Which factors concerning perceived road safety are influenced by platooning?

A study that looks into the risk factors affected by platooning

Bachelor Thesis Transport Economics

Lars van Zaanen (408561)

Thesis supervisor: Senior Researcher Giuliano Mingardo

Rotterdam, July 2018

ERASMUS UNIVERSITEIT ROTTERDAM

Summary

Platooning is considered to be the future of transportation. The requirements, the possibilities, and the advantages and disadvantages of platooning have already been extensively investigated. Yet, the consequences of platooning on perceived road safety are unknown at the moment. This study investigated which factors concerning perceived road safety are affected when platooning is applied. Literature review and empirical research has been done in order to do so. A survey was distributed among individuals with a driver licence with the aim of mapping the relevant perceived risk factors that are affected by the implementation of platooning. The result show that when platooning is applied, road related risk factors such as road design, road layout and roadside objects affect the perceived road safety of road users. This study shows that road users perceive more safety when roads are wide when platooning is applied. It has also been shown that road users seem to perceive more safety when a clear road layout is present when platooning is applied. Finally, the results show that road users perceive more safety when roadside objects that reduce the risk of serious injury are present when platooning is applied. In addition, vehicle design also seems to be partly influenced by platooning. This study shows that road users perceive less safety when heavy vehicles platoon. Policy however, should only focus on road related risk factors. It does not make sense to ban heavy vehicle platoons, because truck platooning has many societal and business benefits.

Index

Chapter 1 Introduction

The Dutch transport sector shows signs of recovery after a setback due to the financial crisis in 2008. The index of the total turnover in the Dutch transport sector was at the highest level ever in 2017 (CBS, 2018). Moreover, the turnover in the Dutch transport sector in the first quarter of 2018 was 3.8% higher compared to the turnover in the sector in question in the first quarter of 2017 (NU.nl, 2018). The turnover of the largest industry in the transport sector, road freight transport, increased with more than 5%. Dutch trucks transported 666 million tons of goods last year, 1.5 percent more than the year before (NU.nl, 2018). However, the average distance travelled by trucks has decreased by 2%. This trend is caused by strict demands from the European Commission (NU.nl, 2018).

The European Commission wants to reduce road freight transport over long distances (NU.nl, 2018). Important reasons for reducing road freight transport are related to the negative externalities of this type of transport (Europa Nu, n.d.). Examples of negative externalities of road freight transport are air pollution (Janic, 2007) and increasing congestion (Blaauw, 2012). However, in addition to drafting strict rules, the European Commission also encourages innovative projects (VERKEERSNET, 2017). There are several economic, ecological and societal motives to implement logistics solutions that minimize the negative externalities of road freight transport (Janic, 2007). A topical project with a lot of potential is platooning. This new logistics solution is considered the future of road freight transportation (de Weerd, 2017).

Platooning is the automatic following of a preceding vehicle. With this new logistics solution, vehicles are electronically linked to each other. The front vehicle, the leading vehicle, determines the speed and route of the procession. The following vehicles, which are electronically coupled to the leading vehicle, automatically follow the leading vehicle (de Weerd, 2017). Research has shown that platooning can be beneficial for both society and business (Janssen, Zwijnenberg, Blankers & de Kruijff, 2015). For example, the implementation of platooning could result in fuel savings (Davila, 2013) and lower labour costs (Janssen et al., 2015). Moreover, platooning deals with certain risk factors regarding road safety. Studies have shown that the automatic following of a preceding vehicle will result in fewer fatal and non-fatal traffic accidents (Peden et al., 2004). In short, the objective risk of being involved in a traffic accident is likely to decrease when implementing platooning. However, the implementation of platooning may have adverse effects on the perceived road safety of other road users (Janssen et al., 2015).

Perceived road safety describes the feeling that a road user has with regard to the safety of a particular traffic system (Zakowska, 1995). Research has shown that perceived road safety affects the driving behaviour of motorists (Vlakveld, Goldenbeld & Twisk, 2009). Therefore, the success of platooning also depends on the effects that its implementation will have on perceived road safety. The requirements, the possibilities, and the advantages and disadvantages of platooning have already been extensively investigated. Yet, the consequences of platooning on perceived road safety are unknown at the moment. Hence the following research question;

Which factors concerning perceived road safety are influenced by platooning?

The ultimate goal of this research is to give well-founded advice to all parties involved in the development of platooning. This thesis is both scientifically and socially relevant. It is assumed that the implementation of platooning may have adverse effects on the perceived safety of other road users (Janssen et al., 2015). However, it is unknown which factors concerning perceived road safety will be affected. This thesis is therefore scientifically relevant. Moreover, this thesis is also socially relevant, because the success of platooning partly depends on the effects that its implementation will have on perceived road safety.

An attempt to answer the research question will be based on two important steps, namely literature review and empirical research. The first step involves finding the most important factors that affect the perceived road safety of motorists. It is important to identify these factors in order to investigate which of these factors are affected as a result of platooning. The relevant factors will be retrieved and analyzed by means of literature review. During the second step, the main factors relating to perceived road safety will be weighted on the basis of a survey. It is important to find the factors that are influenced by platooning, so that policy advice focuses on the factors that actually matter. The results of the survey will be analysed by means of a statistical software.

First, the two most important concepts will be explained, namely platooning (Chapter 2) and perceived road safety (Chapter 3). The factors that may be affected when implementing platooning will be discussed in the latter chapter. The content of the survey, the hypotheses regarding the survey and the statistical methods used will be discussed in the next chapter (Chapter 4). Next, the descriptive statistics (Chapter 5) and results (Chapter 6) will be displayed and explained. Finally, the research question will be answered (Chapter 7). In the latter chapter the limitations and advice will also be discussed.

Chapter 2 Platooning

2.1 Introduction

In this chapter the important aspects of platooning are discussed. First, the concept of platooning will be explained (2.2). Next, the importance of platooning will be discussed on the basis of economic motives, ecological motives and societal motives (2.3). Moreover, the societal benefits and business benefits will be introduced (2.4). Finally, the requirements for implementing platooning will be briefly described (2.5).

2.2 What is platooning?

Platooning is considered to be the future of transportation (de Weerd, 2017). This relatively new technology can be grouped under the so-called ITS applications, Intelligent Transportation System applications. Which means that platooning uses communication technologies between vehicles (V2V) and with the surrounding infrastructure (V2I). ITS applications are considered very efficient, because such applications can tackle multiple problems at the same time. Research has shown that communication enabled vehicles and infrastructure can form a cooperative system where the users exchange information and cooperate to improve characteristics such as safety, fuel economy, traffic efficiency and comfort (Bergenhem, Shladover, Coelingh, Englund & Tsugawa, 2012). Platooning is one of the ITS applications with a lot of potential (Janssen et al., 2015).

The automatic following of a preceding vehicle is called platooning. Put simply, platooning is a logistics solution whereby vehicles are electronically connected to each other. The front vehicle, the leading vehicle, determines the speed and route of the platoon. The following vehicles, which are electronically coupled to the leading vehicle, automatically follow the leading vehicle. This also means that the following vehicles automatically adjust their speed to the speed of the leading vehicle (de Weerd, 2017). In addition, the leading vehicle can adjust its speed and position based on the response of the following vehicles, due to the fact that the vehicles communicate both ways (Janssen et al., 2015). As a result, platooning makes it possible to drive at smaller inter-vehicle time gaps. Nowadays, vehicles can drive cooperatively at less than 1 second apart due to rapid technological developments in the automated driving sector (Janssen et al., 2015). In theory, different types of vehicles such as passenger cars, buses and trucks can participate in an electronically connected platoon if the required technology is installed in the vehicle in question. In addition, vehicles with the required technology can easily hop-on and hop-off from the platoon (Janssen et al., 2015).

An advanced Automated Driving (AD) system must be present in order to implement platooning (Bergenhem, Huang, Benmimoun & Robinson, 2010). Platooning uses a Cooperative Adaptive Cruise Control (CACC) system that makes it possible for vehicles to operate in closely-coupled automated platoons (Nowakowski, Shladover, Lu, Thompson & Kailas, 2015). This system uses, among other things, Adaptive Cruise Control (ACC), Lane Keeping Assist (LKA), Autonomous Emergency Braking (AEB) and Automated Parking. In addition, a CACC system also uses global positioning systems (GPS) and inertial navigation systems in order to locate the vehicles participating in the platoon. A specific Wi-Fi connection ensures that vehicles interconnect and ensures that vehicles communicate with the infrastructure (Janssen et al., 2015). Put simply, platooning uses a combination of sensors and wireless communication, allowing vehicles to follow each other automatically (Janssen et al., 2015). A simplified representation of this process is shown in the figure below (Figure 1).

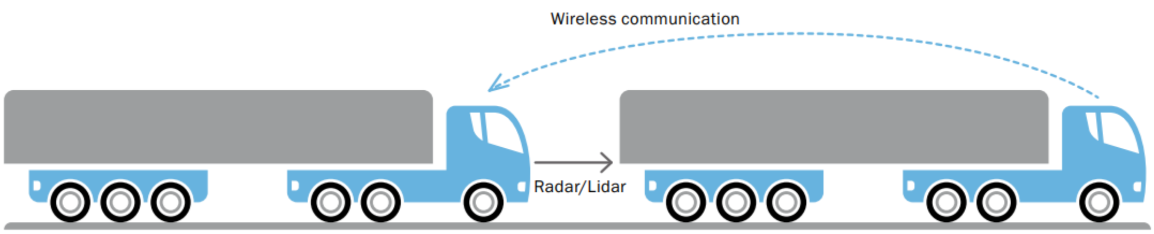


Figure 1. Simplified representation of platooning (Source: Janssen et al., 2015)

2.3 The importance of platooning

Governments require companies to become more and more sustainable. Investing in environmental friendly processes and a sustainable personnel policy has almost become an obligation. Freight transportation still plays a major role in the supply chain of companies. Companies and third parties are therefore always looking for new sustainable logistics solutions. The motives for implementing a new logistics solution can be divided in three main categories; economic motives, ecological motives and societal motives (Figure 2). Although there is overlap, the relevant motives can be divided over the categories mentioned. Most motives arise from the negative externalities of road freight transport (Janic, 2007).

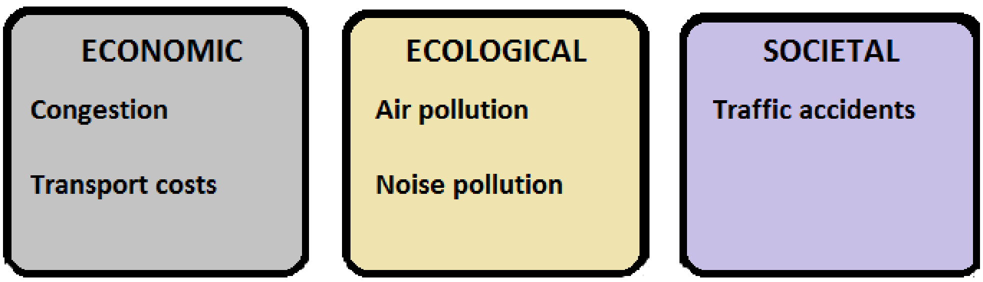


Figure 2. Overview of the most relevant motives (Based on: Janic, 2007)

2.3.1 Economic motives

A negative externality of road freight transport is congestion (Janic, 2007). Road traffic has increased enormously in recent years due to, among other things, greater access to cars, population growth and falling retail prices (Bull & Thomson, 2002). In addition, the demand for road freight transport has increased as well. This explosive increase in road traffic has had major consequences such as an increase in the number of accidents, environmental problems and increasing congestion. According to Bull and Thomson (2002), a congestion arise due to the fact that the cost of congestion is not fully perceived by the users who contribute to it. As a result, motorized vehicles are used more than desirable according to the social optimum, which leads to the excessive use of existing road infrastructure (Bull & Thomson, 2002). A schematic representation of the concept of traffic congestion is shown in Figure 3. An increase in the number of congestions can lead to a loss of economic efficiency. Road freight transport is responsible for about 10% of the total number of congestions in the Netherlands (Blaauw, 2012). The related annual economic burdens are estimated at 0.35 billion Euros. In addition, congestions have a negative impact on both public health and the environment (Levy, Buonocore & Von Stackelberg, 2010). It is therefore important to find solutions that reduce the number of congestions caused by road freight transport.

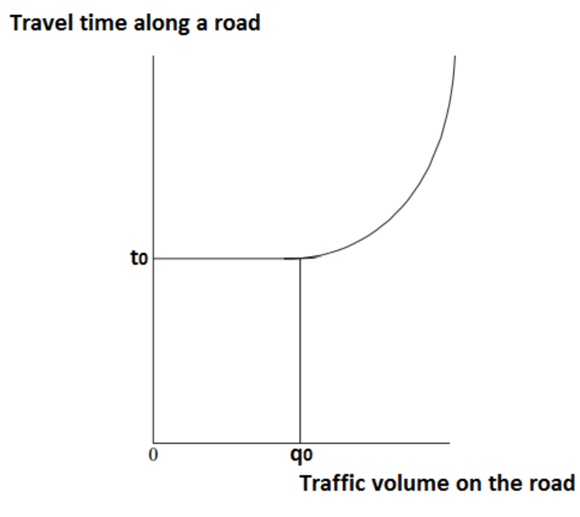


Figure 3. Schematic representation of traffic congestion (Source: Bull & Thomson, 2002)

Reducing transportation costs is the second economic motive. This motive is related to the internal costs of companies (Janic, 2007). In this case, the motive is driven by the business world instead of a third party. Approximately 82% of the 630 million tons of freight in the Netherlands is transported by road transport (Centraal Bureau voor de Statistiek, 2016). The road freight transport sector therefore plays an important role in the supply chain of many companies. In theory, a company always tries to minimize its transportation costs and is therefore always looking for new logistics solutions (Vidal & Goetschalckx, 2001).

2.3.2 Ecological motives

The first ecological motive is heavily related to climate change. Climate change has various causes such as air pollution (Janic, 2007). The consequences of climate change vary widely and differ per country. Research has shown that the average temperature in the Netherlands will rise due to climate change, which will simultaneously lead to an increase in the amount of precipitation, an increase in the intensity of rain showers, heat waves and extreme drought. In addition, the sea level will rise even more rapidly and there will be an increased risk of new or recurring diseases (Minnen et al., 2012). One of the main negative externalities of road freight transport is air pollution (Janic, 2007). About 20% of the total CO_2 emissions produced by road traffic in the Netherlands comes from freight trucks. In addition, a freight truck emits five times more CO_2 compared to a passenger car. Moreover, freight trucks are also responsible for 47% of the total NO_X emissions and 15% of the total PM_{10} emissions produced by road traffic in the Netherlands (Blaauw, 2012). It is therefore important to find solutions that reduce the air pollution of road freight transport.

Another negative externality of road freight transport is noise pollution (Janic, 2007). Noise pollution leads to annoyance, sleep problems and concentration problems in the short term. In addition, long-term exposure to noise pollution can even lead to serious health issues such as heart and vascular diseases (Stansfeld & Matheson, 2003). According to research, more than 30% of the Dutch population indicates that they suffer from noise pollution (Blaauw, 2012). Moreover, besides the negative health effects, noise pollution can also have economic consequences. Research has shown that noise pollution has a negative impact on residential property values (Nelson, 1982). The impact of noise pollution on residential property values is shown in Figure 4. About 47% of the noise pollution in the Netherlands is caused by road freight transport (Blaauw, 2012). It is therefore important to find solutions that reduce the noise pollution of road freight transport.

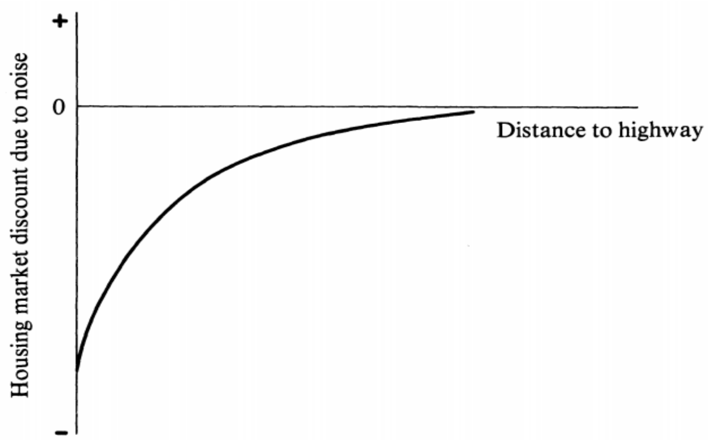


Figure 4. Impact of noise pollution on property values (Source: Nelson, 1982)

2.3.3 <u>Societal motives</u>

Although the number of traffic accidents in the Netherlands has enormously decreased since the rise of motorized vehicles, the number of traffic accidents has increased again in the last years (Centraal Bureau voor de Statistiek, n.d.). This is clearly shown in the figure below (Figure 5). Traffic accidents are considered a negative externality of road freight transport due to the fact that traffic accidents have negative consequences for the affected people and companies (Janic, 2017). People who are involved in a traffic accident do not only suffer from physical complaints. Moreover, besides the possibility of getting an injury or even worse, dying from fatal injuries, people involved in a traffic accident can also become psychologically traumatized (Mayou, Bryant, & Duthie, 1993). Research has shown that in the Netherlands, 14% of fatal traffic accidents and 6% of non-fatal traffic accidents are caused by road freight transport (Blaauw, 2012). In addition, traffic accidents also cause damage to the infrastructure and lead to the loss of property (Janic, 2017). It is therefore important to find solutions that reduce the number of traffic accidents caused by road freight transport.

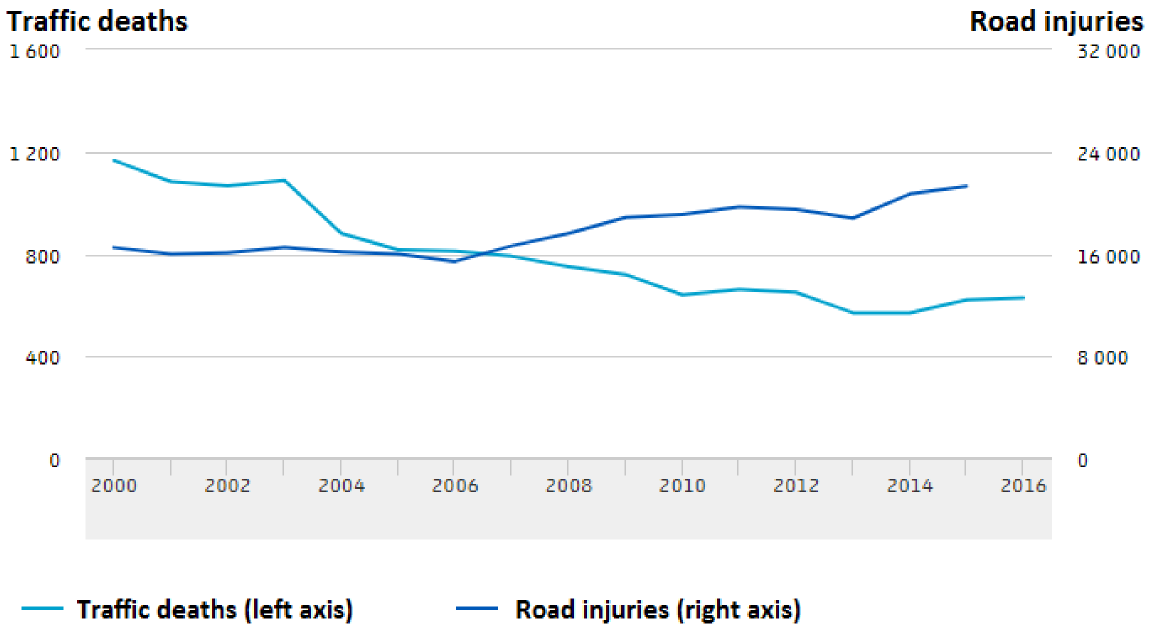


Figure 5. Traffic deaths and road injuries in the Netherlands (Source: CBS, n.d.)

2.4 Potential benefits of platooning

As stated before, platooning is considered to be the future of transportation. This logistics solution can potentially tackle multiple problems at the same time (Janssen et al., 2015). Research has shown that platooning can be beneficial for both society and business. On the one hand, the implementation of platooning leads to emission reduction, fewer traffic accidents and road capacity optimisation. While on the other hand, the introduction of platooning leads to asset utilisation optimisation, lower fuel consumption and lower labour costs (Janssen et al., 2015). In the figure below the benefits of platooning are shown.

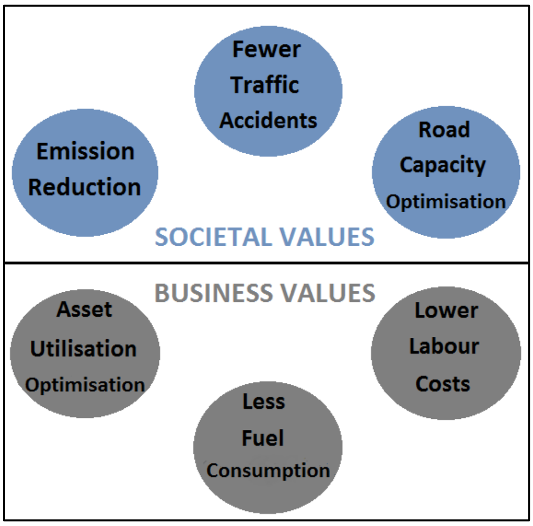


Figure 6. Overview of the benefits of platooning (Based on: Janssen et al., 2015)

2.4.1 Societal benefits

The first societal benefit of platooning is the reduction of CO_2 emissions. Platooning is better for the environment compared to driving without platooning due to the reduction in fuel usage. Research has shown that the implementation of platooning will lead to a fuel reduction of 10%, which means less CO_2 will be emitted. These fuel savings can lead to substantial environmental benefits and are therefore beneficial for society (Janssen et al., 2015). Second, the safety of road users will increase after the introduction of platooning. According to the magazine The Economist (2012), more than 90% of the accidents are caused by human error. In an electronically connected platoon, human actions are minimized and replaced by dedicated technology. Implementing platooning will therefore lead to fewer traffic accidents, fewer fatalities and fewer wounded (The Economist, 2012). Another societal benefit of platooning is road capacity optimisation. Platooning makes it possible to drive at smaller inter-vehicle time gaps, resulting in a more optimal use of the available road capacity (Janssen et al., 2015). In other words, the capacity of the existing infrastructure can be increased without investing in additional lanes or roads. In addition, the number of congestions will decrease because the flow of the traffic will be more consistent.

2.4.2 Business benefits

Asset utilisation optimisation is the first business benefit. According to Janssen et al. (2015), trucks can drive more efficiently if platooning is implemented. Truck drivers will be able to sleep while driving when driving a following vehicle, reducing the rest periods. The route is accomplished faster because of this. Another business benefit is the decline in the use of fuel. As stated before, the implementation of platooning will lead to a fuel reduction of about 10%. A following vehicle can reduce its fuel consumption by up to 13%, while a leading vehicle can reduce its fuel consumption by up to 8% (Davila, 2013). Thus, savings can be made on fuel consumption when implementing platooning. This makes road freight transport cheaper. The implementation of platooning will also lead to lower labour costs. However, the savings depend on the stage of implementation. Savings will be limited in the initial stage. As mentioned earlier, truck drivers will be able to sleep while driving, reducing the rest periods. The optimization of rest periods can save 45 minutes per truck driver per workday (Janssen et al., 2015). The savings increase enormously in later stages. Following vehicles will drive completely automatically in later stages, which makes truck drivers superfluous. Research has shown that about 25% of the total labour time can be saved if platooning is implemented (Janssen et al., 2015). Platooning will in any case result in better utilisation of driver capacity and therefore lead to lower labour costs.

2.5 Requirements for implementing platooning

As mentioned earlier, vehicles must have the required technology such as dedicated sensors and wireless communication, to participate in an electronically connected platoon. However, the exact technology required depends on the degree of infrastructure usage, the platoon formation and the level of automation (Janssen, 2015). Currently there are five ongoing projects related to platooning, namely; SARTRE, PATH, GCDC, SCANIA-platooning and Energy ITS (Bergenhem et al., 2012). These projects differ in goals, implementation, mix of vehicles, requirements on infrastructure, and level of automation. The requirements can therefore be very different. The exact differences between the five project can be found in Table 1 (see Appendix). The impact on the infrastructure and on other road users will have to be minimized in all cases (Bergenhem et al., 2010). The perceived safety of motorists therefore plays an important role in the implementation of platooning.

2.6 Conclusion

Platooning is a logistics solution whereby vehicles are electronically connected to each other. Platooning uses a Cooperative Adaptive Cruise Control (CACC) system that makes it possible for vehicles to operate in closely-coupled automated platoons. This new logistics solution is considered to be the future of transportation, because platooning can tackle multiple problems at the same time. For example, the implementation of platooning will lead to a fuel reduction of 10%, which means less CO_2 will be emitted. Thus, savings can also be made on fuel consumption when implementing platooning. This makes road freight transport cheaper. Moreover, the safety of road users will increase after the introduction of platooning. Implementing platooning will lead to fewer traffic accidents, fewer fatalities and fewer wounded. Platooning makes it also possible to drive at smaller inter-vehicle time gaps, resulting in a more optimal use of the available road capacity. Furthermore, the implementation of platooning will lead to higher efficiency and to lower labour costs. Approximately 25% of the total labour time can be saved if platooning is implemented. Vehicles must have the required technology such as dedicated sensors and wireless communication, to participate in an electronically connected platoon.

Chapter 3 Perceived road safety

3.1 Introduction

In this chapter the important aspects of perceived road safety are discussed. First, the concept of road safety will be explained (3.2). The most important risk factors concerning road safety are also described in this paragraph. Moreover, the concept of perceived road safety will be introduced. The important aspects of perceived road safety will be discussed (3.3) and the most important risk factors concerning perceived road safety will be described (3.4).

3.2 Road safety

According to the World Health Organization (2009), more than 1.2 million people die each year on the world's roads. In addition, up to 50 million people suffer from non-fatal injuries on the world's roads every year. The World Health Organization also expects that both numbers will increase considerably in the near future. The organization in question predicts that traffic accidents will become the fifth leading cause of death by 2030. Traffic accidents however, have been the leading cause of death for the age group 15-29 for years now (World Health Organization, 2009). Fortunately, the Netherlands has one of the lowest modeled road traffic fatality rates in the world. Nevertheless, 613 people were killed in a traffic accident last year (Centraal Bureau voor de Statistiek, 2018). As mentioned earlier, the number of traffic accidents in the Netherlands has increased again in recent years (Centraal Bureau voor de Statistiek, n.d.). In 2013 for example, "only" 570 people died in a traffic accident (Centraal Bureau voor de Statistiek, 2018).

The number of fatal and non-fatal traffic accidents is related to so-called risk factors (Peden et al., 2004). In case of traffic accidents, risk is a function of four elements; the exposure, the probability of a crash, the probability of injury and the outcome of injury. According to the World report on road traffic injury prevention (2004), there are three types of risk factors; risk factors influencing crash involvement, risk factors influencing injury severity and risk factors influencing post-crash injury outcome (Peden et al., 2004). The latter will be left out of consideration, because these types of risk factors does not affect road safety. Risk factors influencing post-crash injury outcome only have consequences for the aftermath of a traffic accident. Well-known examples of these types of risk factors are the lack of appropriate pre-hospital care and the lack of appropriate care in the hospital emergency rooms (Peden et al., 2004). The risk factors influencing crash involvement and the risk factors influencing injury severity are shown in Figure 7.

Risk factors influencing crash involvement

- Speed
- Pedestrians and cyclists
- Young drivers and riders
- Alcohol
- Medicinal and recreational drugs
- Driver fatigue
- Hand-held mobile telephones
- Inadequate visibility
- Road-related factors
- Vehicle-related risk factors

Risk factors influencing injury severity

- Lack of in-vehicle crash protection
- Non-use of crash helmets by two-wheeled vehicle users
- Non-use of seat-belts and child restraints in motor vehicles
- Roadside objects

Figure 7. Risk factors influencing crash involvement and injury severity (Based on: Peden et al., 2004)

3.2.1 Risk factors influencing crash involvement

The first risk factor influencing crash involvement is *speed*. Speed is one of the main risk factors related to the number of fatal and non-fatal traffic accidents, because speed affects both crash risk and crash consequence. Speed studies have shown that there is a significant and positive relationship between mean speed and crash risk, which means that crash risk increases as speed increases (Elvik, Christensen & Amundsen, 2004). On average, an increase of the average speed by 1 kilometre per hour will result in a 3% increase in the incidence of injury crashes and a 5% increase in the incidence of fatal crashes (Peden et al., 2004). In other words, if the average speed is increased by 1 kilometre per hour, the risk of getting a traffic accident will increase by at least 3%. There is also empirical evidence for the positive relationship between mean speed and crash consequence. The number of severity injuries increases as speed increases (Elvik et al., 2004). Most traffic accidents however, are caused by excess speed and inappropriate speed. The term 'excess speed' indicates trespassing the maximum speed as defined by the government. On the other hand, 'inappropriate speed' concerns driving at a speed that is unsuitable for the type of infrastructure one is using. The speed drivers choose to travel at is influenced by road and vehicle related factors, traffic and environment related factors, and driver related factors (Peden et al., 2004). A number of examples of these factors can be found in the appendix (Table 2).

Another risk factor influencing crash involvement is being a *pedestrian or cyclist*. Both means of transport can be grouped under the so-called unprotected road users. Unprotected road users are at much greater risk compared to car users. This is mainly due to the fact that contemporary traffic systems are designed from the perspective of a motorist (Peden et al., 2004). In many countries pedestrians and cyclists use the same roads as motorized, leaving unprotected road users at high risk. Contemporary traffic systems lack adequate separate pedestrian and cyclist facilities. In addition, appropriate road management and vehicle speed management systems are lacking in many countries (Peden et al., 2004). Unprotected road users are often involved in traffic accidents due to the absence of these factors. In the Netherlands for example, 264 of the 613 people who were killed in a traffic accident in 2017 were pedestrians or cyclists (Centraal Bureau voor de Statistiek, 2018).

The presence of *young drivers and riders* is also a risk factor (Peden et al., 2004). As stated before, traffic accidents are the leading cause of death for the age group 15-29 (World Health Organization, 2009). Young drivers and riders lack experience and have insufficient skills, causing them to be more frequently involved in traffic accidents compared to other age groups (Ulleberg, 2001). In addition, young drivers and riders also have a more aggressive driving style compared to other road users. Research has shown that young drivers and riders have a tendency not to stick to the speed limits, keep too little distance and overtake dangerously (Ulleberg, 2001). This high-risk behaviour is the result of self-overestimation. Young drivers and riders overestimate their own driving skills and underestimate the risks of certain traffic situations (Ulleberg, 2001).

Like speed, *alcohol* is one of the main risk factors related to the number of fatal and non-fatal traffic accidents. Studies have shown that there is a significant and positive relationship between alcohol consumption and crash risk, which means that crash risk increases as alcohol consumption increases (Peden et al., 2004). Moreover, crash risk increases rapidly with blood alcohol content (BAC). Research has shown that at a blood alcohol content of 0.04 g/dl the risk of being involved in a traffic accident increases significantly (Peden et al., 2004). The relationship between the blood alcohol content and crash risk is shown in Figure 8. Consuming alcohol influences driving performance, because alcohol affects the central nervous system. According to Ogden and Moskowitz (2004), the analysis of sensory information, the control of complicated movement patterns and the short-term memory are particularly sensitive to alcohol. This affects, among other things, reaction time, vigilance, visual functions and driving skills. Motorists under the influence of alcohol make more steering errors, ignore rules faster and are slower to correct position errors compared to motorist who are completely sober (Ogden & Moskowitz, 2004).

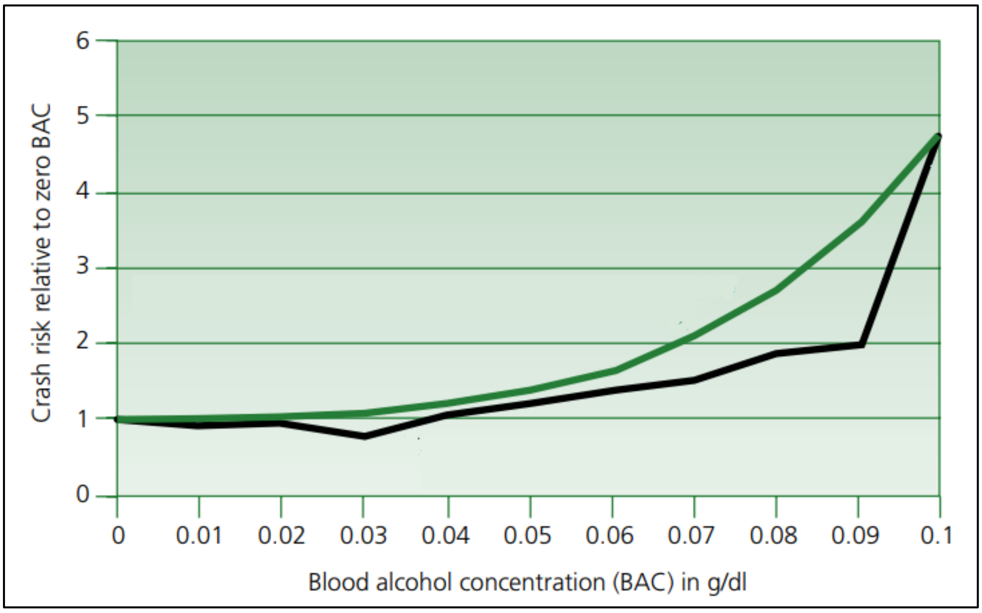


Figure 8. Relationship between the blood alcohol content and crash risk (Source: Peden et al., 2004)

Medicinal and recreational drugs contribute to a much lesser extent to the number of traffic accidents compared to alcohol (Peden et al., 2004). However, drugged driving is still a global problem. Common medicinal and recreational drugs are benzodiazepines, opioids, amphetamines, cocaine, cannabis, antihistamines and antidepressants. Although there is currently relatively little empirical evidence, it is assumed that using certain drugs will affect driving performance in a negative way. Both medicinal and recreational drugs are expected to influence psychomotor performance, and therefore also driving ability (Walsh, Gier, Christopherson, & Verstraete, 2004).

Another risk factor influencing crash involvement is *driver fatigue*, or driver sleepiness. According to Brown (1994), human efficiency is affected by fatigue. Fatigue leads to concentration problems, causing motorists to unwittingly pay less attention to road and traffic demands (Brown, 1994). Important driving skills that are affected by fatigue are vehicle control and the ability the avoid collisions. Driver fatigue is estimated to play a role in 25% of all single-vehicle traffic accidents (Brown, 1994). Studies have shown that driving while feeling drowsy, driving after less than five hours of sleep, and driving between 2 a.m. and 5 a.m., increases the likelihood of being involved in a traffic accident (Peden et al., 2004). Driver fatigue is influenced by temporal factors, environmental factors and sleep-related factors. A number of examples of these factors can be found in the appendix (Table 3). Research has shown that there are three high-risk groups with regard to driver fatigue; young males (16-29 years), people who work at irregular hours and people with untreated sleep disorders (Peden et al., 2004).

The use of *hand-held mobile telephones* in traffic is a big problem nowadays. The use of cell phones while driving does not only affect driver behaviour, but also affect the decision-making abilities of a motorist (Peden et al., 2004). According to Peden et al. (2004), the reaction time of a motorist increases by at least 0.5 seconds if the driver in question uses a mobile phone. The main affect of using cell phones in traffic is the significant decrease in the inter-vehicle distance (Rosenbloom, 2006). In addition, motorists using a cell phone while driving have difficulty maintaining the correct lane position, keeping the appropriate speed and judging safe gaps in traffic (Peden et al., 2004). Researchers estimate that the probability of having a traffic accident is ten times as high when using a cell phone while driving (NOS, 2017).

Inadequate visibility is another important risk factor related to the number of fatal and non-fatal traffic accidents. The visibility of everyone involved in traffic is of fundamental importance for road safety. Everything is about 'seeing' and 'being seen' (Peden et al., 2004). Studies have shown that bad visibility increases the probability of having a traffic accident (Vorko-Jović, Kern & Biloglav, 2006). Visibility is affected by various factors such as vehicle design and infrastructure design. An example of bad visibility caused by the vehicle design are the so-called blind spots. Blind spots are areas around a vehicle where the visibility of the driver of the vehicle in question is obstructed. It is therefore almost impossible to see other road users when these road users are in a blind spot (Peden et al., 2004). In addition, weather conditions also affect visibility. For example, there is an increased risk for traffic accidents during sunrise and sunset (Vorko-Jović et al., 2006). Negligence of road users also plays a major role with regard to inadequate visibility. For example, pedestrians and cyclists are poorly visible in the evening if they wear dark clothes or do not have bicycle lights.

Road-related factors also have a huge impact on crash involvement. Research has shown that infrastructure influences the behaviour of road users through road design and road layout. The road design includes everything that has to do with the construction and use of a road network, while the road layout includes everything that has to do with the provision of instructions regarding a particular road network. Road markings and road signs belong to this last category. Traffic accidents occur when the design and layout of a road network contradict each other (Peden et al., 2004). Moreover, the risk of traffic accidents increases if a road network has bad road surface conditions or unclear markings and signs. Poorly designed and maintained road networks can therefore contribute to traffic accidents (Peden et al., 2004).

Vehicle-related risk factors play a significantly smaller role when it come to causing traffic accidents. The number of traffic accidents caused by vehicle defects varies between 3 and 5% (Peden et al., 2004). However, this does not apply to the design of a vehicle. Research has shown that the design of a vehicle can affect the aftermath of a traffic accident (Mackay, 1994). It is therefore important that vehicle manufacturers continue to improve vehicle safety and ensure that all safety standard are met (Peden et al., 2004). According to Mackay (1994), there are certain vehicle design characteristic which can minimize crash consequence. For example, one can think about supplementary airbags, better structural integrity and safer vehicle fronts.

3.2.2 Risk factors influencing injury severity

The first risk factor influencing injury severity is the *lack of in-vehicle crash protection*. As mentioned earlier, the design of a vehicle can affect the aftermath of a traffic accident (Mackay, 1994). In-vehicle crash protection should protect both occupants and unprotected road users. Occupants of motorized vehicles should be protected against frontal and side-impact crashes (Peden et al., 2004). The in-vehicle crash protection should prevent them from hitting the interior parts of the vehicle and from being ejected from the car (Abbas, Hefny & Abu-Zidan, 2011). According to Peden et al. (2004), up to 50% of all traffic-related fatal and non-fatal injuries can be prevented if all motorized vehicles have the contemporary in-vehicle crash protection. Moreover, motorized vehicles must be designed in such a way that the impact on pedestrians is minimized. Studies have shown that more than a third of all traffic-related fatal and non-fatal injuries arise from traffic accidents between motorized vehicles and pedestrians (Peden et al., 2004).

Not using a helmet while driving a two-wheeled vehicle is another risk factor. The non-use of crash helmets is the main risk factor for drivers of motorized two-wheeled vehicles (Peden et al., 2004). Head injury is the main cause of mortality and morbidity for the drivers of motorized two-wheeled vehicles. Wearing a crash helmet is associated with a reduction in the risk of fatal and serious head injury. Research has shown that drivers of a motorized two-wheeled vehicle can reduce the risk of fatal and serious head injury up to 45% by wearing a crash helmet (Peden et al., 2004). In addition, people who do not wear a crash helmet are three times more likely to suffer head injuries compared to people who wear a crash helmet (Kulanthayan, Umar, Hariza, Nasir & Harwant, 2000). The results found also apply for cyclist. Studies have shown that cyclists can reduce the risk of fatal and serious head injury up to 88% by wearing a crash helmet (Peden et al., 2004).

Injury severity is also influenced by the use or *non-use of seat-belts and child restraints in motor vehicles* (Peden et al., 2004). There is empirical evidence that not using seat-belts increases the likelihood of more serious injuries (Holdridge, Shankar & Ulfarsson, 2005). Seat-belts reduce injuries in two ways; seat-belts prevent occupants from hitting the interior parts of the vehicle and seat-belts prevent occupants from being ejected from the car (Abbas et al., 2011). Abbas, Hefny, and Abu-Zidan (2011) showed that there is a negative relationship between the number of occupants wearing seat-belts and road traffic death rates. In other words, if the number of occupants wearing seat-belts increases, road traffic death rates decrease. Child restraints work in the same way as seat-belts for adults (Peden et al., 2004).

The last risk factors influencing injury severity are *roadside objects*. According to Peden et al. (2004), roadside objects pose a risk for road safety. Roadside objects are involved in up to 42% of all fatal traffic accidents (Peden et al., 2004). Studies have shown that the presence of particular roadside objects, such as leading ends of guardrails, threes and utility poles, increase the probability of fatal injury (Holdridge et al., 2005). However, the presence of several other roadside objects, such as the face of guardrails and concrete barriers, are associated with a reduction in the risk of serious injury (Holdridge et al., 2005). In short, the risk of fatal and serious injury differs per roadside object.

3.3 Perceived road safety

Although in theory a traffic system can be very safe, road users can still label the traffic system in question as unsafe. This phenomenon is called perceived road safety. Perceived road safety, also called subjective road safety, reflects the safety level of a traffic system as perceived by a road user (Zakowska, 1995). In other words, perceived road safety describes the feeling that a road user has with regard to the safety of a particular traffic system. Perceived road safety is therefore personal and often not based on the actual safety (objective data). Studies have shown that traffic behaviour is influenced by perceived road safety (Vlakveld et al, 2009). Risk perception plays a major role in this relationship. The term risk perception indicates the estimation of the probability and severity of an accident. Hansson (2010) showed that risk perception contains both objective and subjective components. Objective risk concerns the actual facts about possible outcomes and their probabilities while subjective risk, or perceived risk, concerns the outcome of social processes (Hansson, 2010). However, risk perception is mostly subjective; the amount of risk that one is willing to take to achieve a certain goal and the emotions that arise when perceiving risk vary per individual (Vlakveld et al., 2009). The objective risk of being involved in a traffic accident therefore differs from the perceived risk of being involved in a traffic accident. This means that actual road safety and perceived road safety differ as well.

The perceived road safety of road users could be affected in case of platooning. Although there is currently relatively little empirical evidence, it is assumed that the implementation of platooning may have adverse effects on the perceived safety of other road users (Janssen et al., 2015). This while there are strong indications that the implementation of this logistics solution will result in fewer traffic accidents, fewer fatalities and fewer wounded (Janssen et al., 2015). In other words, the objective risk of being involved in a traffic accident is likely to decrease and the perceived risk of being involved in a traffic accident is likely to increase when implementing platooning.

There is still a lot of discussion about the exact reason of behavioural change in traffic. However, it is certain that the perceived risk of being involved in a traffic accident, and therefore also perceived road safety, influence the driving behaviour of road users (Vlakveld et al., 2009). If the above is indeed the case, the implementation of platooning can result in changes in driving behaviour. In the worst case, individuals can choose to make less use of certain traffic systems. This will make them less mobile, which can result in social exclusion (Cass, Shove & Urry, 2005). Social exclusion has been found to have a negative effect on well-being.

3.4 Factors that affect perceived road safety

Risk perception plays an important role in the subjectively safety level of a traffic system. Risk perception contains both objective and subjective components (Hansson, 2010). As stated before, objective risk concerns the actual facts about possible outcomes and their probabilities, while subjective risk, or perceived risk, concerns the outcome of social processes. In case of perceived road safety, objective risk concerns all risk factors influencing crash involvement and risk factors influencing injury severity (Peden et al., 2004). This in contrary with the subjective components of risk perception with regard to perceived road safety; subjective risk concerns certain personal characteristics. This section discusses the objective risk factors on which a car driver has little or no influence. Risk factors caused by the road user himself will therefore not be addressed in this section. Thus, risk factors such as the use of alcohol, driver fatigue and the use of hand-held mobile telephones will be excluded. Moreover, the other risk factors are grouped under road-related risk factors or vehicle-related risk factors. In addition, only the personal characteristics that have been proven to have an influence on risk perception are discussed. Figure 9 shows all important factors that affect risk perception and therefore also perceived road safety.

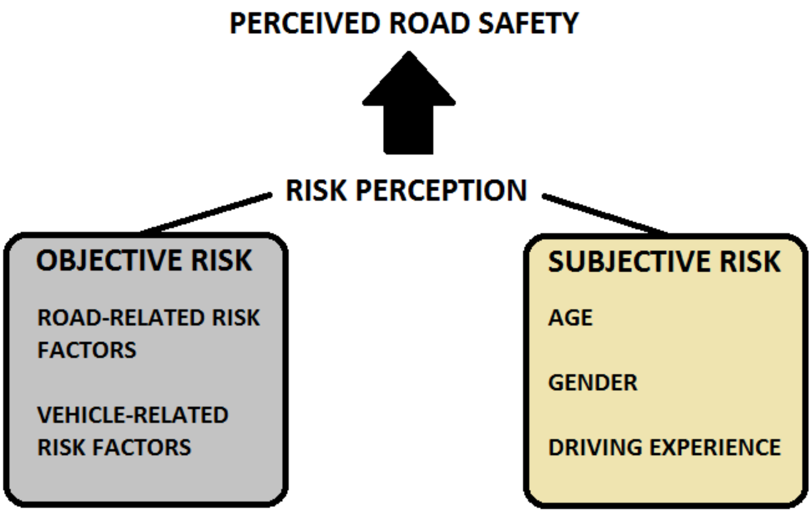


Figure 9. Important factors that affect perceived road safety

3.4.1 Objective risk factors

The *road-related risk factors* are the first objective risk factors that may affect perceived road safety. The following risk factors belong to this category; road design, road layout and roadside objects. The road width and the curve radius are road design elements that affect the risk perception of motorists. Lewis-Evans and Charlton (2006) showed that road users adjust their driving behaviour based on the width of the road. The researchers found a relationship between the road width and the perceived risk of road users. Apparently, road users adjust their speed and lane position based on the road width. Narrow roads were associated with lower speeds and lane positions further away from the road edge while wider roads had higher speeds and lane positions closer to the road edge (Lewis-Evans & Charlton, 2006). In addition, Kanellaidis, Zervas and Karagioules (2000) showed that the curve radius also affect the risk perception of road users. Although there is a negative relationship between the curve radius and accident rate (Choueiri, Lamm, Kloeckner, & Mailaender, 1994), the perceived risk of road users increases as the curve radius increases (Kanellaidis, Zervas & Karagioules, 2000). In other words, a relatively straight road is considered safer by road users compared to a relatively curved one. Road layouts also play a major role in perceived road safety. Road users are aware of certain risks when seeing particular road markings and road signs (Martens, Compte & Kaptein, 1997). According to Martens, Compte and Kaptein (1997), road users will adjust their driving behaviour based on the perceived risk associated with certain road layouts. However, this does not apply for certain roadside objects. Although particular roadside objects increase the objective risk of being involved in a traffic accident, the perceived risk of being involved in a traffic accident does not appear to change with the presence of this type of roadside objects (Bella, 2013). However, the presence of roadside objects that reduce the risk of serious injury seems to have a positive effect on the perceived safety of road users (Bella, 2013; Yau, 2004).

Vehicle-related risk factors affect perceived road safety as well. The following risk factors belong to this category; speed of other road users, inadequate visibility and vehicle design. Research has shown that motorists are influenced by the driving behaviour of other road users (Zaidel, 1992). In particular, the speed of other road users seems to play a major role in the driving behaviour of motorists. As stated before, speed is one of the main risk factors related to the number of fatal and non-fatal traffic accidents (Peden et al., 2004). Connolly and Åberg (1993) suggested that motorists compare their own speed with the speed of other road users, after which they adjust their own speed based on this comparison. In other words, motorists adjust their driving behaviour based on the driving behaviour of others. As driving behaviour and risk perception are related (Vlakveld et al., 2009), the speed of other road users affects the risk perception of motorists, and therefore the perceived road safety of motorists as well. This also applies for inadequate visibility. Studies have shown that motorists adjust their driving behaviour based on visibility (Trick, Toxopeus & Wilson, 2010). As visibility deteriorates, the perceived risk of road users increases and the perceived road safety of road users decreases. In general, road users compensate inadequate visibility by slowing down (Trick et al., 2010). Vehicle design also plays a major role in perceived road safety. Research has shown that both vehicle mass and vehicle model year have a significant effect on driving behaviour (Wasielewski, 1984). According to Wasielewski (1984), perceived risk decreases as vehicle mass increases. Motorists who drive relatively heavy vehicles therefore also take more risks compared to motorists who drive relatively light vehicles (Wasielewski, 1984). This is also applicable to the vehicle model year. The more modern a vehicle is, the less risk motorists perceive (Wasielewski, 1984). Moreover, the vehicle make and body style, including the in-vehicle crash protection, also seem to correlate with perceived road safety in the same way as the above factors.

3.4.2 Subjective risk factors

The first subjective risk factor that affects perceived road safety is *age*. As mentioned earlier, young drivers lack experience and have insufficient skills, causing them to be more frequently involved in traffic accidents compared to other age groups (Ulleberg, 2001). However, the most important difference between age groups is risk perception. Finn and Bragg (1986) showed that relatively young drivers perceive risk differently compared to relatively old drivers. The perceived risk of being involved in a traffic accident and the perceived road safety therefore also differ per age group. In general, young drivers estimate risks too low compared to older drivers; they underestimate the risks of certain traffic situations and overestimate their own driving skills (Ulleberg, 2001). However, as people age, their risk perception changes (Finn & Bragg, 1986). Their perspective on road safety will therefore also change over the years, because road users will assess the risks of certain traffic situations better.

Gender affects perceived road safety as well. Studies have shown that men and women perceive risk differently (DeJoy, 1992). According to DeJoy (1992), male motorists tend to be more optimistic with regard to assessing their driving skills compared to female motorists. Moreover, men appear to perceive less risk in a variety of dangerous driving behaviors (DeJoy, 1992). Women generally take the following risk factors more seriously; driving without a seat belt, driving with a blood alcohol over the legal limit, and not making a full stop at a stop sign (DeJoy, 1992). In addition, DeJoy (1992) showed that male drivers estimate the risk of being involved in a traffic accident differently than female drivers do. Especially in situations that involve quick driving reflexes or substantial vehicle-handling skills (DeJoy, 1992). In short, gender affects risk perception, and therefore affects perceived road safety as well.

Another subjective risk factor that affects perceived road safety is *driving experience*. The effect of driving experience on risk perception has many similarities with the effect of age on risk perception. Novice drivers detect hazards less quickly and less efficiently compared to experienced drivers (Deery, 1999). This is caused by the same reasons as for age; novice drivers underestimate the risks of certain traffic situations and overestimate their own driving skills (Deery, 1999; Ulleberg, 2001). As road users gain more driving experience, their risk perception changes (Deery, 1999). Road users will assess risks more realistically as they drive more. Gaining experience will therefore also affect the perceived road safety of a road user.

3.5 Conclusion

The number of fatal and non-fatal traffic accidents is related to so-called risk factors. There are three types of risk factors; risk factors influencing crash involvement, risk factors influencing injury severity and risk factors influencing post-crash injury outcome. The risk factors influencing crash involvement and the risk factors influencing injury severity are shown in Figure 7 (page 16). These risk factors also play an important role regarding perceived road safety. Perceived road safety, also called subjective road safety, reflects the safety level of a traffic system as perceived by a road user. Risk perception plays a major role in this relationship. The risk factors influencing crash involvement and the risk factors influencing injury severity are the objective components of risk perception. The following objective risk factors play an important role regarding perceived road safety: road design, road layout, roadside objects, speed of other road users, inadequate visibility and vehicle design. Risk perception also consists of subjective components. Subjective risk concerns certain personal characteristics such as age, gender and driving experience.

Chapter 4 Methodology

4.1 Introduction

As stated before, subjective road safety can influence the success of platooning. Although platooning is relatively safe, it cannot be excluded that the subjective safety of motorists is influenced by platooning. Research has shown that subjective safety affects the driving behaviour of motorists (Vlakveld et al., 2009). This study investigates which factors concerning perceived road safety are influenced by platooning. To study this, a survey was distributed among individuals with a driver licence. In this chapter, the content of the survey, the hypotheses regarding the survey and the statistical methods used will be discussed.

4.2 Survey

The main factors relating to perceived road safety will be weighted on the basis of a survey. A survey was distributed among the target group (individuals with a driver licence) with the aim of generating a quantitative dataset. The focus here is on mapping the relevant perceived risk factors that are affected by the implementation of platooning. In the dataset that is generated, a distinction is made based on age, gender and driving experience. The generated data is quantitative, so a statistical program is needed for the analysis. SPSS will be used in this study. The analyzes generated by SPSS will be underpinned by the literature review.

The survey consists of three phases; an exploratory phase (Phase 1), the platooning phase (Phase 2) and a closing phase (Phase 3). In the exploratory phase, respondents will answer questions about certain traffic situations that are classified as dangerous according to the literature. The respondents will indicate how they feel about a certain traffic situation, which is measured by using a Likert Scale ranging from 1 (extremely unsafe) to 7 (extremely safe). An example of this scale is shown in Figure 10. The last traffic situation will refer to platooning. However, the respondents will not be informed about this. The traffic situations in question can be found in the Appendix. The data gathered in this stage will not be used for this study.

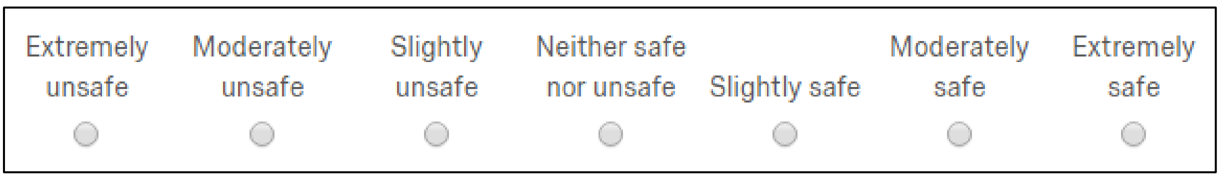


Figure 10. The Likert Scale used in this study.

In the second phase, the platooning phase, respondents will be introduced to the concept of platooning. This new logistics solution will be briefly explained (also a visual representation – Figure 11), after which the respondents will answer a number of questions regarding platooning. These questions depict certain traffic situations in which platooning is applied. For each question in this phase, the exact same traffic situations will be displayed twice. However, a risk factor will be omitted or added to the second of the two traffic situations. The risk factors that will be omitted or added affects perceived road safety according to the literature. The respondents will then indicate which traffic situation they perceive as safer. The responses of this phase will be used to test whether the relevant risk factors have a significant influence on the perceived safety of road users in practice.

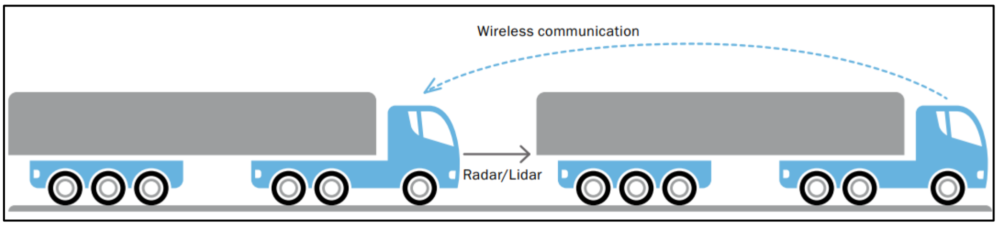


Figure 11. The visual representations of platooning shown in the survey

In the last phase, the closing phase, respondents will answer questions about a number of personal characteristics. The relevant personal characteristics for this research are *Age*, *Gender* and *Driving experience*. The latter will be a multiple choice question, with respondents having the choice of the following options: '0 years', '0 – 5 years' and 'more than 5 years'. Individuals with 0 – 5 years of experience will be considered *novice drivers*, and individuals who have more than 5 years of experience will be considered *experienced drivers* (ANWB, n.d.). The data gathered in this stage will be used only for descriptive statistics.

4.3 Hypotheses

Road design has been found to influence the perceived road safety of motorists. One of the most important aspects of road design is the width of a road. Lewis-Evans and Charlton (2006) showed that road users adjust their driving behaviour based on the width of the road. Narrow roads were associated with lower speeds and lane positions further away from the road edge while wider roads had higher speeds and lane positions closer to the road edge. In short, the narrower a road, the higher the perceived risk of road users. If this is indeed the case, a road user will prefer a wide road over a narrow road. In the survey, the respondent is asked to choose between a three-lane road (*Traffic situation 1*) and a four-lane road (*Traffic situation 2*). It is expected that respondents will prefer *Traffic situation 2* over *Traffic situation 1* in terms of perceived safety. Hence the following hypothesis:

H0: Road users do not feel safer when roads are wide

Road layout also plays an important role in perceived road safety. According to Martens, Compte and Kaptein (1997), road users are aware of certain risks when seeing particular road markings and signs. Road users will adjust their driving behaviour based on the perceived risk associated with certain road layouts. Moreover, perceived road safety decreases if a road network has unclear markings and signs (Martens, Compte & Kaptein, 1997). If this is indeed the case, a road user will prefer a clear road layout over an unclear road layout. In the survey, the respondent is asked to choose between a road network with an unclear road layout (*Traffic situation 1*) and a road network with a clear road layout (*Traffic situation 2*). It is expected that respondents will prefer *Traffic situation 2* over *Traffic situation 1* in terms of perceived safety. Hence the following hypothesis:

H0: Road users do not feel safer when a clear road layout is present

Other risk factors that affect perceived road safety are roadside objects. The presence of roadside objects that reduce the risk of serious injury seems to have a positive effect on the perceived safety of road users (Bella, 2013; Yau, 2004). This certainly applies to guardrails, which are, according to Holdridge et al. (2005), associated with a reduction in the risk of serious injury. The presence of guardrails will therefore increase the perceived safety of road users (Bella, 2013; Yau, 2004). If this is indeed the case, a road user will prefer a road network with guardrails over a road network without guardrails. In the survey, the respondent is asked to choose between a road network without guardrails (*Traffic situation 1*) and a road network with guardrails (*Traffic situation 2*). It is expected that respondents will prefer *Traffic situation 2* over *Traffic situation 1* in terms of perceived safety. Hence the following hypothesis:

H0: Road users do not feel safer when guardrails are present

Vehicle-related risk factors affect perceived road safety as well. One of the most important vehicle-related risk factors is vehicle design, among which the external characteristics of a vehicle (visibility). Visibility is affected by various factors such as vehicle design. Studies have shown that bad visibility increases the probability of having a traffic accident (Vorko-Jović, Kern & Biloglav, 2006). Moreover, as visibility decreases, the perceived road safety of road users decreases (Trick et al., 2010). If this is indeed the case, a road user will prefer a clearly visible platoon over a badly visible platoon. In the survey, the respondent is asked to choose between a badly visible platoon (*Traffic situation 1*) and a clearly visible platoon (*Traffic situation 2*). It is expected that respondents will prefer *Traffic situation 2* over *Traffic situation 1* in terms of perceived safety. Hence the following hypothesis:

H0: Road users do not feel safer when platoons are clearly identifiable

In addition to the external characteristics of a vehicle, in-vehicle crash protection also affects perceived safety. Studies have shown that perceived safety increases as vehicle mass increases (Wasielewski, 1984). However, this is based on the perspective of the driver of the vehicle in question. The relationship between perceived road safety and the mass of surrounding vehicles is different. Research has shown that perceived safety decreases as vehicle mass of surrounding vehicles increases (Wang, Hensher & Ton, 2002). In short, the heavier the vehicles of other road users, the less safe a road user feels. If this is indeed the case, a road user will prefer a light vehicle platoon over a heavy vehicle platoon. In the survey, the respondent is asked to choose between a heavy vehicle platoon (*Traffic situation 1*) and light vehicle platoon (*Traffic situation 2*). It is expected that respondents will prefer *Traffic situation 2* over *Traffic situation 1*. Hence the following hypothesis:

H0: Road users do not feel safer when light vehicles platoon

The last factor that plays a role with respect to perceived road safety is the speed of other road users. Research has shown that motorists compare their own speed with the speed of other road users, after which they adjust their own speed based on this comparison (Connolly & Åberg, 1993). Moreover, motorists feel unsafe when other road users drive fast (Walton, 1999). According to Walton (1999), the faster other road users drive, the less safe motorists feel. This certainly applies when speeding is involved. If this is indeed the case, a road user will prefer a slow-moving platoon over a fast-moving platoon. In the survey, the respondent is asked to choose between a slow-moving platoon (*Traffic situation 1*) and a fast-moving platoon (*Traffic situation 2*). It is expected that respondents will prefer *Traffic situation 1* over *Traffic situation 2*. Hence the following hypothesis:

H0: Road users do not feel safer when platoons drive slow

4.4 Statistical methods

As stated before, the respondents will answer a number of questions regarding platooning. For each question in this phase, the exact same traffic situations will be displayed twice, with a risk factor being omitted or added to the second of the two traffic situations. The respondents can indicate which traffic situation they perceive as safer by means of three options, namely:

- *Traffic situation 1*;
- *Traffic situation 2*;
- *In both situations I perceive the same amount of safety*.

The hypotheses regarding these questions have been tested on the basis of a One Sample Chi-Square Test. The One Sample Chi-Square Test is used to determine whether a single categorical variable follows a hypothesized population distribution (SPSS Tutorials, n.d.).

Although it is expected that respondents have a preference for one of the three options, the null hypotheses regarding the questions of the platooning phase state that respondents are indifferent about the three options. If this is indeed the case, each option should be chosen by roughly the same number of respondents (SPSS, n.d.). In total, 161 people completed the survey, of which 158 respondents meet the criteria that have been drawn up to perform the analyses to test the hypotheses. Given the 158 valid respondents, the expected frequency for each option is (158 valid respondents / 3 options =) 52.7. In other words, it is expected that each option is chosen approximately 53 times per question. If the One Sample Chi-Square Test is significant ($p < 0.05$), a difference between the observed frequency (Observed N) and the expected frequency ($N = 52.7$) of an option exists. In other words, if the One Sample Chi-Square Test is significant, it means that the options deviate significantly from each other in terms of frequency. This may be an indication of the fact that a risk factor plays an important role in practice with regard to the consequences for perceived road safety when implementing platooning.

4.5 Conclusion

A survey was distributed among the target group (individuals with a driver licence) with the aim of generating a quantitative dataset. The survey consists of three phases, of which the second phase is the most important. For the second phase, the platooning phase, a hypothesis has been formulated for each question. The following hypotheses have been defined:

- *H0: Road users do not feel safer when roads are wide*
- *H0: Road users do not feel safer when a clear road layout is present*
- *H0: Road users do not feel safer when guardrails are present*
- *H0: Road users do not feel safer when platoons are clearly identifiable*
- *H0: Road users do not feel safer when light vehicles platoon*
- *H0: Road users do not feel safer when platoons drive slow*

The hypotheses regarding these questions have been tested on the basis of a One Sample Chi-Square Test. If the One Sample Chi-Square Test is significant, one of the three options is significantly more chosen compared to the other options.

Chapter 5 Descriptive statistics

5.1 Introduction

A descriptive analysis has been conducted to give a structured overview of the respondent population. The aim of this analysis is to gain insight into whether the respondents represent the population well. In total, 161 people completed the survey. Of the 161 respondents, 158 respondents meet the criteria that have been drawn up to perform the analyses to test the hypotheses. The other respondents (3 respondents) did not complete the survey and will therefore be removed from the dataset. For the descriptive statistics, the distributions within the following variables have been investigated: *Age*, *Gender*, and *Driving experience*. In this chapter, the various analyses will be discussed separately.

5.2 Descriptive analysis – Age

As shown in Figure 12, the dataset is not equally distributed in terms of *age*. Although the dataset consists of respondents between the ages of 18 and 69, people between the ages of 19 and 25 are overrepresented. Of the 158 valid respondents, 114 respondents (72.2%) belong to this age group. The distribution is therefore right-skewed. Moreover, some ages are completely missing. This can have consequences for the outcome, because the age of a road user affects the perceived road safety of that road user. A detailed overview about the age of the respondents can be found in the Appendix (Table 4).

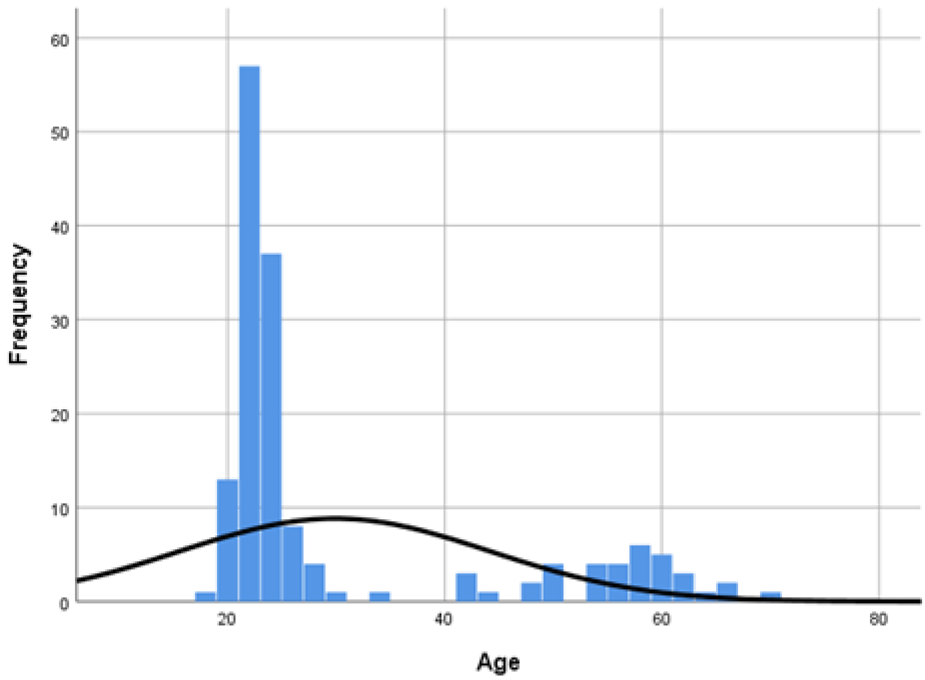


Figure 12. Descriptive analysis – Age

5.3 Descriptive analysis – Gender

As shown in Table 5, the dataset is equally distributed in terms of *gender*. Among the 158 valid respondents are 80 women (50.6%) and 78 men (49.4%).

Table 5

Descriptive analysis – Gender

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	78	48,4	49,4	49,4
	Female	80	49,7	50,6	100,0
	Total	158	98,1	100,0	
Missing	System	3	1,9		
Total		161	100,0		

5.4 Descriptive analysis – Driving experience

As shown in Table 6, the dataset is not equally distributed in terms of *driving experience*. Among the 158 valid respondents are 11 people without driving experience (7%), 85 novice drivers (53.8%) and 62 experienced drivers (39.2%). People without driving experience are therefore underrepresented. This, however, should not be a problem because the implementation of platooning will only affect people who are allowed to drive. Moreover, novice drivers are slightly overrepresented. This can have consequences for the outcome, because driving experience affects the perceived road safety of a road user.

Table 6

Descriptive analysis – Driving experience

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0 years	11	6,8	7,0	7,0
	0 – 5 years	85	52,8	53,8	60,8
	More than 5 years	62	38,5	39,2	100,0
	Total	158	98,1	100,0	
Missing	System	3	1,9		
Total		161	100,0		

5.5 Conclusion

As described above, the dataset is only equally distributed in terms of *gender*. The dataset contains about the same number of women as men (respectively 50.6% and 49.4%). Moreover, the dataset is not equally distributed in terms of *age* and *driving experience*. The dataset is right-skewed in terms of *age*. In addition, people without driving experience are therefore underrepresented and novice drivers are slightly overrepresented.

Chapter 6 Results

6.1 Introduction

In this chapter the results are discussed. As mentioned earlier, a hypothesis has been formulated for each question regarding the platooning phase. The hypotheses regarding these questions have been tested on the basis of a One Sample Chi-Square Test. Of the 161 respondents, 158 respondents meet the criteria that have been drawn up to perform the analyses to test the hypotheses. The results of the One Sample Chi-Square Tests will be discussed and analyzed per hypothesis. The important tables will also be shown here.

6.2 Results with regard to road design

The first hypothesis relates to the width of the road;

H0: Road users do not feel safer when roads are wide

The above hypothesis has been tested on the basis of a One Sample Chi-Square Test. The results of this test are shown in Table 7. Given the 158 valid respondents, it is expected that each option is chosen approximately 53 times. The results show that this is not the case for risk factors with regard to road design. *Traffic situation 2*, a relatively wide road, is chosen more often than expected on the basis of the null hypothesis (Residual = 63.3), while *Traffic situation 1*, a relatively small road, is chosen less often than expected on the basis of the null hypothesis (Residual = -42.7). The latter observation also applies to option 3 to a lesser extent (Residual = -20.7). The Chi-Square test statistic (see Table 8) indicates that the overall difference between the data and the hypothesis is almost 119. This result is significant: χ^2 (2) = 118.835, p = .000. In other words; H0 is rejected and the alternative hypothesis (HA) is adopted; road users do feel safer when roads are wide.

Table 7

One Sample Chi-Square Test

	Observed N	Expected N	Residual
Traffic situation 1	10	52,7	-42,7
Traffic situation 2	116	52,7	63,3
In both situations I perceive the same amount of safety	32	52,7	-20,7
Total	158		

Table 8

Test Statistics

Chi-Square	118,835[a]
df	2
Asymp. Sig.	,000

6.3 Results with regard to road layout

The second hypothesis relates to the layout of a road;

H0: Road users do not feel safer when a clear road layout is present

The above hypothesis has been tested on the basis of a One Sample Chi-Square Test. The results of this test are shown in Table 9. Given the 158 valid respondents, it is expected that each option is chosen approximately 53 times. The results show that this is not the case for risk factors with regard to road layout. *Traffic situation 2*, a clear road layout is present, is chosen more often than expected on the basis of the null hypothesis (Residual = 64.3), while *Traffic situation 1*, an unclear road layout is present, is chosen less often than expected on the basis of the null hypothesis (Residual = -47.7). The latter observation also applies to option 3 to a lesser extent (Residual = -16.7). The Chi-Square test statistic (see Table 10) indicates that the overall difference between the data and the hypothesis is 127. This result is significant: χ^2 (2) = 127.000, p = .000. In other words; H0 is rejected and the alternative hypothesis (HA) is adopted; road users do feel safer when a clear road layout is present.

Table 9

One Sample Chi-Square Test

	Observed N	Expected N	Residual
Traffic situation 1	5	52,7	-47,7
Traffic situation 2	117	52,7	64,3
In both situations I perceive the same amount of safety	36	52,7	-16,7
Total	158		

Table 10

Test Statistics

Chi-Square	127,000[a]
df	2
Asymp. Sig.	,000

6.4 Results with regard to roadside objects

The third hypothesis relates to the present of guardrails;

H0: Road users do not feel safer when guardrails are present

The above hypothesis has been tested on the basis of a One Sample Chi-Square Test. The results of this test are shown in Table 11. Given the 158 valid respondents, it is expected that each option is chosen approximately 53 times. The results show that this is not the case for risk factors with regard to roadside objects. *Traffic situation 2*, guardrails are present, is chosen more often than expected on the basis of the null hypothesis (Residual = 48.3), while *Traffic situation 1*, guardrails are not present, is chosen less often than expected on the basis of the null hypothesis (Residual = -31.7). The latter observation also applies to option 3 to a lesser extent (Residual = -16.7). The Chi-Square test statistic (see Table 12) indicates that the overall difference between the data and the hypothesis is almost 69. This result is significant: χ^2 (2) = 68.671, p = .000. In other words; H0 is rejected and the alternative hypothesis (HA) is adopted; road users do feel safer when guardrails are present.

Table 11

One Sample Chi-Square Test

	Observed N	Expected N	Residual
Traffic situation 1	21	52,7	-31,7
Traffic situation 2	101	52,7	48,3
In both situations I perceive the same amount of safety	36	52,7	-16,7
Total	158		

Table 12

Test Statistics

Chi-Square	68,671[a]
df	2
Asymp. Sig.	,000

6.5 Results with regard to vehicle design (1)

The fourth hypothesis relates to the external characteristics of a vehicle (visibility);

H0: Road users do not feel safer when platoons are clearly identifiable

The above hypothesis has been tested on the basis of a One Sample Chi-Square Test. The results of this test are shown in Table 13. Given the 158 valid respondents, it is expected that each option is chosen approximately 53 times. The results show that this is not the case for risk factors with regard to vehicle design. Both *Traffic situation 2*, platoons are clearly identifiable, and *Traffic situation 1*, platoons are not clearly identifiable, are chosen less often than expected on the basis of the null hypothesis (respectively: Residual = -33.7; Residual = -17.7). However, option 3, *In both situations I perceive the same amount of safety*, is chosen more often than expected on the basis of the null hypothesis (Residual = 51.3). The Chi-Square test statistic (see Table 14) indicates that the overall difference between the data and the hypothesis is approximately equal to 77. This result is significant: χ^2 (2) = 77.4811, p = .000. In other words; H0 is not rejected; road users do not feel safer when platoons are clearly identifiable.

Table 13

One Sample Chi-Square Test

	Observed N	Expected N	Residual
Traffic situation 1	35	52,7	-17,7
Traffic situation 2	19	52,7	-33,7
In both situations I perceive the same amount of safety	104	52,7	51,3
Total	158		

Table 14

Test Statistics

Chi-Square	77,481[a]
df	2
Asymp. Sig.	,000

6.6 Results with regard to vehicle design (2)

The fifth hypothesis relates to the mass of vehicles;

H0: Road users do not feel safer when light vehicles platoon

The above hypothesis has been tested on the basis of a One Sample Chi-Square Test. The results of this test are shown in Table 15. Given the 158 valid respondents, it is expected that each option is chosen approximately 53 times. The results show that this is not the case for risk factors with regard to vehicle design. *Traffic situation 2*, light vehicles platoon, is chosen more often than expected on the basis of the null hypothesis (Residual = 14.3), while *Traffic situation 1*, heavy vehicles platoon, is chosen less often than expected on the basis of the null hypothesis (Residual = -23.7). Option 3, *In both situations I perceive the same amount of safety*, is also chosen more often than expected on the basis of the null hypothesis (Residual = 9.3). The Chi-Square test statistic (see Table 16) indicates that the overall difference between the data and the hypothesis is approximately equal to 16. This result is significant: χ^2 (2) = 16.190, p = .000. In other words; H0 is rejected and the alternative hypothesis (HA) is adopted; road users do feel safer when light vehicles platoon.

Table 15

One Sample Chi-Square Test

	Observed N	Expected N	Residual
Traffic situation 1	29	52,7	-23,7
Traffic situation 2	67	52,7	14,3
In both situations I perceive the same amount of safety	62	52,7	9,3
Total	158		

Table 16

Test Statistics

Chi-Square	16,190[a]
df	2
Asymp. Sig.	,000

6.7 Results with regard to the speed of other road users

The sixth hypothesis relates to the speed of other road users;

H0: Road users do not feel safer when platoons drive slow

The above hypothesis has been tested on the basis of a One Sample Chi-Square Test. The results of this test are shown in Table 17. Given the 158 valid respondents, it is expected that each option is chosen approximately 53 times. The results show that this is not the case for risk factors with regard to the speed of other road users. *Traffic situation 1*, a slow-moving platoon, is chosen less often than expected on the basis of the null hypothesis (Residual = -28.7), while *Traffic situation 2*, a fast-moving platoon, is chosen more often than expected on the basis of the null hypothesis (Residual = 5.3). Moreover, option 3, *In both situations I perceive the same amount of safety*, is also chosen more often than expected on the basis of the null hypothesis (Residual = 23.3). The Chi-Square test statistic (see Table 18) indicates that the overall difference between the data and the hypothesis is approximately equal to 26. This result is significant: χ^2 (2) = 26.481, p = .000. In other words; H0 is not rejected; road users do not feel safer when platoons drive slow.

Table 17

One Sample Chi-Square Test

	Observed N	Expected N	Residual
Traffic situation 1	24	52,7	-28,7
Traffic situation 2	58	52,7	5,3
In both situations I perceive the same amount of safety	76	52,7	23,3
Total	158		

Table 18

Test Statistics

Chi-Square	26,481[a]
df	2
Asymp. Sig.	,000

6.8 Conclusion

The results have shown that the following alternative hypotheses must be adopted;

- *HA: Road users do feel safer when roads are wide*
- *HA: Road users do feel safer when a clear road layout is present*
- *HA: Road users do feel safer when guardrails are present*
- *HA: Road users do feel safer when light vehicles platoon*

Moreover, the results have also shown that the fourth and sixth hypotheses cannot be rejected.

Chapter 7 Conclusion

This Bachelor Thesis studied the consequences of platooning on perceived road safety. Studies have shown that perceived road safety affects the driving behaviour of motorists. Therefore, the success of platooning also depends on the effects that its implementation will have on perceived road safety. It is assumed that the implementation of platooning may have adverse effects on the perceived safety of other road users. However, it was unknown which factors concerning perceived road safety are affected when implementing platooning. In this study, an answer was found to the following question:

Which factors concerning perceived road safety are influenced by platooning?

The research methods used in this Bachelor Thesis were literature research and a survey. In order to answer the above research question, numerous studies were consulted and data from a survey was collected and analyzed.

7.1 Factors that affect perceived road safety according to literature

Risk perception plays an important role in the subjectively safety level of a traffic system. Risk perception contains both objective and subjective components (Hansson, 2010). Perceived road safety is therefore also affected by objective and subjective components. In case of perceived road safety, objective risk concerns all risk factors influencing crash involvement and risk factors influencing injury severity, while subjective risk concerns certain personal characteristics (Peden et al., 2004). Objective risk factors include road related factors such as road design, road layout and roadside objects, and include vehicle related factors such as vehicle design and speed. Moreover, subjective risk include personal characteristics such as age, gender and driving experience.

According to literature, road design, road layout and roadside objects affect the perceived road safety of road users. The road width and the curve radius are road design elements that affect the risk perception of motorists. The perceived risk of road users increases as the curve radius increases or the road becomes narrower (Kanellaidis, Zervas & Karagioules, 2000; Lewis-Evans & Charlton, 2006). Moreover, road layouts also seem to affect the perceived road safety of road users. According to literature, the perceived risk of motorists increases as the road layout becomes more unclear (Martens, Compte & Kaptein, 1997). Finally, roadside objects also play a major role in the perceived road safety of road users. The presence of roadside objects that reduce the risk of serious injury seems to have a positive effect on the perceived safety of road users (Bella, 2013; Yau, 2004).

Studies have shown that vehicle design and speed affect the perceived road safety of road users. The external characteristics of a vehicle (visibility) and in-vehicle crash protection are vehicle design elements that affect the risk perception of motorists. The perceived risk of road users increases as visibility decreases or vehicle mass of surrounding vehicles increases (Trick et al., 2010; Wang, Hensher & Ton, 2002). Moreover, the speed of other road users seems to play a major role in the driving behaviour of motorists. According to literature, the perceived risk of motorists increases as the speed of surrounding vehicles increases (Walton, 1999).

According to literature, age, gender and driving experience also affect the perceived road safety of road users. Studies have shown that relatively young drivers perceive risk differently compared to relatively old drivers. The perceived risk of being involved in a traffic accident and the perceived road safety therefore also differ per age group (Finn & Bragg, 1986). This also applies to gender. In short, gender affects risk perception, and therefore affects perceived road safety as well (DeJoy, 1992). Finally, driving experience also plays a major role in the perceived road safety of road users. Novice drivers detect hazards less quickly and less efficiently compared to experienced drivers (Deery, 1999). As road users gain more driving experience, their risk perception changes.

7.2 Factors that affect perceived road safety according to quantitative data

A survey was distributed among the target group (individuals with a driver licence). The respondents had to answer a number of questions regarding platooning. The results show that, when platooning is applied, not all objective risk factors affect the perceived road safety of road users. For example, road users do not seem to perceive more safety when platoons drive slow. In other words, the perceived risk of motorists does not increase as the speed of surrounding vehicles increases. This is therefore in contrast with the literature, which states that motorists feel unsafe when other road users drive fast (Walton, 1999). Moreover, vehicle design seems to play a smaller role than expected in terms of the external characteristics of a vehicle (visibility). According to literature, road user will prefer a clearly visible platoon over a badly visible platoon (Trick et al., 2010). However, the results show that this is not the case in practice. Road users do not seem to perceive more safety when platoons are clearly identifiable. Vehicle design however seems to play a role when it comes to in-vehicle crash protection.

According to literature, perceived safety decreases as vehicle mass of surrounding vehicles increases (Wang, Hensher & Ton, 2002). The results show that this is indeed the case. Road users do seem to perceive more safety when light vehicles platoon. In practice, a road user prefers a light vehicle platoon over a heavy vehicle platoon. In-vehicle crash protection, and therefore vehicle design as well, affects the perceived road safety of motorists. In short, vehicle design seems to play a smaller role in terms of the external characteristics of a vehicle (visibility), but seems to affect the perceived road safety of road users in terms of in-vehicle crash protection.

The results show that road design actually has an impact on the perceived road safety of motorists. Road users seem to perceive more safety when roads are wide. This result is in line with the literature. Studies have shown that narrow roads are associated with lower speeds and lane positions further away from the road edge while wider roads have higher speeds and lane positions closer to the road edge (Lewis-Evans & Charlton, 2006). In short, the narrower a road, the higher the perceived risk of road users. The results show that this is indeed the case. The perceived risk of road users seem to increase as the road becomes narrower. Road wide, and therefore road design as well, affect the perceived road safety of motorists.

This also applies to the layout of a road. According to literature, the perceived risk of motorists increases as the road layout becomes more unclear (Martens, Compte & Kaptein, 1997). This is confirmed by the results. Road users seem to prefer a clear road layout over an unclear road layout. Therefore, road users do perceive more safety when a clear road layout is present. In practice, perceived road safety increases if a road network has clear markings and signs. Thus, road layout affects the perceived road safety of motorists.

According to literature, roadside objects affect the perceived road safety of motorists. Studies have shown that the presence of roadside objects that reduce the risk of serious injury have a positive effect on the perceived safety of road users (Bella, 2013; Yau, 2004). This is in line with the results. The results show that road users do perceive more safety when guardrails are present. Road users prefer a road network with guardrails over a road network without guardrails. In short, the presence of guardrails increases the perceived safety of road users. Guardrails, and therefore roadside objects that reduce the risk of serious injury as well, affect the perceived road safety of motorists.

7.3 Which factors concerning perceived road safety are influenced by platooning?

According to literature, perceived road safety is affected by road design, road layout, roadside objects, vehicle design and speed. The result of the survey show that when platooning is applied, only road related risk factors affect the perceived road safety of road users. Road design, road layout and roadside objects play an important role in this relationship. Road users perceive more safety when roads are wide when platooning is applied. Also, road users perceive more safety when a clear road layout is present when platooning is applied. Finally, road users perceive more safety when roadside objects that reduce the risk of serious injury are present when platooning is applied. Vehicle related risk factors do not affect the perceived road safety of road users in practice when platooning is applied. However, in-vehicle crash protection seems to play a role in the relationship between platooning and perceived road safety. The results show that road users perceive less safety when heavy vehicles platoon. In short, the risk factors road design, road layout, roadside objects and, to a lesser extent, vehicle design are influenced by platooning.

7.4 Policy implications

The success of platooning depends on the effects that its implementation will have on perceived road safety. This study has shown that when platooning is applied, perceived road safety is affected by road design, road layout, roadside objects and, to a lesser extent, vehicle design. The success of platooning will therefore also depend on how policymakers deal with these risk factors. Policymakers can deal with the risk factors mentioned in two ways:

- Platooning can only be applied to road networks that take these risk factors into account;
- When platooning is implemented, the road network must also be adjusted on the basis of the risk factors mentioned.

It is however, not recommended to focus on vehicle related risk factors. In practice, vehicle related risk factors do not seem to affect the perceived road safety of motorists. Only the weight of the vehicles seems to have a significant effect on the perceived road safety. However, it does not make sense to ban heavy vehicle platoons, because truck platooning has many societal and business benefits.

Road related risk factors however, will in any case have to be taken into account. First, a road network should be wide when platooning is implemented. In practice, road users do feel safer when road are wide when platooning is applied. It is therefore recommended to apply platooning to road networks of at least three lanes. In this case, road users can, if necessary, take sufficient distance from an electronically connected platoon. Moreover, and at least as important, road users will perceive less risk when platooning is applied to road networks of at least three lanes.

In addition, a road network should have a clear road layout when platooning is implemented. In practice, road users do feel safer when a clear road layout is present when platooning is applied. It is therefore recommended to apply platooning to road networks with clear markings and signs. It should be clear to road users that platooning is applied. The following actions could be taken:

- Road users are informed by road signs of the fact that platooning is being applied;
- The part of the road on which platooning is applied is given clear markings;
- Platooning takes place on a lane separated from the rest of the road network by means of a roadside or guardrail.

Whatever action is taken, it must in any case be clear to the road user that platooning is applied, so that perceived risk is minimized.

Finally, guardrails, or similar alternatives, should be present when platooning is implemented. In practice, road users do feel safer when roadside objects that reduce the risk of serious injury are present when platooning is applied. It is therefore recommended to apply platooning to road networks where this kind of roadside objects are present, so that perceived risk is reduced to a minimum.

7.5 Limitations

This study has a number of limitations that may have affected the results. These limitations mainly relate to the survey. First, the sample size is not sufficient. As mentioned earlier, the survey was distributed among the target group; individuals with a driver licence. In the Netherlands, a total of 11.070.447 people are in possession of a driving license (CBS, 2018). The minimum sample size in this case is therefore equal to 385. It can be concluded that the number of respondents used for this study (161) does not meet this requirement. This study has reduced statistical power due to the inadequate sample size. Second, the dataset is not equally distributed in terms of age and driving experience. This can have consequences for the outcome, because both age and driving experience affect the perceived road safety of road users. Finally, only a limited number of risk factors were dealt with in the survey. It is possible that there are other risk factors that are affected when platooning is applied. The completeness of this study can therefore be questioned. It is therefore recommended to conduct more extensive research into the effect of platooning on perceived road safety.

Bibliography

Abbas, A. K., Hefny, A. F., & Abu-Zidan, F. M. (2011). Seatbelts and road traffic collision injuries. *World journal of emergency surgery*, *6*(1), 18.

ANWB. (n.d.). *Beginnend bestuurder*. Retrieved from https://www.anwb.nl/auto/rijbewijs/het-rijbewijs/beginnend-bestuurder

Bella, F. (2013). Driver perception of roadside configurations on two-lane rural roads: Effects on speed and lateral placement. *Accident Analysis & Prevention*, *50*, 251-262.

Bergenhem, C., Hedin, E., & Skarin, D. (2012). Vehicle-to-vehicle communication for a platooning system. *Procedia-Social and Behavioral Sciences*, *48*, 1222-1233.

Bergenhem, C., Huang, Q., Benmimoun, A., & Robinson, T. (2010, October). Challenges of platooning on public motorways. In *17th world congress on intelligent transport systems* (pp. 1-12).

Bergenhem, C., Shladover, S., Coelingh, E., Englund, C., & Tsugawa, S. (2012). Overview of platooning systems. In *Proceedings of the 19th ITS World Congress, Oct 22-26, Vienna, Austria (2012)*.

Blaauw, K. (2012). *Naar een effectieve kilometerprijs voor het vrachtverkeer*. Retrieved from https://vetron.org/wp-content/uploads/2013/05/factsheet_vrachtauto.pdf-rapport-natuur-en-millieu-MAUT.pdf

Brown, I. D. (1994). Driver fatigue. *Human factors*, *36*(2), 298-314.

Bull, A., & Thomson, I. (2002). Urban traffic congestion: its economic and social causes and consequences. *Cepal review*.

Cass, N., Shove, E., & Urry, J. (2005). Social exclusion, mobility and access. *The sociological review*, *53*(3), 539-555.

Centraal Bureau voor de Statistiek. (n.d.). *Doden en gewonden in het wegverkeer*. Retrieved from https://www.cbs.nl/nl-nl/maatschappij/verkeer-en-vervoer/transport-en-mobiliteit/mobiliteit/verkeersongevallen/categorie-verkeersongevallen/doden-en-gewonden-in-het-wegverkeer

Centraal Bureau voor de Statistiek. (2018). *Omzet in transportsector op hoogste niveau ooit*. Retrieved from https://www.cbs.nl/nl-nl/nieuws/2018/10/omzet-in-transportsector-op-hoogste-niveau-ooit

Centraal Bureau voor de Statistiek. (2018). *Personen met een rijbewijs; rijbewijscategorie, leeftijd, regio, 1 januari*. Retrieved from http://statline.cbs.nl/StatWeb/publication/?DM=SLNL&PA=83488ned

Centraal Bureau voor de Statistiek. (2016). *Transport en mobiliteit*. Retrieved from https://www.cbs.nl/nl-nl/publicatie/2016/25/transport-en-mobiliteit-2016

Centraal Bureau voor de Statistiek. (2018). *Verkeersdoden, 2017*. Retrieved from https://www.cbs.nl/nl-nl/maatwerk/2018/17/verkeersdoden-2017

Choueiri, E. M., Lamm, R., Kloeckner, J. H., & Mailaender, T. (1994). Safety aspects of individual design elements and their interactions on two-lane highways: international perspective. *Transportation Research Record*, (1445).

Connolly, T., & Åberg, L. (1993). Some contagion models of speeding. *Accident Analysis & Prevention*, *25*(1), 57-66.

Davila, A. (2013). Report on fuel consumption. *SARTRE, Deliverables*.

Deery, H. A. (1999). Hazard and risk perception among young novice drivers. *Journal of safety research*, *30*(4), 225-236.

DeJoy, D. M. (1992). An examination of gender differences in traffic accident risk perception. *Accident Analysis & Prevention*, *24*(3), 237-246.

Elvik, R., Christensen, P., & Amundsen, A. (2004). Speed and road accidents. *An evaluation of the Power Model. TØI report*, *740*, 2004.

Europa Nu. (n.d.). *Beleid vervoer*. Retrieved from https://www.europa-nu.nl/id/vg9pkzu1yryd/beleid_vervoer

Finn, P., & Bragg, B. W. (1986). Perception of the risk of an accident by young and older drivers. *Accident Analysis & Prevention*, *18*(4), 289-298.

Hansson, S. O. (2010). Risk: objective or subjective, facts or values. *Journal of Risk Research*, *13*(2), 231-238.

Holdridge, J. M., Shankar, V. N., & Ulfarsson, G. F. (2005). The crash severity impacts of fixed roadside objects. *Journal of Safety Research*, *36*(2), 139-147.

Janic, M. (2007). Modelling the full costs of an intermodal and road freight transport network. *Transportation Research Part D: Transport and Environment*, *12*(1), 33-44.

Janssen, R., Zwijnenberg, H., Blankers, I., & de Kruijff, J. (2015). Truck platooning. *Driving The Future of Transportation, TNO*.

Kanellaidis, G., Zervas, A., & Karagioules, V. (2000). Drivers' risk perception of road design elements. *Transportation Human Factors*, *2*(1), 39-48.

Kulanthayan, S., Umar, R. R., Hariza, H. A., Nasir, M. M., & Harwant, S. (2000). Compliance of proper safety helmet usage in motorcyclists. *Medical Journal of Malaysia*, *55*(1), 40-44.

Levy, J. I., Buonocore, J. J., & Von Stackelberg, K. (2010). Evaluation of the public health impacts of traffic congestion: a health risk assessment. *Environmental health*, *9*(1), 65.

Lewis-Evans, B., & Charlton, S. G. (2006). Explicit and implicit processes in behavioural adaptation to road width. *Accident Analysis & Prevention*, *38*(3), 610-617.

Mackay, M. (1994). Engineering in accidents: vehicle design and injuries. *Injury*, *25*(9), 615-621.

Martens, M. H., Compte, S., & Kaptein, N. A. (1997). The effects of road design on speed behaviour: a literature review.

Mayou, R., Bryant, B., & Duthie, R. (1993). Psychiatric consequences of road traffic accidents. *Bmj*, *307*(6905), 647-651.

Minnen, J. V., Ligtvoet, W., Bree, L. V., Hollander, G. D., Visser, H., Schrier, G., ... & Klein Tank, A. M. G. (2012). Effecten van klimaatverandering in Nederland: 2012. *Beleidsstudies*, 1-125.

Nelson, J. P. (1982). Highway noise and property values: a survey of recent evidence. *Journal of transport economics and policy*, 117-138.

NOS. (2017). *Tien keer zoveel kans op ongeluk bij gebruik smartphone in auto*. Retrieved from https://nos.nl/artikel/2171112-tien-keer-zoveel-kans-op-ongeluk-bij-gebruik-smartphone-in-auto.html

Nowakowski, C., Shladover, S. E., Lu, X. Y., Thompson, D., & Kailas, A. (2015). Cooperative adaptive cruise control (CACC) for truck platooning: Operational concept alternatives.

NU.nl. (2018). *Transportsector boekt omzetgroei van bijna 4 procent in eerste kwartaal*. Retrieved from https://www.nu.nl/ondernemen/5302874/transportsector-boekt-omzetgroei-van-bijna-4-procent-in-eerste-kwartaal.html

NU.nl. (2018). *'Vrachtwagens vervoeren meer, maar rijden minder ver'*. Retrieved from https://www.nu.nl/economie/5173319/vrachtwagens-vervoeren-meer-maar-rijden-minder-ver.html

Ogden, E. J., & Moskowitz, H. (2004). Effects of alcohol and other drugs on driver performance. *Traffic injury prevention*, *5*(3), 185-198.

Peden, M., Scurfield, R., Sleet, D., Mohan, D., Hyder, A. A., Jarawan, E., & Mathers, C. (2004). World report on road traffic injury prevention.

Ploeg, J., Serrarens, A. F., & Heijenk, G. J. (2011). Connect & Drive: design and evaluation of cooperative adaptive cruise control for congestion reduction. *Journal of Modern Transportation*, *19*(3), 207-213.

Robinson, T., Chan, E., & Coelingh, E. (2010, October). Operating platoons on public motorways: An introduction to the sartre platooning programme. In *17th world congress on intelligent transport systems* (Vol. 1, p. 12).

Rosenbloom, T. (2006). Driving performance while using cell phones: An observational study. *Journal of Safety Research*, *37*(2), 207-212.

Sjöberg, L. (2000). Factors in risk perception. *Risk analysis*, *20*(1), 1-12.

Sjöberg, L., Moen, B. E., & Rundmo, T. (2004). Explaining risk perception. *An evaluation of the psychometric paradigm in risk perception research*, *10*(2), 665-612.

SPSS Tutorials. (n.d.). *SPSS One Sample Chi-Square Test*. Retrieved from https://www.spss-tutorials.com/spss-one-sample-chi-square-test/

Stansfeld, S. A., & Matheson, M. P. (2003). Noise pollution: non-auditory effects on health. *British medical bulletin*, *68*(1), 243-257.

The Economist. (2012). *Look, no hands*. Retrieved from https://www.economist.com/node/21560989

Trick, L. M., Toxopeus, R., & Wilson, D. (2010). The effects of visibility conditions, traffic density, and navigational challenge on speed compensation and driving performance in older adults. *Accident Analysis & Prevention*, *42*(6), 1661-1671.

Ulleberg, P. (2001). Personality subtypes of young drivers. Relationship to risk-taking preferences, accident involvement, and response to a traffic safety campaign. *Transportation Research Part F: Traffic Psychology and Behaviour*, *4*(4), 279-297.

VERKEERSNET. (2017). *Europese subsidie voor platooning en alternatieve brandstoffen*. Retrieved from https://www.verkeersnet.nl/smart-mobility/23608/europese-subsidie-platooning-en-alternatieve-brandstoffen/

Vidal, C. J., & Goetschalckx, M. (2001). A global supply chain model with transfer pricing and transportation cost allocation. *European Journal of Operational Research*, *129*(1), 134-158.

Vlakveld, W. P., Goldenbeld, C., & Twisk, D. A. M. (2009). Beleving van verkeersonveiligheid: een probleemverkenning over subjectieve veiligheid.

Vorko-Jović, A., Kern, J., & Biloglav, Z. (2006). Risk factors in urban road traffic accidents. *Journal of Safety Research*, *37*(1), 93-98.

Walsh, J. M., Gier, J. J., Christopherson, A. S., & Verstraete, A. G. (2004). Drugs and driving. *Traffic injury prevention*, *5*(3), 241-253.

Walton, D. (1999). Examining the self-enhancement bias: professional truck drivers' perceptions of speed, safety, skill and consideration. *Transportation research part F: traffic psychology and behaviour*, *2*(2), 91-113.

Wang, B., Hensher, D. A., & Ton, T. (2002). Safety in the road environment: a driver behavioural response perspective. *Transportation*, *29*(3), 253-270.

Wasielewski, P. (1984). Speed as a measure of driver risk: Observed speeds versus driver and vehicle characteristics. *Accident Analysis & Prevention*, *16*(2), 89-103.

de Weerd, P. (2017, March 21). *Wat is platooning?*. Retrieved from http://www.logistiek.nl/distributie/artikel/2017/03/wat-is-platooning-101153746

World Health Organization. (2009). Global status report on road safety: time for action.

Yau, K. K. (2004). Risk factors affecting the severity of single vehicle traffic accidents in Hong Kong. *Accident Analysis & Prevention*, *36*(3), 333-340.

Zaidel, D. M. (1992). A modeling perspective on the culture of driving. *Accident Analysis & Prevention*, *24*(6), 585-597.

Zakowska, L. (1995). The effect of environmental and design parameters on subjective road safety—a case study in Poland. *Safety science*, *19*(2-3), 227-234.

Appendix

Table 1

A comparison of five platooning projects (Source: Bergenhem et al., 2012)

	Vehicle type	Control	Infrastructure requirements	Traffic integration	Sensors	Goals
SARTRE	Mixed	Lat + Long	None	Highway, Mixed	Production	Comfort, safety, congestion, energy
PATH	Cars or Heavy	Lat + Long	Reference markers in road surface	Dedicated lane	Mixed	Increased throughput per lane, energy saving
GCDC	Mixed	Long	Augmented GPS	Mixed	SoA and production	Accelerate deployment of cooperative driving systems
Energy-ITS	Heavy	Lat + Long	Lane markings	Dedicated lane	SoA	Mitigate lack of skilled drivers
SCANIA	Heavy	Long	None	Highway, Mixed	No V2V comm. in first stage.	Commercial fleet, energy

Table 2

Examples of factors affecting drivers' choice of speed (Source: Peden et al., 2004)

Road and vehicle related	Traffic and environment related	Driver related
Road	Traffic	Age
Width	Density	Sex
Gradient	Composition	Reaction time
Alignment	Prevailing speed	Attitudes
Surroundings	Environment	Thrill-seeking
Layout	Weather	Risk acceptance
Markings	Surface condition	Hazard perception
Surface quality	Natural light	Alcohol level
Vehicle	Road lighting	Ownership of vehicle
Type	Signs	Circumstances of journey
Power/weight ratio	Speed limit	Occupancy of vehicle
Maximum speed	Enforcement	
Comfort		

Table 3

Factors that predispose a driver to fatigue (Source: Peden et al., 2004)

Drivers at risk of fatigue	Temporal factors causing fatigue	Environmental factors in fatigue	Sleep-related factors
Young drivers (up to 25 years)	Driving between 02.00 and 05.00	Driving in remote areas with featureless terrain	Driving with sleep debt
Drivers over 50 years	More than 16 hours of wakefulness before trip	Monotonous roads	Driving with a sleep-related condition
Males	Long work period before trip	Main arterial roads	Driving when normally asleep
Shift workers	Long time since start of trip	Long-haul driving	Drivers disposed to nodding off
Those for whom driving is part of job	Irregular shift work before trip	Unexpected demands, breakdowns, etc.	Driving after poor-quality sleep
Those with medical conditions (such as narcolepsy)	Driving after successive nights of shift work	Extreme climatic conditions	
After consuming alcohol	Driving under time pressure	Driving an unfamiliar route	
Driving after inadequate rest and sleep	Some drivers are drowsy in the afternoon		

Table 4

Descriptive analysis – Age

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		3	1,9	1,9	1,9
	18	1	,6	,6	2,5
	19	6	3,7	3,7	6,2
	20	7	4,3	4,3	10,6
	21	28	17,4	17,4	28,0
	22	29	18,0	18,0	46,0
	23	24	14,9	14,9	60,9
	24	13	8,1	8,1	68,9
	25	7	4,3	4,3	73,3
	26	1	,6	,6	73,9
	27	2	1,2	1,2	75,2
	28	2	1,2	1,2	76,4
	30	1	,6	,6	77,0
	34	1	,6	,6	77,6
	41	1	,6	,6	78,3
	42	2	1,2	1,2	79,5
	43	1	,6	,6	80,1
	47	2	1,2	1,2	81,4
	49	1	,6	,6	82,0
	50	3	1,9	1,9	83,9
	53	2	1,2	1,2	85,1
	54	2	1,2	1,2	86,3
	55	3	1,9	1,9	88,2
	56	1	,6	,6	88,8
	57	3	1,9	1,9	90,7
	58	3	1,9	1,9	92,5
	59	3	1,9	1,9	94,4
	60	2	1,2	1,2	95,7
	61	3	1,9	1,9	97,5
	63	1	,6	,6	98,1
	65	1	,6	,6	98,8
	66	1	,6	,6	99,4
	69	1	,6	,6	100,0
	Total	161	100,0	100,0	

Survey

Introduction

Thank you for taking the time to complete this survey. I am a student at the Erasmus University and am currently in the phase of completing my Bachelor Thesis. In order to be able to do so, I would like to ask you to fill out a short survey with questions that relate to perceived road safety. Answering the questions will cost you **less than 5 minutes**. For all questions and answers, it merely concerns your opinion and, therefore, there is no right or wrong. This survey does not include any personal information and the outcome of your answers will be used for this study only.

Introduction Phase 1

In the first phase of this survey, I would like to ask you to assess your feelings concerning safety in different road situations. Imagine you find yourself in the following situations;

Phase 1:

On a scale from 1 (extremely unsafe) to 7 (extremely safe), how do you feel about the following traffic situation?

Extremely unsafe / Nor unsafe, nor safe / Extremely safe

On a scale from 1 (Extremely unsafe) to 7 (Extremely safe), how do you feel about the following traffic situation?

Extremely unsafe / Nor unsafe, nor safe / Extremely safe

On a scale from 1 (Extremely unsafe) to 7 (Extremely safe), how do you feel about the following traffic situation?

Extremely unsafe / *Nor unsafe, nor safe* / *Extremely safe*

On a scale from 1 (Extremely unsafe) to 7 (Extremely safe), how do you feel about the following traffic situation?

Extremely unsafe / *Nor unsafe, nor safe* / *Extremely safe*

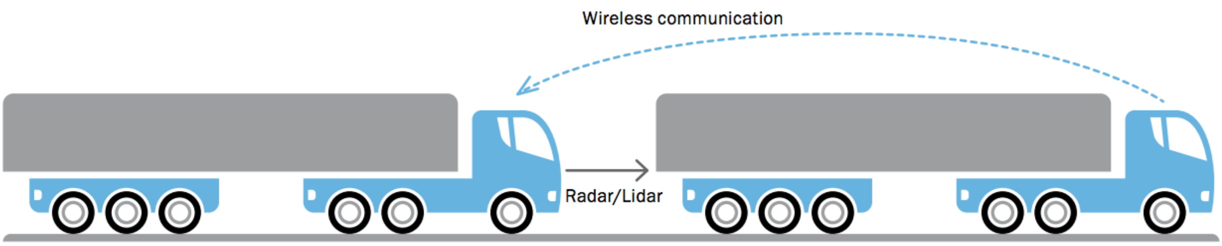
On a scale from 1 (Extremely unsafe) to 7 (Extremely safe), how do you feel about the following traffic situation?

Extremely unsafe | *Nor unsafe, nor safe* / *Extremely safe*

Introduction Phase 2:

PLATOONING

The following questions will be about a new logistic solution called **platooning.** Platooning is the automatic following of a preceding vehicle. With this new logistics solution, trucks are electronically linked to each other. The front truck, the leading truck, determines the speed and route of the procession. The following trucks, which are electronically coupled to the leading truck, automatically follow the leading truck. Platooning is applied in the following questions. In the figure below a simplified representation of platooning is shown.



The following questions are about your perception of safety when driving close to a platooning convoy. Imagine yourself driving in one of the following situations;

In which traffic situation do you perceive more safety?

A) Traffic situation 1

B) Traffic situation 2

C) In both situations I perceive the same amount of safety

In which traffic situation do you perceive more safety?

A) Traffic situation 1

B) Traffic situation 2

C) In both situations I perceive the same amount of safety

In which traffic situation do you perceive more safety?

A) Traffic situation 1

B) Traffic situation 2

C) In both situations I perceive the same amount of safety

In which traffic situation do you perceive more safety?

A) Traffic situation 1

B) Traffic situation 2

C) In both situations I perceive the same amount of safety

In which traffic situation do you perceive more safety?

A) Traffic situation 1

B) Traffic situation 2

C) In both situations I perceive the same amount of safety

In which traffic situation do you perceive more safety?

A) Traffic situation 1

B) Traffic situation 2

C) In both situations I perceive the same amount of safety

Phase 3

Finally a few questions about yourself. *As stated before, the following answers are only used for this thesis.*

What is your age?

[ ]

What is your gender?

Male / Female

For how long have you been in possession of a driving license?

- 0 years
- 0 – 5 years
- More than 5 years

Final word

You have successfully completed the survey. Thanks again for completing the survey.

Link

https://erasmusuniversity.eu.qualtrics.com/jfe/form/SV_em3Wj3UQsBfYGrj