same road. If you look at the west, or Groningen, you see more segregated cycling lanes, and more urban areas. Here in Drenthe, more rural roads, and thus you can see these accidents more.

E1: Another possibility for this is that elderly people cycle a lot more because of the e-bikes. On a normal bike, they cycle around 12km/h. But now, race at around 25km/h. If something happens with these elderly, like running off road or crashing into something, the chance of a severe injury of fatality is a lot higher than back in the day, because than they couldnt. So, i think the rise of the e-bike has to do something with it.

R: Okay, does the municipality of Midden-Drenthe also look at policies to solve the issue of rural roads, where the speed limit is already 60km/h, but these are roads where cyclists have to cycle on a small strip on the road, and if you want it or not, people still drive 80km/h there. Does the municipality of Midden-Drenthe look at buying land near these roads? Or do they think of something else so that they can still create a segregated cycling lane near the road?

E1: Our ultimate wish is a safe cycling path everywhere. But buying land has a long history with farmers. An entire cycling path near such a road is also very costly. If the concrete is laid down, you don't have any work from it for the next 40 years. If this can't be done, like at the Beilvervaart, then we want to create broader cycling strips of atleast 1.50meter broad. This is also a development from the past. Historically, nowehere cycling strips were present because you had car traffic and mixed traffic. At one moment, the cyclist got a 70cm strip, but it was a bit small, then it became 1 meter, and now it is 1.5 meter up to 1.70 meter.

E2: Minimally 1.70 meter yes.

E1: If you take a road in the rural area, where roads are 5 meter broad or something, and you subtract 2 times 1.7 for the cycling strip, the road would be very small for cars. We are trying to puzzle in a way to check which size is acceptable and has a good appearance.In some places in the Netherlands, you see 2 cycling strips with a very tiny carstrip of about 0.5 meter or something. Than you also don't know what to do, so it needs to have a good appearance.

R: Okay, if you don't have anything to say anymore, or have any questions anymore than it concludes this interview.

E2: Okay, great, do you want to mail your final results to us? Because when do you finish?

R: The first of July it needs to be finished, barring any feedback, the final product needs to be finished in the first of August, so I can email the final report in the first week of August. Thanks for your time!

E1 and E2: Good luck, bye

Appendix F - Consent Form

Consent form

Before the interview, we will ask our interviewee(s) to fill out this form, to comply with the ethical guidelines for research.
Consent form for the research project 'Making the unsafest roads in Drenthe safe: How to improve traffic safety in the Dutch province of Drenthe?'
This research is about informing us on how to improve traffic safety in Drenthe through spatial and infrastructural changes.

I fully understand the research project. I was able to ask questions and my questions were answered. I had enough time to decide to participate in the research.
My participation is completely voluntary. I can withdraw from the research at any time, without having to give a reason. I also accept that this interview may be recorded for research purposes only.
I give my permission to use the interview data for educational research purposes only.
I agree to participate in this interview.
Name and signature of the research participant. Date.

[redacted] 8/5/24

I declare that I have informed the research participant about the research. I will notify the participant about matters that could influence his/her participation in the research.

Name and signature of the researcher. 08/05/2024

Remco van Dijk

Appendix G - Calculations

Chi-square Test of Independence

Table GA: Observed Contingency table for the Chi-square test of Independence (data from SWOV, 2023a)

Accident severity Location	Fatality	Injured	Material Damage only	Total
Urban area	27	1183	3610	4820
Rural Area	89	974	3098	4161
Total	116	2157	6708	8981

Expected frequencies are calculated by the formula:

$$\frac{(\text{Row } r \text{ total} \times \text{Column } c \text{ total})}{\text{Grand total}}$$

Expected frequency urban area fatality: (4820 x 116) / 8981 = 62.256
Expected frequency urban area injured: (4820 x 2157) / 8981 = 1157.637
Expected frequency urban area material damage only: (4820 x 6708) / 8981 = 3600.107
Expected frequency rural area fatality: (4161 x 116) / 8981 = 53.744
Expected frequency rural area injured: (4161 x 2157) / 8981 = 999.363
Expected frequency rural area material damage only: (4161 x 6708) / 8981 = 3107.893

The calculated expected frequencies are displayed in Table GB.

Table GB: Expected frequency table for the Chi-square test of Independence (data from SWOV, 2023a)

Accident severity Location	Fatality	Injured	Material Damage only	Total
Urban area	62,256	1157,637	3600,107	4820
Rural Area	53,744	999,363	3107,893	4161
Total	116	2157	6708	8981

X^2= chi-square
df= degrees of freedom
p=p-value
O= Observed value(s)
E= Expected value(s)

$$\chi^2 = \sum \frac{(O - E)^2}{E}$$

So,
X^2 for urban area fatality: $(27 - 62{,}256)^2 / 62{,}256 = 19.966$
X^2 for urban area injured: $(1183 - 1157{,}637)^2 / 1157{,}637 = 0.556$
X^2 for urban area material damage only: $(3610 - 3600{,}107)^2 / 3600{,}107 = 0.027$
X^2 rural area fatality: $(89 - 53{,}744)^2 / 53{,}744 = 23.128$
X^2 for rural area injured: $(974 - 999{,}363)^2 / 999{,}363 = 0.644$
X^2 for rural area material damage only: $(3098 - 3107{,}893)^2 / 3107{,}893 = 0.031$

Table GC: Chi-square statistic per category

Accident severity Location	Fatality	Injured	Material Damage only
Urban area	19,966	0,556	0,027
Rural Area	23,128	0,644	0,031

$X^2 = 19.966 + 0.556 + 0.027 + 23.128 + 0.644 + 0.031 =$ **44.35**
$df=(r-1)\times(c-1)$
$df=(2-1)\times(3-1)=1\times2=2$

P-value
Given that the chi-square statistic = 44.35 and the degrees of freedom df=2, we can compare this to the critical value from the chi-square distribution table. A x^2 value of
44.35 with 2 degrees of freedom is much higher than the critical value (usually around 5.991 for $\alpha=0.05$), indicating a p-value much less than 0.05.

Pearson correlation:

Table GC: Data for the Pearson correlation (CROW Databank, 2024a; 2024d)

Municipality	**Traffic fatality per 1 billion kilometre driven**	**Average distance to facilities in km**
Aa en Hunze	11.62	3.9
Assen	4.65	1.6
Borger-Odoorn	11.99	4.1
Coevorden	7.74	3.7
de Wolden	13.09	3.5

Emmen	5.64	2.7
Hoogeveen	7.55	2
Meppel	1.37	1.7
Midden-Drenthe	15.21	4.5
Noordenveld	11.05	3.7
Tynaarlo	6.94	3.5
Westerveld	12.82	4.9

X: X Values
Y: Y Values
Mx: Mean of X Values
My: Mean of Y Values
X - *Mx* & *Y* - *My*: Deviation scores
*(X - Mx)*2 & *(Y - My)*2: Deviation Squared
(X - Mx)(Y - My): Product of Deviation Scores

X Values
∑ = 109.67
Mean = 9.139
∑(X - Mx)2 = SSx = 186.022

Y Values
∑ = 39.8
Mean = 3.317
∑(Y - My)2 = SSy = 12.897

X and Y Combined
N = 12
∑(X - Mx)(Y - My) = 41.726

R Calculation
r = ∑((X - My)(Y - Mx)) / √((SSx)(SSy))

r = 41.726 / √((186.022)(12.897)) = 0.8519

Meta Numerics (cross-check)
r = 0.8519

The value of R is 0.8519.

This is a strong positive correlation, which means that high X variable scores go with high Y variable scores (and vice versa).

P-Value :
R=0.8519.
N=12
P= .000435.
The result is significant at p < .05