
# How to keep credibility?

The transition from 50 km/h to 30 km/h within the urban area

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# Preface

In front of you lies my master thesis called *How to keep credibility – The transition from 50 km/h to 30 km/h within the urban area*. This report is the result of the master thesis research, which I conducted as my final assessment of the master study programme Civil Engineering and Management, at the University of Twente in Enschede. In about five months, I have researched the credibility of the speed limit on 30 km/h roads.

At the end of 2019, I approached Goudappel Coffeng and asked if the were possibilities for a graduation thesis. The 'Het Nieuwe 30' project came along, and I thought it would be an interesting project to contribute to. This project is carried out by traffic consultants Goudappel Coffeng and DTV Consultants. Within the project, the effect of the design of 30 km/h roads on speed, traffic safety and livability is investigated. An in-depth study of the credibility of these roads fitted well within this project. It was interesting research to do and suited my interests well.

Soon after the start of the research, national measures were taken to prevent the spread of the coronavirus. A lot of things that always seemed normal were suddenly no longer self-evident. Although the working environment suddenly changed (from office to home), the research could continue to be carried out relatively undisturbed. My supervisors played an important role in this and helped me through the research process. First, I want to thank Rico Andriesse from Goudappel Coffeng for his guidance and dedication. I was always able to ask questions and to get feedback to steer me in the right direction. Moreover, I was provided with the freedom to shape the study myself.

Furthermore, I would like to thank my supervisors Tom Thomas and Eric van Berkum from the University of Twente, for their supervision and sharing of knowledge. Prior to the research, they played an important role in developing the proposal. Also, during the study, their feedback was helpful to improve the research. They looked at the research from a different (more scientific) perspective, which resulted in valuable insights.

Finally, I would like to thank all the other people who helped me set up and carry out the research. First of all, I would like to thank Goudappel Coffeng for allowing me to carry out my graduation research at their company. I would also like to thank the employees of the company for making me feel welcome and helping me with specific issues such as setting up the survey and analysing data. I would also like to thank everyone in my environment who helped with the testing of the survey, all the municipalities who participated in the distribution of the survey and all the respondents who completed the survey. Without their help, it was not possible to reach the current result.

I hope you will enjoy reading this report.

Joran van Kessel

Lunteren, August 2020

# Summary

In recent years there has been more and more discussion about speed limits in built-up areas. One of the most discussed proposals is to transform 50 km/h roads to 30 km/h roads. 30 km/h should become the new standard within built-up areas according to certain organisations. The most frequently mentioned argument for this speed limit reduction is road safety. At lower speeds, the severity of many accidents is lower, resulting in fewer (fatal) casualties. A lower speed would also contribute to an improved living environment, for example by reducing traffic noise pollution.

However, in order to benefit from the advantages of a possible speed reduction, drivers must adapt to the new limit and reduce their speed. On many 30 km/h roads, speeding is still excessive. The incredible design of roads contributes to this. Changing a 50 km/h sign to a 30 km/h sign is not enough, the road will also have to be adapted to make the limit credible. Different road and environmental characteristics play an important role in this process and determine whether the image of the road and surroundings matches the speed limit.

The number of studies into the credibility of the speed limit on 30 km/h roads is still very limited. Most studies into a credible design are aimed at roads with higher speed limits. Therefore, it was decided to investigate which road and environmental characteristics influence the credibility of 30 km/h roads, so that these roads can be designed more credibly. The core of the research consists of a survey in which respondents (car drivers) were shown photographs of a selection of 30 km/h roads. For each road, the respondent was asked about the preferred speed and estimated limit. The credibility has been quantified as the difference between these speeds and the speed limit. In addition to the survey, literature research was carried out to find out which road and environment characteristics from earlier studies influenced the credibility and speed. These characteristics were collected for the selection of 30 km/h roads from the survey.

Finally, the respondents' speeds and the characteristics of the roads were combined in data analysis to determine the influence of the individual road and environmental characteristics on the credibility. Multiple regression analyses with combinations of relevant characteristics were also carried out. In this way, the effect of the individual characteristics in conjunction with other characteristics on credibility was assessed. The results show that environmental characteristics have the most influence on credibility. Roads with shops, connected buildings and buildings on both sides of the road are characteristics that contribute most to credibility and reducing speed. Additionally, various characteristics of the road have a significant influence on credibility, especially the presence of parked cars and the location of cyclists (mixed with other traffic instead of bicycle lanes).

Moreover, an existing method for comparing the credibility of roads was tested. However, the credibility scores of roads turn out to have no relation whatsoever with both the speeds of respondents and the measured speeds. For this reason, a new tool, a credibility indicator, has been developed that can be used to determine the credibility of 30 km/h roads more accurately. This indicator is based on the results of the data analysis and requires some road and environmental characteristics to be entered. After the entry of these characteristics, an indication of the credibility is directly displayed on a speedometer with colour scales.

The research can be classified as exploratory research and offers sufficient starting points for possible follow-up research. For example, the number of 30 km/h roads in the survey was limited, meaning that the influence on credibility could not be determined for all characteristics. Insufficient observations were made of some of the characteristics, resulting in an unknown influence on credibility. Follow-up research with a larger group of roads, therefore, leads to more diversity of characteristics, resulting in a more complete overview of the influence of characteristics on credibility. With these new insights, the existing credibility indicator can also be expanded.

# Samenvatting

De laatste jaren is er steeds meer discussie over snelheidslimieten binnen de bebouwde kom. Een van de meest besproken voorstellen is om 50 km/u wegen te transformeren naar 30 km/u wegen. Volgens bepaalde organisaties zou 30 km/u de nieuwe snelheidsnorm binnen de bebouwde kom moeten worden. Het meest genoemde argument voor deze verlaging van de maximumsnelheid is de verbetering van de verkeersveiligheid. Met een lagere snelheid is de ernst van veel ongelukken lager, waardoor er minder (dodelijke) slachtoffers zouden vallen. Ook zou een lagere snelheid bijdragen aan een verbeterde leefomgeving, bijvoorbeeld door minder geluidsoverlast van verkeer.

Echter, om de voordelen van een mogelijke snelheidsverlaging te kunnen benutten, is het van belang dat automobilisten zich aanpassen aan de nieuwe limiet en hun snelheid verminderen. Op veel 30 km/u wegen wordt nog te hard gereden. Een van de oorzaken hiervoor is de ongeloofwaardige inrichting. Het verwisselen van een 50 km/u bord door een 30 km/u bord volstaat niet, ook de weg zal aangepast moeten worden om de limiet geloofwaardig te maken. Verschillende kenmerken van de weg- en de omgeving spelen hierbij een belangrijke rol en bepalen of het beeld van de weg en omgeving past bij de snelheidslimiet.

Het aantal onderzoeken naar de geloofwaardigheid van de snelheidslimiet op 30 km/u wegen is nog zeer beperkt. De meeste onderzoeken naar een geloofwaardige inrichting zijn gericht op wegen met hogere snelheidslimieten. Daarom is ervoor gekozen om te onderzoeken welke weg en omgevingskenmerken de geloofwaardigheid van specifiek 30 km/u wegen beïnvloeden, zodat deze wegen geloofwaardiger ontworpen kunnen. De kern van het onderzoek bestaat uit een enquête waarin automobilisten foto's van verschillende 30 km/u wegen werden getoond. Bij elke weg werd gevraagd naar de voorkeurssnelheid en geschatte limiet van de respondent. De geloofwaardigheid is gekwantificeerd als het verschil tussen deze geantwoorde snelheden en de snelheidslimiet. Daarnaast is met behulp van literatuuronderzoek onderzocht welke kenmerken uit eerdere onderzoeken invloed hebben op de geloofwaardigheid en snelheid. Deze kenmerken zijn verzameld voor de selectie van 30 km/u wegen uit de enquête.

Uiteindelijk zijn de snelheden van de respondenten en de kenmerken van de wegen gecombineerd in een data-analyse, zodat dat de invloed van de individuele weg en omgevingskenmerken op de geloofwaardigheid bepaald kon worden. Ook zijn meervoudige regressie analyses uitgevoerd met combinaties van relevante kenmerken. Het doel hiervan was om het effect van de individuele kenmerken in samenhang met andere kenmerken op de geloofwaardigheid vast te stellen. De resultaten laten zien dat omgevingskenmerken de meeste invloed op de geloofwaardig hebben. Wegen met winkels, aangesloten bebouwing en gebouwen aan beide kanten van de weg zijn kenmerken die het meest bijdragen aan het geloofwaardiger maken van 30 km/u wegen en het verlagen van de snelheid. Maar ook diverse kenmerken van de weg hebben een significante invloed op de geloofwaardigheid, met name de aanwezigheid van geparkeerde auto's, het type verharding (klinkers in plaats van grijs asfalt) en de locatie van fietsers (gemengd met ander verkeer in plaats van fietsstroken).

Daarnaast is een bestaande methode uit de literatuur om de geloofwaardigheid van wegen te kunnen vergelijken getest door de geloofwaardigheid van de wegen uit de enquête te bepalen. De uiteindelijke geloofwaardigheidsscores blijken echter geen enkele relatie te hebben met zowel de snelheden van respondenten als de gemeten snelheden. Daarom is een opzet gemaakt voor een nieuwe tool, waarmee nauwkeuriger de geloofwaardigheid van 30 km/u wegen bepaald kan worden. Deze indicator is gebaseerd op de resultaten van de data-analyse en vraagt om een aantal weg- en omgevingskenmerken in te voeren. Na invoering van deze kenmerken wordt direct een indicatie van de geloofwaardigheid weergegeven op een snelheidsmeter.

Het onderzoek kan worden geclassificeerd als verkennend onderzoek en biedt voldoende aanknopingspunten voor mogelijk vervolgonderzoek. Zo was het aantal 30 km/u wegen in de enquête beperkt, waardoor niet van alle kenmerken de invloed op de geloofwaardigheid bepaald kon worden. Van sommige kenmerken waren onvoldoende observaties, waardoor de invloed op de geloofwaardigheid nog onbekend is. Vervolgonderzoek met een grotere groep wegen leidt daarom tot meer diversiteit van kenmerken, waardoor een completer beeld van de invloed van kenmerken op de geloofwaardigheid ontstaat. Met deze nieuwe inzichten kan ook de bestaande geloofwaardigheidsindicator uitgebreid worden.

### *Aanbevelingen*

Er is geen eenvoudige oplossing om wegen met een limiet van 30 km/u geloofwaardiger te maken. Veel kenmerken van zowel de weg als omgeving hebben invloed op de geloofwaardigheid. Tevens zijn er diverse interacties tussen de kenmerken waarmee rekening mee gehouden moet worden. Bovendien spelen dynamische kenmerken (zoals andere verkeersdeelnemers en weersomstandigheden) en persoonlijke kenmerken (waarvan op dit moment nog onvoldoende inzicht in is) een rol bij de beoordeling van de geloofwaardigheid van een bepaalde automobilist op een bepaald moment op een bepaalde weg. Er is dus een samenspel van allerlei kenmerken die met elkaar samenhangen. Hierdoor is het vrijwel onmogelijk om een weg zo in te richten, dat deze voor iedereen geloofwaardig is. Wel is het mogelijk om met behulp van bepaalde aanpassingen de weg voor (bijna) iedereen geloofwaardiger te maken, omdat het lijkt dat automobilisten zich grotendeels laten beïnvloeden door dezelfde weg- en omgevingskenmerken.

Op basis van de resultaten lijken de omgevingskenmerken de meeste invloed op de geloofwaardigheid te hebben. Winkels, aaneengesloten bebouwing en gebouwen aan beide kanten van de weg dragen het meeste bij aan de verbetering van de geloofwaardigheid en vermindering van de snelheid. Ook de afstand naar gebouwen heeft een significante invloed op de geloofwaardigheid, waarbij een grotere afstand leidt tot een hogere snelheid. Hoewel deze kenmerken niet eenvoudig aan te passen zijn, wordt het wel aanbevolen om er rekening mee te houden. Ze kunnen worden gebruikt om te bepalen in welke straten een overgang naar een limiet van 30 km/u het meest kansrijk lijkt te zijn gezien de kenmerken van de omgeving. Met behulp van de eigenschappen van de omgeving kan worden getoetst of het kansrijk is om te komen tot een geloofwaardige 30 km/u weg. Als de kenmerken van de omgeving in grote mate overeen komen met de kenmerken die ook in positieve mate bijdragen aan de geloofwaardigheid, dan is het veel kansrijker dat een eventuele nieuwe snelheidslimiet van 30 km/u later ook als geloofwaardig wordt beoordeelt door de automobilisten. Bovendien kunnen bepaalde meer eenvoudig aan te passen kenmerken van de weg worden toegepast om de geloofwaardigheid te bevorderen, zoals het toevoegen van parkeerplaatsen voor auto's, het gebruik van klinkers en fietsers op dezelfde rijbaan gemengd tussen auto's laten rijden.

De gecreëerde geloofwaardigheidsindicator is een eerste aanzet voor toepassing van de resultaten en kan de wegbeheerder meer inzicht geven in de wegen die extra aandacht verdienen met betrekking tot geloofwaardigheid en snelheid. De inrichting van bestaande wegen en potentiële ontwerpen van nieuwe wegen kunnen worden getoetst. Uiteindelijk kan dit leiden tot aanpassing van de limiet of aanpassing van de weg- en omgevingskenmerken ten gunste van de geloofwaardigheid.

# Content

# 1 Introduction

In recent years there has been an increasing debate whether it makes sense to introduce a speed limit of 30 km/h instead of 50 km/h in built-up areas in favour of road safety and quality of life. A lower speed will, among other things, reduce speed differences between cars and slow traffic such as cyclists and pedestrians. As a result, the severity of possible accidents will be reduced. Several municipalities are already considering increasing the number of 30 km/h roads within their municipality. However, in order to achieve the desired (safety) effects, drivers will also have to comply with the new speed limit.

On current 30 km/h roads, the limit is often exceeded. One of the causes is that these roads are not credibly designed. When a speed limit is incredible, the image of the road and its surroundings does not match with the speed limit. In this case, drivers are less inclined to stick to the limit. Moreover, if limits are found to be incredible regularly, the limit system as a whole may be found to be incredible. Drivers will then be more and more inclined to follow their own opinion about the right speed instead of the limit, which is undesirable. The study will, therefore, investigate how the transformation from 50 km/h roads to 30 km/h roads can take place, resulting in credible speed limits.

The research was carried out at traffic consultancy Goudappel Coffeng in Deventer. In 2019, Goudappel Coffeng started a research project called 'Het Nieuwe 30' together with consultancy firm DTV Consultants. Both companies received more and more questions from municipalities about the design of 30 km/h roads. As there was still little knowledge available in this area, the companies decided, in cooperation with several municipalities, to investigate how busy 30 km/h roads can be designed safely and attractively and what are the possible consequences for the surrounding area and the city. The project focuses on the safe and attractive design of roads. Credibility was not directly included in the research but was seen as a useful addition.

The number of studies into the credibility of the speed limit on 30 km/h roads is still minimal. Most investigations into a credible design are aimed at roads with higher speed limits. Therefore, it was decided to investigate which road and environmental characteristics specifically influence the credibility of 30 km/h roads, so that these roads can be designed more credibly for the benefit of traffic safety. The core of the research consists of a survey in which drivers were shown photographs of various 30 km/h roads and were asked about the speed the respondent would drive on the road in question.

Besides, literature research was conducted to determine which characteristics from earlier studies influence credibility and speed. These characteristics were collected for the used selection of 30 km/h roads in the survey. Finally, the speeds of the respondents and the characteristics of the roads were combined in data analysis to determine the influence of the individual road and environmental characteristics on credibility.

As described earlier, various developments in recent years have prompted the research. These developments and further context information are described in chapter 2. Subsequently, chapter 3 contains a literature review in which existing knowledge and previous research are reported. This literature review forms the basis for the problem analysis presented in chapter 4. The research objective, the research questions, scope and research methods are also described in this chapter. Because the survey is the core of the research, the design of the survey is described in detail in chapter 5. Subsequently, the data analysis is provided in chapter 6 and the results are presented in chapter 7. The application of the results is given in chapter 8. Moreover, chapter 9 and 10 provide the discussion and conclusion. Finally, references and appendices are included.

# 2 Context

At the end of the 1990s, a start was made with the implementation of the categorisation and design of the road network in the Netherlands according to the principles of the Sustainable Safety vision ('Duurzaam Veilig Wegverkeer'). This vision means that the traffic area is organized in such a way that serious accidents are prevented and, if an accident does occur, the severity of the accident is limited. Many residential areas are therefore safely designed with a maximum speed limit of 30 km/h. In addition, the busiest city roads were given a maximum speed limit of 50 km/h and safe separate bicycle facilities. In the period 1998-2007, measures have been taken that fit in the Sustainable Safety vision. These measures led to a decrease in road fatalities. The measures proved to yield up to four times more benefits than costs (SWOV, 2019).

In recent years, however, mobility has continued to increase, with road and bike paths becoming increasingly busy. Also, more and more new types of motorised and electrified vehicles are becoming involved in traffic, and older people remain mobile at a higher age. As a result of these developments, there are increasing speed differences between vulnerable road users and fast motorised traffic, resulting in a higher risk of accidents (RAI Vereniging, 2019). In 2017, more than a quarter of fatalities in traffic were due to an accident on a 50 km/h road within the built-up area (see Figure 1). The numbers for 2018 (see Figure 2) show a similar trend: the vast majority of fatal accidents occur on 50 km/h roads. That is why road safety at 50 km/h roads is an important issue.

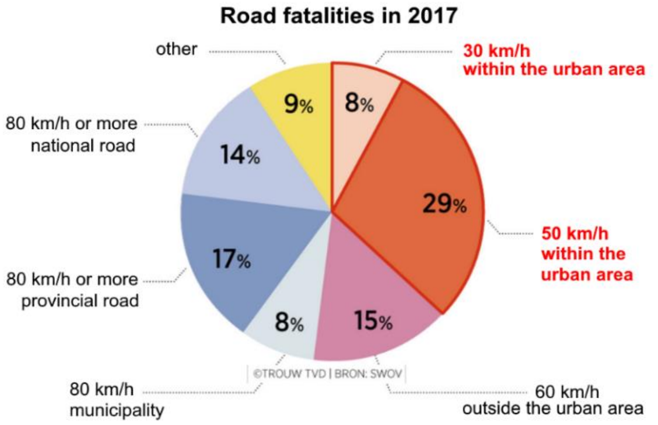


*Figure 1: Road fatalities per road type in the Netherlands in 2017 (Engels, 2019)*

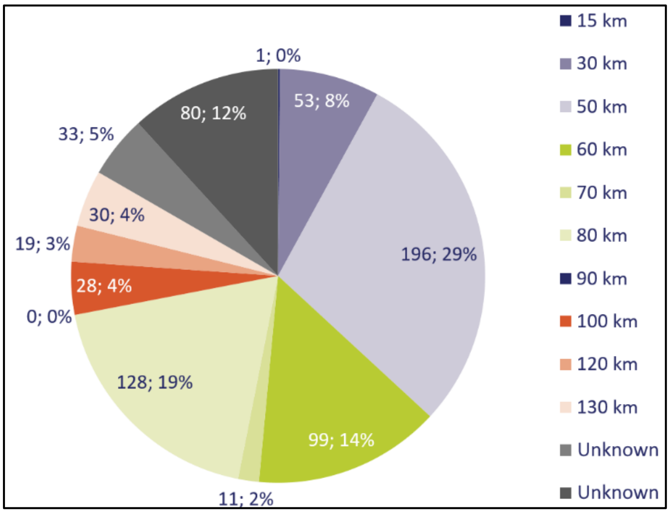


*Figure 2: Road fatalities per speed limit in the Netherlands in 2018 (SWOV, 2020)*

As a consequence of the developments described, the question is increasingly being asked whether it would not be wiser to make all roads in built-up areas 30 km/h in the interests of quality of life and road safety. When the speed is reduced from 50 km/h to 30 km/h, the braking distance decreases enormously from 19 to 7 meters on a dry road. This reduction can be the difference between life and death (Engels, 2019). Several municipalities are already considering increasing the number of 30 km/h roads in their city. For example, the municipality of Amsterdam is going to investigate whether a maximum speed limit of 30 km/h can be introduced throughout the city. Many streets already have a limit of 30 km/h. However, 30 km/h should become the norm and 50 km/h an exception according to the city (Deems, 2020). The municipality of Enschede also wants more 30 km/h roads, specifically in the area within the city's ring road. By taking these measures, the municipality wants to keep the city centre attractive only for local traffic, cyclists and pedestrians (Louwes, 2019). Smaller municipalities also want to reduce the speed limit. For example, the municipality of Barneveld wants to reduce the speed limit on the centre ring road from 50 km/h to 30 km/h. In combination with an adapted layout of the road, the aim is to increase traffic safety (Van Dijk, 2020).

Several organisations have also expressed their views on the subject. For example, the RAI Association advocated a speed limit of 30 km/h within built-up areas. This association represents the interests of many manufacturers and importers of passenger cars, among others. The RAI Association believes that this measure will further reduce the number of casualties in traffic and also limit noise pollution. For this reason, the association advocates that municipalities should put much more effort into the expansion of 30 km/h zones when developing mobility policy. However, the RAI does not believe that traffic flows on important access roads should be obstructed too much. At important locations, 50 km/h or sometimes 70 km/h should, therefore, be maintained (RAI Vereniging, 2019). Steven van Eijck, chairman of the RAI Association, states that drivers often do not reach 30 km/h on average within the urban area. According to him, the traffic flow will improve due to fewer speed differences (Van Der Aa, 2019). The social organisation 'Veilig Verkeer Nederland' (VVN, Safe traffic in the Netherlands) supports the RAI's proposal. The VVN believes that implementation in every city is necessary in order to avoid misunderstandings about speed limits (NOS, 2019).

The Cycling Union ('Fietsersbond') is also in favour of a speed limit of 30 km/h within the urban area. The union believes the increasing traffic density is putting the safety and cycling pleasure of cyclists under pressure. If cars do not go faster than 30 km/h, this will provide more space on the cycle path. Faster cyclists such as e-bikes, racing bicycles and speed-pedelecs can then get onto the road more safely. Moreover, for the 'normal cyclist,' more space is left on the cycle paths and bicycle lanes. Also, 30 km/h ensures a more pleasant streetscape for everyone. Furthermore, the association states that on 80% of the roads within the built-up area, the speed limit is already 30 km/h, reaching 100% coverage will give more clarity for car drivers. Besides, the union believes that the extra travel time for drivers and emergency services is limited to a few seconds. In an area of 25 hectares (2.5 x 2.5 km), it would be 11 seconds extra travel time. Like the RAI, however, the association believes that exceptions should be possible for ring roads or major access roads, provided they are constructed in combination with proper cycling infrastructure (Fietsersbond, 2018).

The Cycling Union considers the improvement of road safety to be one of the main reasons for the extension of 30 km/h roads. The speed reduction should result in fewer casualties, the risk of a serious accident at 30 km/h is 3.5 times lower than at 50 km/h roads. Moreover, a quarter of all fatalities in 2017 and 2018 occurred on a 50 km/h road within the built-up area. Potentially, therefore, the impact on road safety may be significant, according to the Cycling Union. A fully Sustainable Safe cycling infrastructure would reduce the number of road fatalities among cyclists by 100-130, which is more than half of the number of cyclists who die in traffic each year. Also, the number of seriously injured persons could be reduced by at least 3,500 (Hendriksen, Van der Linden, Bot, & Kluit, 2018).

However, there is also criticism of the proposal to introduce 30 km/h in built-up areas. Traffic expert Sjoerd Nota states that it appears to be a sympathetic call, but that the proposal undermines the unique and worldwide most safe traffic approach Sustainable Safe. The traffic engineer believes that the traffic system can only function safely with a hierarchically structured network of roads. Based on Sustainable Safe, a dichotomy has arisen between roads with a flow or access function and roads in residential areas. Roads with an access function play an essential role in the safe and smooth handling of supra-local traffic. If lower speeds limit the traffic flow, this will result in short-cuts through residential areas and inner-city areas with many negative consequences for traffic safety and the living environment. Also, Nota states that the psychology of travel behaviour is overlooked. Many road users are willing to adapt their driving behaviour to the environment for a short period, for example driving slower on a 30 km/h street with speed bumps and narrowing. However, if this period is too long, it is felt that wanting to drive faster will gain the upper hand among road users. This principle underlines the importance of a hierarchical network of roads, in which 30 km/h zones cannot be made too large (Nota, 2019).

In addition, the road image must match the expected behaviour of drivers. For example, at 30 km/h a narrow street, a mixture of motorised and slow traffic and possible traffic inhibiting measures are appropriate. The redesign of the current 50 km/h roads into suitable new 30 km/h roads will, therefore, require an enormous social investment. The redevelopment of the current 30 km/h zones since their introduction in the 1990s has not even been completed. It is therefore questionable whether redevelopment on a large scale is possible according to Nota. That is why he believes, for now, it is much more critical to design the already existing 30 km/h zones according to the guidelines. This will seduce drivers to lower speeds and create more support for enforcement from the police. Well-designed 50 km/h roads with a smooth traffic flow remain necessary for a sustainable and safe traffic network (Nota, 2019).

Traffic psychologist Gerard Tertoolen mainly shares the opinion of Nota. According to him, the adjustment from 50 km/h to 30 km/h will not work. Through-roads are not made to drive 30 km/h. Therefore, drastic adjustment is necessary, and the traffic flow could also be severely hindered. The lower speed leads to unnecessary traffic jams and congestion. He is also of the opinion that safety takes priority, but that measures must be realistic and well thought out. This does not seem to be the case with this plan, according to Tertoolen. That is why he proposes as an alternative plan to expand the number of 30 km/h zones and residential areas, and to the number of car-free zones in inner cities (Tertoolen, 2019).

A study by research agency I&O Research shows that the Dutchmen are divided over the proposal. 49% of the respondents are in favour or strongly in favour of the proposal, while 37% of the respondents do not think it is a good idea at all. Among cyclists, the support for the proposal is much higher, 71% is in favour of the measure. Among car drivers, this percentage is only 39% (Van Der Aa, 2019). In the end, car drivers should comply with the speed. So, more support from car drivers seems desirable to able to expect less resistance and lower speeds.

The current Minister of Infrastructure and Water Management, Cora van Nieuwenhuizen, does not intend to adjust the current speed limit in built-up areas nationally. The municipalities are free to do so and are best placed to judge for themselves where a lower speed limit is desirable, according to the minister (NOS, 2019). However, the foundation for scientific research on road safety (SWOV, 'Stichting Wetenschappelijk Onderzoek Verkeersveiligheid') believes that municipalities are still very slow in the transition to 30 km/h and would, therefore, like the government to play a pioneering role. It could be that the burden of proof will be reversed. In this case, a municipality would have to argue why the maximum speed limit should be 50 km/h. Moreover, a national standard would provide more clarity for drivers, according to SWOV (Engels, 2019).

The road safety problem is not limited to the Netherlands. In March 2020, traffic ministers and other experts and representatives from 140 countries signed the Stockholm Declaration in Sweden. Among other things, they expressed their support for the introduction of a speed limit of 30 km/h in built-up areas. This declaration aims to halve the number of road deaths by 2030 and can be seen as a joint declaration of intent by the countries. Traffic accidents are the leading cause of death among young people. As an example of usefulness, reference is made to Oslo and Helsinki, where a speed limit of 30 km/h has already been introduced in built-up areas. These are the only two European cities where no cyclists or pedestrians died in 2019 (Kouwenhoven, 2020).

All in all, it can be concluded that opinions are divided on the proposal. It is a topical issue on which many different actors have felt involved and have expressed their opinions in recent years. Many parties agree that exceptions should be made for major ring roads and that national implementation is desirable to create more clarity for drivers. Table 1 gives an overview of the provided advantages and disadvantages of introducing 30 km/h on roads in the build-up area. Some advantages and disadvantages are opposed to each other. For example, it is mentioned that the flow is improved by fewer speed differences. On the other hand, it is described that travel times will become longer due to extra congestion. Therefore, more research is needed to determine the effects of a possible speed reduction.

*Table 1: Advantages and disadvantages of more 30 km/h roads within the urban area mentioned by stakeholders*

| Advantages | Disadvantages |
|---|---|
| Improved road safety by reducing speed differences | Creation of shortcuts due to weaker hierarchical structure of the network |
| More space for cyclists by moving faster modes of transport to the road | Drastic adaptation of the current 50 km/h roads necessary: significant social investment |
| Less noise nuisance due to lower speeds | Travel time becomes longer due to unnecessary traffic jams and congestion |
| Reduced speed differences improve traffic flow | Contribution to the reduction of emissions dependent on route choice and mobility effects |
| More pleasant streetscape and improved living environment | Reduced driving comfort due to de-accelerators such as speed bumps and road narrowing |

# 3 Literature review

This chapter describes various existing theoretical knowledge that has been used as a basis for the further design of the research. First of all, knowledge about speed limits and the relation to traffic safety is described (section 3.1). Next, the current status of 30 km/h roads (section 3.2) and the concept of a credible speed limit is explained (section 3.3). A definition is given, and various studies on this subject are discussed in which the relations between speed, credibility and characteristics are investigated. In addition, the results of various studies are presented in more detail (section 3.4). Although both sections 3.3 and 3.4 describe the relationship between road and environmental characteristics with speed, the first section mainly tries to give a comprehensive overview of all available studies without going into the details of the study. Section 3.4 describes the results of a number of studies in more detail. Finally, a conclusion is given (section 3.5).

## 3.1 Speed limits and traffic safety

The main objective of the transition to 30 km/h roads in built-up areas is to improve road safety. Speed is at the root of the road safety problem. It is one of the most critical factors which affect the safety of a driver and other road users. At higher speeds, the risk of an accident increases, there is less time to process and react to information, and the braking distance is longer. As a result, at higher speeds, it is more difficult to prevent a collision. Besides, higher speeds make the vehicle less controllable, especially when cornering and when driving on wet roads. Higher speeds also lead to more serious injuries. During a collision, larger external forces are released at higher speeds. However, people are physically vulnerable and can only endure a limited amount of external forces. Effective speed control can, therefore, prevent many casualties in traffic (Goldenbeld, Van Schagen, & Drupsteen, 2006).

Several studies have shown that increases in speed lead to increases in crash rates and severity. So, given a particular road, a higher speed increases not only the chance of an accident but also the chance of serious injury (Lee, Chong, Goonting, & Sheppard, 2017). If on all roads the speed is on average 1 km/h slower, this will save a few per cent of traffic casualties (fatalities and seriously injured). With a certain speed increase, the risk of a crash increases faster on roads inside built-up areas than on roads outside built-up areas. The effects of a speed reduction are therefore largest on urban roads. This is in the first place because the traffic situations inside the built-up area are much more complex than outside the built-up area, especially when compared to motorways. Within the same time frame, urban road users have to perceive and process much more information. Secondly, many more cyclists and pedestrians in built-up areas are very vulnerable to collisions with cars. For example, a pedestrian has a survival rate of approximately 95% at a collision speed of 30 km/h (see Figure 3). At 60 km/h the survival rate has dropped to 80% and at 80 km/h to 60%. To increase road safety for vulnerable road users, it is therefore important that the speeds of motorized vehicles will be reduced (Duivenvoorden, Stelling, Goldenbeld, & Hagenzieker, 2013).

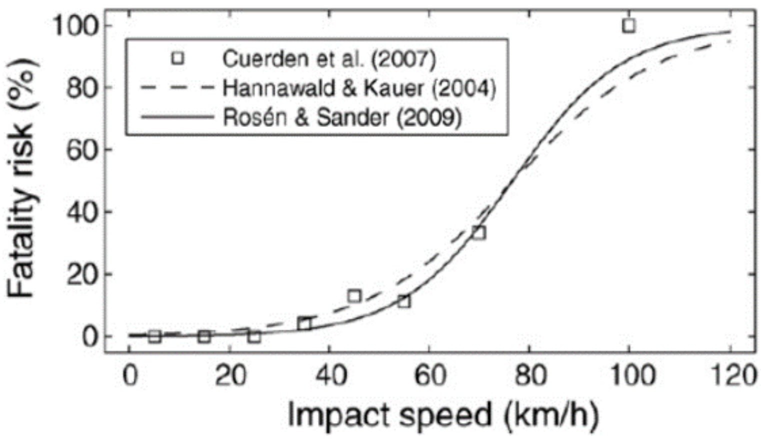


*Figure 3: Probability of a fatal accident as a function of the impact speed (Rosén, Stigson & Sander, 2011)*

As described earlier, it has been found that increasing one's speed decreases the available time to react to sudden changes on roads. It reduces manoeuvrability, and the stopping distance is larger. That is why speed limits are regarded as a crucial part of effective speed management as they should prescribe speeds that are safe for drivers under typical conditions. Research findings suggest that some degree of compliance with speed limits is essential to maximise safety, but studies indicate the speed limit is not the sole factor which affects speed choice (Lee et al., 2017).

Several factors influence the speed choice of drivers of passenger cars. The speed choice is determined by personal factors, social factors, road characteristics, vehicle characteristics and all kinds of interactions between them (SWOV, 2012b). Many drivers in the Netherlands regularly exceed the speed limit. Per type of road, the percentages of the motives mentioned differ, but in general, they are quite similar (see Figure 4). When looking at urban roads, the most frequently mentioned motives for speeding are adjustment to other traffic, hurry, and because it goes unnoticed (Duijm, De Kraker, Schalkwijk, Boekwijt, & Zandvliet, 2012). In another international study, drivers were also asked why they violate speed limits. Their most frequently reported answer was that they do not regard the speed limits as being reliable (Lee et al., 2017). From this, it can be deduced that it is essential that the image of the road and surroundings corresponds to the limit. If this is not the case, the limit will be exceeded more often.

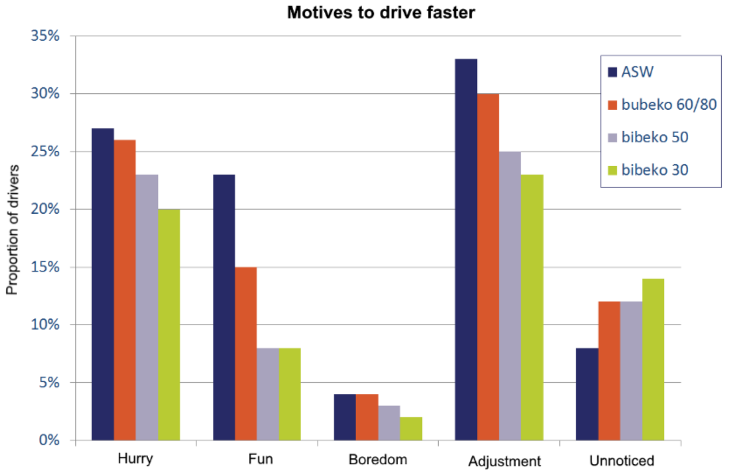


*Figure 4: Percentage of car drivers mentioning these motives to drive faster than limit per road type (respondents could give multiple reasons). Road types: ASW (motorway), bubeko 60/80 (outside the urban area, 60 km/h or 80 km/h) and bibeko 50/30 (inside the urban area, 50 km/h or 30 km/h) (Duijm et al., 2012).*

Reasons not to exceed the limit are mainly road safety, the fact that the limit is an obligation, and the chance of a fine (see Figure 5). The environment and the (fuel) costs are the least mentioned motives and do not appear to play a significant role in the choice of speed (Duijm et al., 2012).

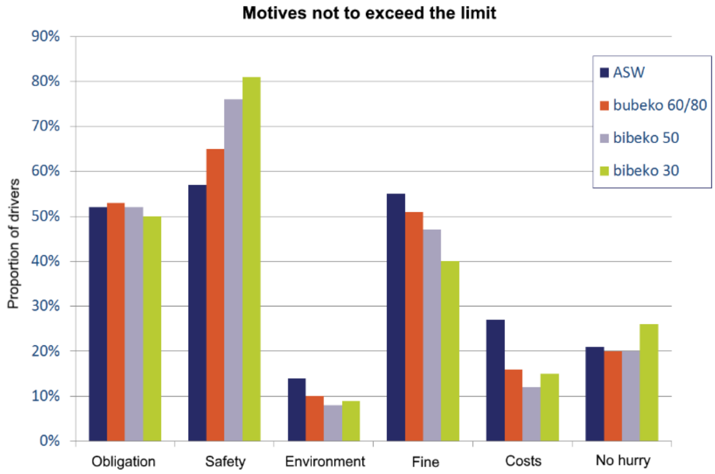


*Figure 5: Percentage of car drivers mentioning these motives to comply with the speed limit per road type (respondents could give multiple reasons). Road types: ASW (motorway), bubeko 60/80 (outside the urban area, 60 km/h or 80 km/h) and bibeko 50/30 (inside the urban area, 50 km/h or 30 km/h) (Duijm et al., 2012).*

Some drivers are more compliant with the limit than others. In general, men exceed the limit more often than women, young people exceed the limit more often than older people, and business drivers exceed the limit more often than people who use the car mainly for commuting. In addition, there is a link between specific personality characteristics and driving speed. People who are in great need of excitement generally also seem to want to drive faster. Many drivers also want to drive faster than the limit they consider safe. This is a confirmation of what has been demonstrated many times, namely that drivers consider themselves to drive better and safer than others. Then, they also think they can drive a little faster than other drivers. Other traffic and passengers also influence the speed. As mentioned earlier, adaptation to other traffic is an important reason to exceed the limit. Drivers are strongly influenced by the supposed speed of other road users in their choice of speed. In general, drivers underestimate the speed of others. This creates a snowball effect and makes people drive faster and faster. The presence of passengers can also influence the speed. However, the influence is not so unequivocal (SWOV, 2012b).

### *Underestimation of speed*

Sometimes drivers exceed the speed limit unnoticed. Nevertheless, all cars have a speedometer with which the driving speed can be determined objectively at any time. But many drivers also seem to be influenced, often unconsciously, by the experienced value of the speed. However, this subjective perception of speed is not reliable and often leads to an overestimation or dangerous underestimation of the actual speed. Several situations can lead to an underestimation of speed (SWOV, 2012b):

- If a driver drives at high speed for a longer time (for example on a motorway), the driver underestimates the speed more and more and goes faster unnoticed. This can be prevented with various functions in the car, such as cruise control.
- When there are few objects along the road (e.g. on the road through an open field), drivers are more likely to underestimate their speed. This is because the perception of speed is mainly determined by the information entering through the peripheral field of vision (view of surroundings) and less by information entering through the central field of vision. If there are no vertical elements (e.g. buildings and trees) along which the speed can be related, the speed is rather underestimated. In general, a lower speed is chosen if the vertical elements are higher than the width of the road.
- If drivers are higher above the road surface, they more often underestimate the speed. In recent years SUV's (Sports Utility Vehicles) have become increasingly popular. These vehicles are higher and distort the perception of speed. Many drivers drive faster unconsciously because of this.
- In transition situations, when the speed has to be reduced considerably, drivers often slow down less than necessary. This is the case, for example, after leaving a motorway and entering a built-up area. In these cases, physical speed brakes such as a roundabout at the end of the exit and a narrowing of the road can help drivers to adapt better to the speed on the subsequent section.

Some of these aspects cannot be directly influenced by a road authority (e.g. the choice and effect of SUVs), several other aspects can. Physical speed de-accelerators, for example, are desired to indicate a transition from 50 km/h to 30 km/h. This prevents drivers from adapting their speed insufficiently to the follow-up trajectory. It is also desirable to have vertical elements such as buildings and trees along the road to which speed can be related. These elements will often already be present around 30 km/h roads but can be extended if necessary.

## 3.2 Current status of 30 km/h roads

An attempt was made to describe the current status of 30 km/h roads by considering the distribution of speed limits in built-up areas and the layout of these roads. Compliance with the limit is also discussed.

### 3.2.1 Distribution of speed limits

The programme 'Sustainable Safety' has been a great stimulus in realising 30 km/h areas, see Table 2. In 1998, at the start of the programme, about 15% of the total length of roads within the built-up area had been set up as a 30 km/h road. After the duration of the programme, this percentage increased from about 45% at the beginning of 2003 to about 70% in 2008. In the period 1998-2008, therefore, more than 40,000 kilometres of 30 km/h roads were constructed. The figures from 1998 and 2003 are based on an evaluation of the 'Sustainable Safety' programme. The 2009 figures are based on a SWOV survey among road administrators (SWOV, 2018). There are no recent data available on the number of 30 km/h areas and the number of 30 km/h roads or their total length.

*Table 2: Distribution 30 km/h and 50 km/h roads within built-up areas in the last decades (SWOV, 2018)*

| | **1998** | **2003** | **2008** |
|---|---|---|---|
| *30 km/h* | 8,900 km (15%) | 29,000 km (45%) | 50,300 km (70%) |
| *50 km/h* | 50,600 km (85%) | 36,500 km (55%) | 21,600 km (30%) |
| *Total inside built-up area* | 59,500 km | 65,500 km | 71,900 km |
| *Design* | | 67%: sober design<br>33%: optimally sustainable safe | 29%: no speed reduction measures<br>30%: speed reduction measures at intersections<br>41%: speed reduction measures at intersections and road sections |

The desired speed limit on residential access roads within the built-up area is either at walking speed (residential areas) or 30 km/h. According to the guidelines, no road markings are allowed on these roads, and cyclists should preferably drive on the carriageway. Speed reducing measures are also required. These measures can be realised in various ways, such as speed bumps, plateaus, clinkers instead of asphalt and the placing of horizontal speed de-accelerators such as plant boxes or parking spaces (Weijermars & Van Schagen, 2009).

Table 2 also describes the general design of roads with a speed limit of 30 km/h in 2003 and 2008. At the beginning of the Sustainable Safety programme, road administrators could apply for a subsidy to construct 30 km/h zones. To promote rapid large-scale application, a sober variant of the 30 km/h zones was introduced that was frequently used. In 2003, according to road administrators, approximately two-thirds of the 30 km/h zones were soberly designed. In general, a sober design indicates that traffic signs have been placed and that speed-reducing measures may have been applied to a limited extent. On the other hand, a sustainably safe road is used to indicate that the limit is physically enforced by speed-reducing measures close to each other. The survey carried out at the beginning of 2009 asked for speed reducing measures. On more than 70% of the roads, the speed is at least braked at intersections and on 41% of the roads speed reduction measures are also applied on road sections. Since the questions of the two surveys for 2003 and 2008 were different, it is difficult to conclude the difference in design. However, if it is assumed that an optimal sustainably safe design means a reduction in speed on intersections and road sections, then there was a slight increase in the number of sustainably safe 30 km/h roads (Weijermars & Van Schagen, 2009).

Although no current figures are available, the latest figures show that there is probably still sufficient potential to convert 50 km/h roads to 30 km/h roads. In addition, due to the sober design in the past, there are presumably still sufficient existing 30 km/h roads of which the design can be improved to make the limit more credible.

### 3.2.2 Speed limit compliance

There are no structural, reported measurements of urban driving speeds in the Netherlands. Only several incidental measurements from various studies are available. Often, the speed measurements in question were part of a study into the effect of certain speed reducing measures. The results of several studies are shown in Table 3 and are briefly described in the overview below.

In 2010, speed measurements were carried out on ten 30 km/h roads in larger and smaller municipalities in the province of Zuid-Holland. From these measurements, it was determined that the average driving speed was 36 km/h. On average, about 70% of the drivers exceeded the limit. Approximately half of the limit exceedances were more than 10 km/h too fast. However, there were major differences between roads. On some roads, the proportion of violations was less than 30%, on others, almost 95% (Van Schagen, Commandeur, Stipdonk, Goldenbeld, & Kars, 2010).

In 2012, comparable results were found in measurements at more than twenty 30 km/h roads in Limburg. The average speeds varied between 33 km/h and 40 km/h. On average, 58% to 86% of drivers broke the speed limit. Besides, the percentage of drivers exceeding the speed limit by more than 10 km/h varied between 34% and 37% (Duivenvoorden et al., 2013). In 2017, measurements took place at ten 30 km/h locations in Zuid-Holland. From these measurements, the average speed was between 25 and 37 km/h. The proportion of vehicles that drove faster than the limit varied between 26% and 85% (C. Goldenbeld, De Groot-Mesken, & Temürhan, 2017).

*Table 3: Results of speed measurements on 30 km/h roads*

| Locations | Average speed | Percentage of speed limit exceedances |
|---|---|---|
| 10 in Zuid-Holland | 36 km/h | 30% - 95% |
| 20 in Limburg | 33 – 40 km/h | 58% – 86% |
| 10 in Zuid-Holland | 25 – 37 km/h | 26% – 85% |

Various studies, therefore, show that on roads with a 30 km/h limit, the majority of drivers often drive faster than the limit. This often involves exceeding the limit by more than 10 km/h. However, incidental speed measurements at specific locations show that there are large differences between the locations. The number of exceedances and the height of the exceedance are probably related to all kinds of factors, such as the traffic intensity, the traffic composition and the local infrastructural characteristics. But credibility probably also plays a role.

## 3.3 Credibility of speed limits and overview studies

A credible speed limit is formulated as: 'a speed limit that corresponds to the image evoked by the road and the (traffic) situation' (Van Schagen, Wegman, & Roszbach, 2004). In addition, by Yao et al. (2019), a credible speed limit is described as: 'a limit that drivers consider logical or appropriate in light of the characteristics of the road and its immediate surroundings through specific consistency and continuity of road design, including the type of the road, road layout, road surface, road curvature, traffic density, weather conditions and a mix of traffic' (Yao, Carsten, Hibberd, & Li, 2019). Furthermore, by Bellalite (2013), it is described 'a credible speed limit corresponds to the speed of the vast majority of drivers (85$^{th}$ percentile speed); this is the speed that drivers consider to be suitable given the roadway features and the roadway environment'.

Based on these definitions, a credible speed means that drivers consider a speed limit as logical or appropriate, considering the characteristics of the road and its immediate surroundings. Both the image of the road itself and the image of the road environment must make it logical and credible that a lower limit applies on one road than one another. Dynamic factors such as the presence of other traffic and weather conditions also play a role. It is generally assumed people will comply with the speed limit if they regard them as being reasonable or credible. On the other hand, if the speed limit is not consistent with the road characteristics, then people may ignore the limit. So, credible speed limits are expected to result in drivers complying better to the applicable speed limit. If a limit is not credible, drivers will be more inclined to determine their own speed choice. Moreover, if it happens too often that a limit is considered incredible, this will affect confidence in the speed limit system as a whole (Lee et al., 2017).

Concerning credibility, a distinction can be made between the image of the road and the image of the situation. The image of the road consists of static characteristics of the road and the road environment, such as marking, curves, buildings and vegetation. The image of the situation relates to the dynamic characteristics of a certain traffic situation, such as weather conditions and traffic intensities. These dynamic characteristics are particularly relevant in relation to dynamic speed limits that are attuned to current road conditions. However, the vast majority of roads have static limits, so the credibility of the limit often depends on static characteristics. Moreover, a credible speed limit has to indicate a safe speed. Which speed can be considered safe depends on the function of the road and therefore on the composition of the traffic and the type of conflicts that can occur. Also, the safe limit has to be credible. The question is, therefore, to what extent credible limits can be attributed to demonstrable characteristics of the road and road environment (SWOV, 2012a).

*Influence personal characteristics*

Research by Goldenbeld, Schagen & Drupsteen (2006) shows that drivers differ in the extent to which they find limits credible. Some drivers want to drive considerably faster than the given speed limit and also consider a (considerably) higher limit to be safe. The differences appear to depend on age and the need for excitement, among other things. Younger people find a higher speed limit safer than older people. And people with a greater need for excitement or taking risks find a higher limit safer than people with a lower need for excitement. There also appears to be a relation between the number of speed tickets and the extent to which a higher limit is still considered safe (Goldenbeld et al., 2006).

Personal differences are given as a reason why it is not possible to set a limit that is equally credible for everyone. However, it is possible to set a limit that is more credible for everyone. Both younger and older drivers are influenced by road and environmental characteristics, but young people do allow themselves to be influenced by fewer road and environmental characteristics than older drivers (Goldenbeld et al., 2006). Table 4 describes several characteristics that appear to influence older and/or younger drivers.

*Table 4: Effect of characteristics on older and younger drivers*

| Characteristic | Effect on older drivers? | Effect on younger drivers? |
|---|---|---|
| On or absence of a curve | Yes | Yes |
| Clarity of the (traffic) situation | Yes | Yes |
| View to the front and to the right | Yes | Yes |
| Presence of buildings | Yes | No |
| Width of the road | Yes | No |
| Trees on the right side of the road | Yes | No |

### 3.3.1 Overview studies

The literature describes various types of research concerning road characteristics, speeds and credible speed limits. Field measurements, driving simulators studies and surveys are used to assess the influence of characteristics on speed and credibility. Each type of study has several advantages and disadvantages, which are described in Table 5.

*Table 5: Advantages and disadvantages of different study types (partly based on Jansen et al., 2018)*

| Study type | Limitations |
|---|---|
| Field measurements | Measurements on location come closest to reality. The quality depends, among other things, on the source. Regularly, existing data can be used, for example, from induction loops that are already present. If this is not the case, new measurements have to be done, which can take a lot of time and effort. If the research focuses on a particular target group, it is also possible to select participants to be tracked for a certain period and collect data. However, participants may change their driving style when they know that everything they are doing is being measured. The tendency to exhibit socially desirable behaviour occurs when participants are afraid of being judged negatively. However, in addition to field studies, survey and simulator studies can also suffer from social desirability. |
| Driving simulator | A driving simulator is closer to reality compared to a survey. However, the behaviour of participants is very dependent on the type of driving simulator in which they are tested. For example, the presence or absence of a car casing, steering feedback and type of screens influence the driving ability. The question is also whether behaviour in a driving simulator can be translated to public roads. Moreover, it is a lot of work to build scenarios into a simulator if they are not yet available and it is difficult to get a large representative group of respondents. |
| Survey | A survey is relatively easy to set up and can be distributed to a large group of respondents. However, surveys using pictures of roads give a limited realistic feeling of speed. Short videos can show a more realistic picture of the road but also have limitations. Also, questionnaire studies generally ask about the expectations of one's behaviour. The question is to what extent the intended behaviour can be translated into reality. |

Based on these three types of research, the available literature is described for each type of research. Finally, an overview is given of all the literature described.

*Field measurements*

In a study by Aarts et al. (2011), the speed on 80 km/h roads was investigated. For some roads, speeds were collected by detection loops. The study did not examine the credibility but examined which characteristics have the most influence on speed. The openness of the environment appeared to influence the speed the most. With a higher density of the environment, the speed decreased (Letty Aarts, Brandenburg, & Van Nes, 2011).

A recent study by Bax et al. (2018) investigated the relationship between credibility and speed for various provincial roads (60, 80 and 100 km/h) in Zeeland. Traffic was monitored at forty locations and speeds were measured. These speeds were compared with the safe speed limit and the credible speed limit. No relation was found between the safe speed limit and the credible speed limit. Also, no relation was found between the credibility and the measured speed (Bax, Schermers, & Kars, 2018).

In the Eindhoven region, Donkers et al. (2010) conducted a study to identify unsafe locations where road safety could potentially be improved. The research focused on distributor roads. Speed profiles were obtained using navigation equipment. Besides, the credibility per road was determined using the VSGS method. The discussion of the results was very limited. Only the results of a certain 30 km/h were discussed. This concerned a road that was assessed as credible, but where drivers often drive too fast. However, because this only concerns a specific situation, no general statement can be made on the relationship between credibility and speed based on the study (Donkers, De Jong, & Scholten, 2010).

The study of Gargoum et al. (2016) uses data from almost 600 different urban roads in the city of Edmonton (Canada), at which over 35 million vehicle spot speeds were collected. Generally, the research provides evidence of the existence of an empirical relationship between road features and compliance with the posted speed limit. That is why the importance of setting credible speed limits on roads is highlighted. In addition, the possibility of achieving higher compliance rates through modifications to the road environment is mentioned (Gargoum, El-Basyouny, & Kim, 2016).

Charlton et al. (2010) have investigated some infrastructural modifications on local and collector road in New Zealand. On several roads, visibility was restricted by placing trees and road markings were removed. Bicycle paths and pedestrian crossings were also constructed, reducing the width of the carriageways at certain locations. The modifications showed a significant reduction in average speed and a more homogeneous speed profile. On local roads, the average speed was reduced from 44 km/h to 30 km/h, and on collector roads from 54 km/h to 37 km/h. Similar roads where no changes had been made did not show these effects. Although the overall package of measures appeared to have had an effect, it is unclear to what extent the individual measures contributed to the speed reduction (Charlton et al., 2010).

In the United States, Ivan et al. (2009) investigated speed at 300 locations. These were different types of roads, such as urban, suburban and rural roads. Only roads without curves and speed checks were selected. Furthermore, only the free speed of vehicles was used, vehicles had to have a minimum following distance of 6 seconds. Wider emergency lanes and long distances from built-up areas were factors that led to a higher speed. A lower speed was achieved with parking spaces and pavements along the side of the road. In general, the conclusion was that an open road environment and a reduced presence of other road users were the most important factors leading to higher speeds (Ivan, Garrick, & Hanson, 2009).

Marshall et al. (2008) carried out specific research into the effect of parking on the road. The result was that the presence of parking spaces on the road resulted in a decrease in speed. But also a small distance between the road and buildings caused a decrease in speed. However, the research only focused on roads with a limit of 65 km/h, so it cannot be deduced from the research whether the results also apply to roads with other speed limits (Marshall, Garrick, & Hansen, 2008).

In the European project UDRIVE, use was made of the 'naturalistic driving method' in which participants from various countries drove with instrumented passenger vehicles for about half a year. They received no instructions, and the aim was to be able to study natural driving behaviour. The study mapped out various dynamic factors that contribute to exceeding the limit. More than half of the exceedances were found on a road with a 50 km/h limit. Furthermore, most exceedances were found during the night, followed by the afternoon and early morning. During the measurements, however, the presence of possible predecessors was not taken into account, making it unclear to what extent the speeds were freely chosen (Dotzauer, Stemmler, & Utesch, 2017).

Jansen et al. (2018) recently researched 50 km/h roads in Amsterdam. Also, in this research, the speed data obtained with the European project UDRIVE were used. In this case, only the data of 33 drivers who drove in Amsterdam during the six-month measurement period was used. In addition, use was made of an earlier study in which road characteristics were identified for a large part of the roads. Long straight lines, no intersections and an open road environment turned out to be the most important factors contributing to a higher speed. The absence of travel direction separation turned out to cause the most speed reduction. Furthermore, for many characteristics, no significant effect on speed was found. And if a significant effect on speed was found, this effect was often small with a maximum of a few kilometres per hour. However, the research was limited to a small area within the built-up area of Amsterdam and the speed behaviour of a small group of car drivers. Additional research is recommended to evaluate whether the results of the study can be generalized to other (urban) areas (Jansen, Van der Kint, & Schermers, 2018).

*Surveys*

Using a questionnaire survey, Goldenbeld & Schagen (2007) assessed the credibility of 80 km/h roads in the Netherlands. Approximately 600 Dutch drivers were given photographs of 27 different road situations. For each situation, the respondents had to indicate their preferred speed and the safe speed limit of those roads. The respondents were unfamiliar with the limit that applies to the road. The (average) difference between the desired speed or safe limit and the existing limit was considered as an indication of the credibility of the applicable speed limit. It was found that drivers preferred to drive about 8 km/h faster than the actual speed limit while they judge the safe speed to be 4 km/h higher than the actual 80 km/h speed limit. Also, the results show that the credibility of the limit is influenced by several road and environmental characteristics. Differences in characteristics appeared to affect credibility, such as the road width, the presence or absence of a curve, the view to the front, the view to the right, the clarity of the situation, the presence or absence of buildings and the presence or absence of trees on the right side. Therefore, credibility can be improved by better matching the limit and specific characteristics of the road and the road environment (Charles Goldenbeld & Van Schagen, 2007).

In the European project ERASER, a similar study was carried out with 24 animated images of rural roads (80 and 100 km/h). More than 300 respondents from various European countries participated in the study. This study showed that the road with and the presence of vegetation affect the speed in all countries. However, the effect of other characteristics on speed, such as the number of lanes and the type of separation of driving directions differed from country to country, so no uniform results were found across countries (Houtenbos, Weller, Aarts, & Laureshyn, 2011).

In a study by Lee et al. (2017), it was investigated how modifying the credibility of the speed limit of roads influences Malaysians drivers' judgements of an appropriate speed to drive. To this pursuit, two experiments were conducted. In the first experiment, the aim was to establish the speed at which drivers judged it was appropriate to drive, by viewing photographs of roads with the speed limit sign erased. Seven different actual speed limits were used, ranging from 40 km/h to 110 km/h. In this way, a baseline for manipulations of speed limit information in the second experiment was created. Drivers chose speeds which correlated with but were higher than the actual speed limits of the roads. Analysis of road characteristics suggested they based their decisions mainly on features of the road itself rather than of the roadside. In the second experiment, the speed limit credibility of each of the roads shown in the first experiment was either manipulated to be low or high. In this way, the impact of the credibility on the speed drivers judges appropriate was assessed. The same photographs as in experiment 1 were presented to a new group of drivers, this time with speed limits posted on traffic signs. But the posted speed limits were either 10% lower or higher than the appropriate speed from experiment or 50% lower or higher than the appropriate speed. As a result, the posted speed limits did affect drivers' judgements about the appropriate speed to drive. The credibility influenced judgements, drivers selected appropriate speeds consistent with the speed limit for the 10% lower condition, but not for speed limits that deviated highly from the appropriate speed judged in experiment 1 (Lee et al., 2017).

*Driving simulator studies*

Credible limits should result in drivers better complying with the (safe) speed limit. A study with a driving simulator by Van Nes et al. (2007) investigated whether this is the case. In the simulator, test drivers twice travelled the same route outside built-up areas on roads with a 60, 80 or 100 km/h limit. The credibility of these limits had been manipulated beforehand by varying some key characteristics identified as relevant (road width, presence or absence of buildings, presence or absence of road vegetation, number of lanes and road marking). The credibility deviates from optimal in two directions: less credible because the limit is perceived as too high for the road and its surroundings or when it is perceived as too low. Half of the participants were supported by Intelligent Speed Assistant (ISA), the other half were not. The results of the study show that the degree of credibility does indeed influence driving speed. When the limit was more credible, the average speed was closer to the limit and on average less time was driven above the limit. Indications were also found that, in that case, there were fewer differences in speed between drivers. Limits that were experienced as too low were on average driven considerably faster than the limit. And for limits that were experienced as too high, the average driver drove slower than the limit. Besides, ISA had a strong influence in speed, especially to situations where the limit is experienced as incredible (Van Nes, Van Schagen, Houtenbos, & Morsink, 2007).

In Germany, a driving simulator study was carried out by Goralzik et al. (2017). The study aimed to determine the effects of the speed limit, geometric road characteristics (curves and straightness) on the chosen speed on roads with a limit of 30 and 50 km/h. The speed on 50 km/h roads decreased when the road width decreased or when there were curves. These effects were not observed on 30 km/h roads (Goralzik & Vollrath, 2017).

*Overview studies*

Most of the studies described are field measurements in which comparable results were regularly found. In several studies, it was found that an open road environment leads to higher speeds. Part of this road environment are buildings in the vicinity of the road. Several studies also found that a smaller distance to buildings leads to lower speeds. Furthermore, the influence of parking spaces was mentioned in several studies. The presence of parking spaces generally leads to lower speeds. The other types of studies ('survey' and 'driving simulator') were carried out less frequently. The number of these studies is too low to discover similarities and differences between studies within the same type and make comparison with other types of studies difficult.

Table 6 gives an overview of the described studies concerning road characteristics, speeds and credible speed limits. The overview shows that there are a limited number of studies in which 30 km/h roads are included. Most studies focus on a single or a limited number of speed limits, often speed limits on roads outside built-up areas. Several other studies also include 30 km/h roads, but there is no specific focus on these types of roads. Moreover, it is questionable to what extent the results of foreign studies can be applied within the Netherlands. The design of roads may vary from country to country, so not all conclusions are transferable.

Furthermore, most studies have collected speed data, often by using existing measurements of detection loops. However, often no assessment is made of the credibility of roads. In this case, the relationship between speed and credibility cannot be assessed. Certainly, for 30 km/h roads, this has not been done or to a very limited extent. There are no previous studies with a specific focus on 30 km/h roads. That is why, for 30 km/h roads it is still unknown to what extent a relation can be found between speed, credibility and various road and environmental characteristics.

*Table 6: Overview of different studies concerning (the relation between) speed and credibility*

| Study | Type | Road focus | Speed data collected? | Assessment of credibility carried out? | Link between speed and credibility determined? |
|---|---|---|---|---|---|
| Aarts et al. (2011) | Field measurements | 80 km/h | Yes | No | No |
| Bax et al. (2018) | Field measurements | 60/80/100 km/h | Yes | Yes | Yes |
| Charlton et al. (2010) | Field measurements | Local and collector roads | Yes | No | No |
| Donkers et al. (2010) | Field measurements | Various dangerous roads | Yes | Yes | Limited |
| Dotzauer et al. (2017) | Field measurements | Various roads | Yes | No | No |
| Gargoum et al. (2016) | Field measurements | Urban roads | Yes | No | No |
| Goldenbeld et al. (2007) | Survey | 80 km/h roads | No | No | No |
| Goralzik et al. (2017) | Driving simulator | 30 and 50 km/h | Yes | No | No |
| Houtenbos et al. (2011) | Survey | 80 and 100 km/h | No | No | No |
| Ivan et al. (2009) | Field measurements | Various roads | Yes | No | No |
| Jansen et al. (2018) | Field measurements | 50 km/h | Yes | Yes | Yes |
| Lee et al. (2017) | Survey | 40-110 km/h | No | No | No |
| Marshall et al. (2008) | Field measurements | 65 km/h | Yes | No | No |
| Van Nes et al. (2007) | Driving simulator | 60/80/100 km/h | Yes | Yes | Yes |

## 3.4 Influence of road and environment characteristics on speed

If a speed limit is not credible, it does not always mean that the limit is not complied with. Enforcement, for example, can prevent drivers from driving too fast despite an incredible limit. On the other hand, a credible limit does not always lead to compliance with the speed limit either, for example, if drivers adapt to other road users. Therefore, a distinction can be made between credibility and compliance with the speed limit (see Table 7). In general, more credible limits lead to better compliance with the limit, but this need not always be the case.

*Table 7: Distinction between compliance with and credibility of speed limits*

| | **Compliance with the limit** | **No compliance with the limit** |
|---|---|---|
| *Credible speed limit* | Example: 80 km/h road with many curves | Example: a 30 km/h road in a residential area |
| *No credible limit* | Example: 100 km/h limit on the motorway with much enforcement | Example: a long straight 60 km/h road in the rural area without obstacles |

But if a limit needs to be made more credible, there are two possibilities to do something about it: adjusting the limit or adjusting the image of the road and surroundings. When choosing the first option (adjust limit), this adjustment must not be at the expense of road safety, a safe limit remains necessary. The function of the road, the traffic composition, potential conflict types and traffic intensities are therefore important. When choosing the second option (adjusting the image of the road and its surroundings), 'accelerators' and 'decelerators' can be used to make the limit more credible. Van Nes et al. (2007) identified five types of accelerators and de-accelerators (see Table 8). Accelerators are elements of the road or road environment that intuitively provoke a higher speed regardless of the limit. De-accelerators are elements of the road or road environment that intuitively provoke a lower speed regardless of the limit. A distinction is then made between primary and secondary accelerators and decelerators. Short straight lines and physical speed de-accelerators force drivers to reduce their speed. Long straight lines and the absence of physical speed de-accelerators, on the other hand, lack physical obstacles for high speeds. These two elements are called primary accelerators and decelerators (Van Nes, Houwing, Brouwer, & Van Schagen, 2007).

The other three elements are considered as secondary accelerators and de-accelerators: visibility, road width and road surface. An open road environment gives a driver an unobstructed view to the left and right and increases the tendency to accelerate. In a closed road environment, for example, due to buildings or vegetation, there is no clear view. This generally slows down the speed. A closed road environment reinforces the decelerator's short straight lines, while an open road environment has a reinforcing effect on the accelerator's long straight lines. Road width and road surface also affect credibility. A wide road is an accelerator, and a narrow road is a de-accelerator. In addition, a smooth road surface (e.g. asphalt) invites higher speeds, while an uneven road surface (e.g. clinkers or bumpy asphalt) leads to lower speeds (Van Nes, Houwing, et al., 2007).

*Table 8: Accelerators and de-accelerators (Van Nes et al., 2007)*

| | **Accelerators** | **De-accelerators** |
|---|---|---|
| *Road type* | Long straights (straight road) | Short straights (many curves or intersections) |
| *Physical speed limiters* | No physical speed limiters | Physical speed limiters present |
| *Visibility* | Open, clear road environment | Closed, confusing road environment |
| *Road width* | Wide road | Narrow road |
| *Road surface* | Smooth road surface | Rough road surface |

Therefore, road characteristics and the characteristics of the direct surroundings have a clear influence on the speed driven. SWOV (2012b) divided three different groups: cross-section, alignment and road environment. Some general relationships within these groups are described in Table 9.

*Table 9 Influence characteristics on speed*

| Characteristics | Relation |
|---|---|
| ***Cross-section*** | |
| Number of lanes | More lanes → higher speed |
| Road width | Wider → higher speed |
| Width of obstacle free-zone | Wider → higher speed |
| Presence/absence of emergency lane | Present → higher speed |
| Presence/absence of cycle track or service road | Present → higher speed |
| Presence/absence of road marking | present → higher speed |
| ***Alignment*** | |
| Curves (sight length) | Fewer curves → higher speed |
| Type and condition of the road surface | Level road surface → higher speed |
| ***Road environment*** | |
| Buildings along the road | Fewer buildings → higher speed |
| Roadside vegetation | Less vegetation → higher speed |

These characteristics are partly related to the subjective perception of speed, which is determined by the amount of peripheral information. But also an estimation of safe speed and an estimation of the current limit can play a role. Speed limits must be supported by the road image so that the limits are credible. Relationships between certain road characteristics and higher speeds are not always negative for safety. Some characteristics (e.g. a wider road) increase safety at the same time and thus (partially) compensate for the higher speed. The vehicle fleet also has a direct or indirect influence on the speed choice of drivers. In recent decades, the driving comfort and power of cars have increased considerably, making it more comfortable to drive at higher speeds (SWOV, 2012b).

The relationships mentioned indicate that roads with more objects on the side (e.g. roads with buildings and trees on the side) are more associated with lower driving speeds compared to open roads with fewer objects on the side. This has also been demonstrated by Elliott et al. (2003). The reason given is that roads with many objects along the road create a busy environment where more visual information is present. Therefore, drivers in busier urban roads with many objects along the side of the road need to process more visual information. This increased cognitive load leads to lower driving speeds. To effectively reduce speed on certain roads, roadsides must be filled with objects that reduce speed through psychological mechanisms (Elliott, McColl, Kennedy, & Transport, 2003).

Elliott et al. (2003) gave an overview of the influence of different characteristics of the road and its surroundings on speed. This overview is based on several studies from the past, where it is not clear what kind of studies (e.g. field measurements, surveys or simulator studies) have been used. Also, no distinction has been made between different speed limits. For each characteristic, an attempt was made to explain the relationship found.

- Trees and vegetation
  Trees and vegetation reduce the average speed by increasing the cognitive load on drivers. Drivers need to process an additional amount of information. Vertical elements in the field of vision can lead to drivers thinking they are driving faster than they do. However, trees and vegetation can obstruct drivers' vision and possible collisions with trees negatively effect road safety.
- Buildings
  Buildings on the side of the road affect the speed in various ways. Just as with trees and vegetation, buildings increase the cognitive load on drivers. Different properties of buildings are of importance. Speeds are slower with more buildings, when buildings are closer to the road and when buildings are higher.
- Pedestrians
  The presence of pedestrians in the vicinity of the road generally reduces the speed because the risk of a dangerous situation is estimated to be higher. Pedestrians are not permanently present, but it is possible to create an environment that facilitates pedestrians, for example, by using footpaths in the presence of shops. But even then, the presence of pedestrians depends on other aspects, such as the time of day and weather conditions.

The idea is similar to the concept of shared space, in which drivers simultaneously share the road with pedestrians, cyclists and other road users. It is suggested that, by a creating a greater sense of uncertainty and making to unclear who has priority, drivers will reduce their speed, in turn reducing the dominance of vehicles, reducing road casualties and improving safety for other road users.

- Lane width
  A narrower lane width reduces speed due to several psychological mechanisms. Driving a vehicle over a narrower lane requires extra effort, which increases the cognitive load. In addition, wider roads offer more time and space to avoid possible dangers.
  Moreover, there is a link with the width of the pavement. In general, wider pavements lead to higher speeds, because buildings then seem to be further away. However, if wider pavements are at the expense of the width of the lane, the speed may decrease. The same applies to bicycle lanes, which may reduce speed as well. The lanes may reduce lane width, and the perceived danger increases due to the presence of cyclists. Specific measures, such as widening the pavement, are therefore related to other measures carried out in the vicinity.
- Parked cars
  Parked cars along the side of the road result in lower speeds compared to the same road where no cars are parked. Vehicles parked at right angles to the road cause a more significant speed reduction compared to vehicles parked parallel to the road.
- Road surface
  A road surface is rougher if, for example, it is laid with bricks instead of asphalt or if there are holes in the road surface. A rough road surface increases the noise and vibrations inside the vehicle, reducing driver comfort. Rougher roads, therefore, reduce the speed.
- Intersections with other roads
  An increasing number of intersections on the road reduces the speed driven. The presence of side roads from which traffic can come increases the possible danger and the amount of information that has to be processed, thus reducing the speed.
- Separation of driving directions
  Roads where the two directions of travel are separated by, for example, a shoulder lead to higher speeds because drivers perceive less danger from separated traffic. Speeds can, therefore, be reduced by not separating the two directions of travel. However, a separation of the driving directions can also lead to a reduced speed if this separation is at the expense of the width of the carriageways.
- Road signs
  The presence of certain traffic signs reduces speed. Flashbulbs or warning signs for speed checks lead to lower speeds because drivers perceive a high chance of enforcement. Signs that are activated when vehicles pass by and drive faster than a pre-set speed also help to reduce speed by making drivers more aware of the applicable limit.
- Road marking
  Road marking can be applied in various forms, such as marking in the middle or on the side of the road. Marking in the middle of the road reduces the width of the lane and increases the separation between two traffic directions. However, also, the absence of marking can lead to lower speeds because it creates uncertainty about the lane to be used by drivers.

In general, more complex environments lead to lower speeds because of the cognitive load and the perceived risk increase. Furthermore, it is important to note that certain measures may work against each other or reinforce each other. Measures should, therefore, be taken in conjunction with each other.

Silvano & Bang (2016) also describe that various road and environmental characteristics have a major influence on speed. Geometric road characteristics, road class, the road environment (suburban or city centre), the presence of parking spaces and the presence of pavements all play an important role. Therefore, speed adjustments should be supported by other measures, such as adjustments to road design and better enforcement. However, the effects of these measures can be limited in space and time. Other options are the application of new technologies in vehicles, such as intelligent speed adaptation (ISA) or an active accelerator pedal (APP). In the longer term, autonomous vehicles can keep themselves at speed (Silvano & Bang, 2016).

Bellalite (2013) presented a model for setting credible speed limits in urban areas. The model is based on eight key parameters whose cumulative effects significantly affect the 85th percentile speed. The model can be used to determine a credible speed limit for a road with specific road and environmental characteristics, which are included in the eight parameters. In decreasing order of importance, the following parameters are used: the number of lanes, the width of the lateral visual clearance, the length of the homogeneous zone, the number of commercial buildings, the type of surroundings, the number of entrance/exit points, the percentage of the street with on-street parking that is continuously occupied, and the pavement width available. The model was developed to set a credible speed limit according to the road features and the road environment. It was assumed a credible speed limit corresponds to the operating speed of the vast majority of drivers (85th percentile speed). This is the speed that drivers consider to be suitable given the road and environment characteristics (Bellalite, 2013).

By Van Nes et al. (2007), based on a literature study, it was investigated which characteristics of the road and its surroundings influence the speed. The literature study resulted in 23 different road and environmental characteristics that are subdivided into five different groups: pedestrian facilities, physical speed brakes de-accelerators, road width, road layout and openness of the road environment (Van Nes, Houwing, et al., 2007). These groups and their corresponding characteristics are shown in Table 10.

*Table 10: Road and environment characteristics influencing the speed (Van Nes et al., 2007)*

| ***Group*** | **Characteristics** |
|---|---|
| *Pedestrian facilities* | Presence of pedestrians |
| | Presence of sidewalks |
| *Physical speed de-accelerators* | Road narrowing |
| | Speed bumps |
| *Road width* | Road width (paving width) |
| | Distance to obstacles |
| | Width of free lanes |
| *Road layout* | Number of carriageways |
| | Number of lanes |
| | Lane width |
| | Separation of driving directions |
| | Road markings |
| | Curviness |
| *The openness of the road environment* | Distance between buildings and road |
| | Number of houses along the road |
| | Number of addresses (front doors) on the right side of the road |
| | Space between buildings along the road |
| | Type of buildings along the road |
| | Number of connections/accesses |
| | Trees close to the road |
| | Open space along the road |
| | Visibility restrictions |
| | Type of road environment |
| | Presence of trees |
| | View of surroundings |
| | Parked cars |

The studies show many similarities about road and environmental characteristics that influence speed. Aspects such as road width, the presence of buildings and trees, the curviness of the road and physical speed brakes occur in almost every study. However, depending on the focus and depth of the study, there are also differences between the characteristics. The results of the studies are used to create a list of characteristics which has been applied during the research (see section 6.1).

## 3.5 Conclusion

To conclude, the choice of speed is a complex process in which many factors play a role. Since all cars have a speedometer, the speed and possible exceeding of the speed limit are in principle, the result of a conscious choice. However, speed is partly also the result of an unconscious process in which subjective perception of speed plays an important role. Certain characteristics of the vehicle and the road can unconsciously lead to higher speeds than desired. For example, the lack of information in the vicinity of the road turns out to be one of the causes that leads to an underestimation of the speed.

The results of different studies suggest that speed limit credibility is likely to be a crucial factor in speed limit compliance. The image of the road and its surroundings must comply with the speed limit. If this is not the case, drivers are more likely to exceed the limit to the disadvantage of road safety. The road safety within the built-up area can potentially be improved by transforming 50 km/h roads into 30 km/h roads. However, on the current 30 km/h roads, drivers often drive faster than permitted. Therefore, an adequate transformation of the road is necessary: road and environmental characteristics must match the speed limit. In that case, a new 30 km/h speed limit can be credible.

However, it will not be possible to determine a limit that is equally credible for all drivers. But, it does seem possible to determine a limit that is more credible for everyone. Drivers allow themselves to be influenced by largely the same road and environmental characteristics. Therefore, those responsible for setting speed limits (in this case municipalities) need to consider the match between road characteristics and the speed limit.

# 4 Research design

This chapter describes the research design. Based on the previous chapters, section 4.1 provides a problem analysis in which the grounds for the study are described. Next, based on this problem description, a research objective (section 4.2) is drawn up, which leads to the main question consisting of various sub-questions (section 4.3). Finally, the scope of the research and the relationship with other research is discussed (section 4.4).

## 4.1 Problem analysis

As described earlier, a possible reduction of the speed within the built-up area to 30 km/h causes many discussions. Supporters and opponents of the proposal have various arguments that are sometimes directly opposed to each other.  The most important reason given for reducing speed is an improvement in road safety. At lower speeds, the seriousness of many accidents is lower. However, then drivers will have to comply with the new limit. On many existing 30 km/h roads, drivers often drive faster than the limit. This is partly because many roads are not designed credibly. In this case, the speed limit does not match the image that the road and its surroundings create. Various road and environmental characteristics play an essential role in this. Most of the existing studies about credibility focused on 80 km/h roads and other rural roads instead of urban 30 km/h roads. Some other studies have looked at the credibility of the speed limit of roads in the city. However, these studies did not focus on the Netherlands, but on cities with a significantly different culture. Credibility also seems to depend on specific national and cultural road design characteristics. Moreover, while several studies indicate that credibility is the main reason for compliance with speed limits, few studies have aimed to directly assess the impact of the speed limit credibility on speed. That is why it is still unclear for municipalities which and to what extent road and environmental characteristics play an essential role in the credibility of 30 km/h roads in the Netherlands. Consultancy firms, too, do not yet have sufficient knowledge of this subject to be able to advise municipalities properly. Identifying these characteristics can lead to more credibly designed 30 km/h roads where more people adhere to the speed limit.

## 4.2 Research objective

The research objective is based on problem analysis. The following objective is formulated:

*Gaining knowledge and insight into the road and environmental characteristics that influence the credibility of 30 km/h roads within the built-up area so that these roads can be designed more credibly.*

Using various research methods, knowledge and insight will be gained into both road and environmental characteristics that influence the credibility of 30 km/h roads. Literature research shows that both road and environmental characteristics influence the credibility of the speed limit. The research focuses explicitly on 30 km/h roads within the built-up area because the adjustment from 50 km/h to 30 km/h is a topical issue Moreover, in the literature, little is known about the credibility of 30 km/h roads. Ultimately, the study aims to obtain more credible roads.

## 4.3 Research questions

Based on the research objective, the following main question has been formulated:

*How can existing 50 km/h roads within built-up areas be efficiently transformed into credible 30 km/h roads?*

As described earlier, the reason for the study is a possible transformation from 50 km/h to 30 km/h within the built-up area in favour of traffic safety. Therefore, these aspects are included in the main question. This main question will be answered by the following sub-questions:

1. How credible are existing 30 km/h roads?
   a) How can credibility be quantified?
   b) How do drivers assess the credibility of the current 30 km/h roads?

2. Which aspects affect the credibility of 30 km/h roads?
   a) Which road and environmental characteristics influence credibility?
   b) Which personal characteristics influence credibility?

3. In what way can 30 km/h roads be designed credibly?
   a) How can a method/tool help to make roads more credible?
   b) Which other measures contribute to the credibility of and compliance with the 30 km/h limit?

These three sub-questions each focus on a different aspect, whereby the combination of the aspects will eventually lead to the answer to the main question. The first sub-question deals with the question of how the credibility of a speed limit can be determined and the assessment of current 30 km/h roads. For this purpose, it is first investigated how credibility can be quantified. This knowledge is necessary to be able to determine the credibility of the current 30 km/h roads. Using a survey, the credibility of 30 km/h roads has been examined.

In order to be able to answer the second sub-question, the results of the survey were combined with characteristics of the road and the environment in data analysis. In this way, the influence of the characteristics on the credibility could be determined. The same was also done for personal characteristics.

Finally, the results of the previous sub-questions are used to make recommendations on how 30 km/h roads can be designed credibly. The relationships between the road and environmental characteristics and the degree of credibility are used to make recommendations regarding the credible design of the road. Moreover, additional measures contributing to the credibility and compliance with the limit are examined.

## 4.4 Scope and relation with other research

The research described is an addition to other research currently being carried out by Goudappel Coffeng and DTV Consultants: 'Het Nieuwe 30'. The preparation of this research started in the spring of 2019, and in the autumn of 2019, the implementation of the research started. Originally the plan was to complete the study before the summer of 2020, but due to the corona outbreak, the planning has been postponed. Both companies received more and more questions from municipalities about how 30 km/h roads can be designed for the benefit of traffic safety and livability. Because little factual research has yet been done on this subject, both companies decided to research this area together. The central question is how busy 30 km/h roads can be designed safely and attractively and what are the possible consequences for the surrounding area and the city.

The basis of the research of Goudappel Coffeng and DTV consultants consists of data analysis in which road characteristics, speeds and traffic accidents of about 200 roads with a speed limit of mainly 30 km/h but also 50 km/h are collected and analysed. First, a collection of suitable roads was made, then various data is collected from these roads, both road and environment characteristics. Examples of road characteristics are the width, maximum speed, presence and visibility of signs, choice of materials, design of intersections and the presence, width and colour of bicycle lanes. Characteristics of the surroundings such as the presence of buildings, vegetation and the design of public space are also included in the study. Furthermore, speed data and accident data of the roads in question is collected. Finally, with the use of statistical analysis, correlations are explored between the data.

The second part of the study focuses on the functioning of practical examples of 30 km/h roads. It is assumed that the success of a road can be determined based on two factors: the satisfaction of users and residents of the street, and the speed of motorised traffic. For this reason, additional research will be carried out for several sample streets submitted by participating municipalities in autumn 2020:

- A street satisfaction survey aimed at cyclists and pedestrians.
- An online satisfaction survey of residents and (all types of) users using an online panel.
- A focus group to deepen both surveys.
- Measurements of intensities and speeds.

The final report consists of an analysis of each of the sample streets with generic conclusions about the relationship between the characteristics of the road (layout, use, safety) and the opinions of different road users. The study involves collaboration with about 15 municipalities. These municipalities financed part of the research and provided one ore more sample roads from their municipality, which are included in the study. These roads are part of the 200 roads that are being analysed. In the end, participating municipalities receive an overview of all findings relating to the supplied roads and a final report with all the results.

The 'Het Nieuwe 30' study by Goudappel Coffeng and DTV Consultants focuses mainly on the safe and attractive design of 30 km/h roads. The aim is to be able to assist municipalities in the design of 30 km/h roads for the benefit of road safety and livability. Possible consequences for the surrounding area and the city are an important part of the research. Several surveys are conducted among road users and residents, quality of life and satisfaction is hereby evaluated. The credibility of the speed limit is not included in the study. Nevertheless, the credibility of the limit is an important aspect. The credibility of speed limits is related to compliance with the limit. On many 30 km/h roads, the limit is not respected, which is at the expense of road safety and quality of life. Therefore, the master thesis aims to arrive at recommendations that lead to a credibly designed road.

The results of both studies can reinforce each other. Whereas the 'Het Nieuwe 30' study can lead to road and environmental characteristics that positively influence traffic safety and liveability, the master thesis leads to the road and environmental characteristics that positively influence the credibility of the limit. The possible similarities and differences in these road and environmental characteristics may lead to extra insights. Therefore, the master thesis complements the research of Goudappel Coffeng and DTV Consultants. In addition, as previously described, whereas other previous research concerning credible speed limits focused mainly on rural roads or city roads in countries outside the Netherlands, this study specifically focused on 30 km/h roads inside built-up areas in the Netherlands. The proposed adaptation of the speeds only concerns the adaptation of 50 km/h roads within the built-up area. The study area is the Netherlands as a whole because the proposal concerns all built-up areas in the Netherlands. Therefore, for the analysis of current 30 km/h roads, several roads throughout the Netherlands are chosen that together form a good representation of the current design of 30 km/h roads within the Netherlands. Furthermore, the study specifically concerns credible speed limits for drivers of passenger cars, although the results will probably also affect vans and trucks.

Several sub-questions have been adjusted in comparison with the research design that was made before the implementation of the research. Originally, the following sub-questions were included in the proposal: 'What is the influence of the size of 30 km/h areas on speed?' (under sub-question 1) and 'To what extent does the credibility of roads change over time?' (under sub-question 2). However, both questions turned out to be very difficult to answer. There is no information available in the literature and it is difficult to answer the questions with own research. Besides, the questions do not play an important role in answering the main question. It was therefore decided to drop these two questions. Moreover, the original sub-question about the current status of 30 km/h roads (distribution within built-up areas and compliance with the limit) was answered in the literature review and no longer included as separate sub-question.

## 4.5 Research methods

To be able to answer the research questions, various research methods are used. This section gives an overview of the research methods used. Only a brief description of the methods is given, in the following chapters, the steps will be described in more detail. Figure 6 shows an overview of the different elements of the study.

The core of the research consisted of a survey in which respondents were shown photographs of roads (mainly roads with a speed limit of 30 km/h). For these roads, the same two questions were asked: 'What speed would you choose on this road?' and 'What do you think the speed limit is on this road?'. The difference between the answered speeds and the actual speed limit was used as an indication of credibility. These questions aimed to determine the credibility of roads and to link the credibility to the characteristics of the road and its surroundings at a later stage.

Regarding credibility, a lot of information based on literature research has already been described in chapter 3. For example, definitions of credibility and various studies into the influence of credibility have been described. However, to answer some sub-questions, more information was collected from the literature. Examples are the quantification of credibility and existing methods for comparing the credibility of roads. A part of the literature review consisted of determining road and environmental characteristics that influence speed and credibility based on previous studies. The results of these studies were used to produce a list of relevant road and environmental characteristics. These characteristics were determined for all roads in the survey. Subsequently, data analysis was done to determine the relationship between the road and environment characteristics and credibility.

The survey also asked for some personal characteristics, such as age, gender and kilometres driven per year. Besides, questions were asked about motives for car use, the use of other means of transport and travel preferences. The purpose of these questions was to better explain a possible spread in the speeds of respondents. In a similar way to road characteristics, a regression analysis was used to investigate the extent to which the various characteristics influence the speed of respondents. The difference with the previous analysis is that this analysis concerned respondents (personal characteristics and speed were per respondent) and that the analysis about road characteristics concerned roads (road characteristics, environmental characteristics and speed were per road).

In addition, an existing method from the literature to determine the credibility of roads has been tested and improved based on the results of the data analysis. In the end, all results were combined with other measures that could contribute to credibility. This led to recommendations on how to efficiently transform existing roads into credible 30 km/h roads.

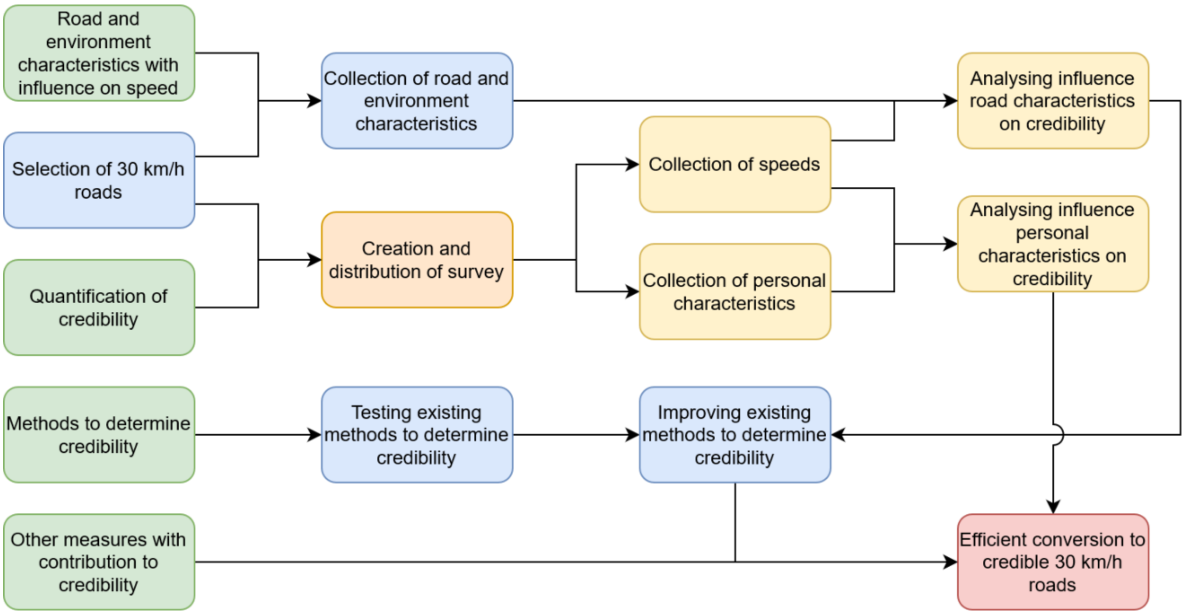


*Figure 6: Overview research design and methods. Green = literature research, orange = survey, yellow = data analysis, blue = other tasks and red = result.*

## 4.6 Floating car data

The credibility of the roads was assessed based on the speeds (mainly using the preferred speed) respondents answered in the survey. The generation of this speed is described in detail in the following chapters. This speed forms the basis of the study and has been used to determine which road and environmental characteristics influence the credibility of roads. However, measured speeds of the roads in the survey were also desirable to have. In this case, it is possible to link the degree of credibility to the actual speed on the road in question. In this way, the survey speeds can be validated and the relationship between the survey preferred speeds and the actual speeds driven can be determined.

But, to be able to compare both speeds, the location of the photograph of the road situation has to be the same as the location to which the speed data refers. Only, in that case, a link can be made between the degree of credibility and the speed. A hypothesis is that the more credibly the speed limit is judged, the more one adheres to the speed limit. A more credible speed limit means that the image of the road is more in line with the speed limit, which makes drivers more inclined to comply with the limit.

There are several ways to collect data on speeds. In the past, speeds and congestion were measured in the Netherlands using fixed, road-bound systems such as detection loops and cameras. These loops are mainly placed on the main network and detect passing vehicles at fixed locations and measure speed. In recent years, a new measurement method based on mobile sources has been added. The data generated by these mobile sources is called floating car data (FCD). This data does not come from the road, but from the vehicles themselves, which are called 'probes'. Examples of systems that can regularly send signals over their location are navigation systems, mobile phones, travel apps on smartphones and connected cars. The received locations of these systems are captured and bundled and, via complex techniques and operations, converted into average vehicle speeds on road sections and travel times on the road (Van der Loop, Francke, Jorritsma, & Moorman, 2017). In most applications, speeds are calculated from a distance covered along a route between time-stamped satellite GPS points (10-60 sec apart). Therefore, the FCD speeds are mainly based on travel time between two known points. The data is assigned to road segments (30m – 2000m) defined by navigation service providers' maps (Jurewicz, Commission, & Han, 2017). The proportion of vehicles that serve as probes is increasing steadily. Within the Netherlands, several companies are active in the mobile data market, such as TomTom, HERE, INRIX, Be-Mobile, Google, Flitsmeister and Vodafone (Van der Loop et al., 2017).

A characteristic of mobile data is that they have a large level of spatial detail: speed data is made available on short segments. This level of detail cannot be achieved with the existing fixed measuring points. Moreover, the data cover a much larger part of the road network than traditional methods such as loop and radar measurements. The measurements do not only concern measurements at a point on a section of the road but provide insight into the average speeds over a whole section of the road (Slinger & Talens, 2017).

The most important limitation of FCD data is that sufficient probes are required to generate reliable data. If speed is calculated on roads with little traffic, the question is to what extent this data is reliable and has a good quality (Slinger & Talens, 2017). Knowledge of 'probe' vehicle sample size is the best way to assure the quality of the extracted data. The sample size is included in the data outputs by some of the FCD providers, but this information is not always known. But in general, use-cases showed that FCD is suitable for monitoring, informing and evaluating speed management programs. Many speed distribution indicators can be derived from FCD speeds, such as mean and 85$^{th}$ percentile speeds (Jurewicz et al., 2017).

Given the fact that there are no detection loops on 30 km/h roads to obtain speed data, the use of FCD is necessary in order to be able to collect speeds at 30 km/h relatively quickly and easily. It is possible to use counts for a selection of 30 km/h roads. However, given the effort required, this is only possible on a limited number of roads. FCD is, therefore, necessary to obtain a complete overview of the speeds. However, given the (unknown) quality of the data, some caution is required when applying the data.

Speed data was collected within the 'Het Nieuwe 30' study of Goudappel Coffeng and DTV consultants. Speed was one of the characteristics of each of the 210 roads included in the data analysis and is acquired for each road. 19 of the 210 roads were supplied by the municipalities for additional analyses. These roads will also be investigated on site. The original plan was to carry out these measurements in the spring of 2020. But because of the coronavirus outbreak, the measurements have been postponed to the autumn of 2020 for the time being.

Within the ‘Het Nieuwe 30’ study, it was decided to make use of HERE data. Contrary to some other sources, historical driving speeds data can be requested from this provider. For all road points included in the analysis, the most suitable HERE road section was determined. The average length of the road sections was 90 meters. For this project, the working day data from 1-1-2019 up to and including 31-12-2019 has been used.

The V85 speed is used because this speed indicates whether a speed limit corresponds well with the road and its surroundings. It indicates the speed that is not exceeded by 85% of the drivers and is exceeded by 15%, on a road with traffic in normal weather conditions. This rule reflects the speed that the majority of drivers consider reasonable and safe in ideal conditions. Insofar as the infrastructure does not present any visible or hidden dangers, a speed regime based on the V85 will benefit a smooth and safe traffic flow. After all, it increases the chance of uniformity in the speed driven on the road. Drivers will be less inclined to show unsafe behaviour, which improves road safety. Moreover, speed limits close to the value of the V85 are more easily accepted. They reflect the speed behaviour of the majority and indicate what is generally considered a reasonable and safe speed.

The use of the described Floating Car Data has a number of disadvantages. As described, on certain 30 km/h roads the intensity of cars is insufficient, making the measurements unreliable. However, it is not known for which roads this is the case. Moreover, the speed refers to a road section that is on average 90 meters long. Within this section, there may be variation in characteristics of the road and its surroundings, making it difficult to link specific characteristics to the measurement. In addition, the measurements are influenced by dynamic conditions, such as the presence of other road users and weather conditions. Within the master thesis research, these conditions could be 'manipulated' by showing pictures of roads without other traffic and with similar weather conditions. This data, therefore, contains fewer disturbances due to unequal conditions in the background. The HERE data could be corrected for other traffic by, for example, using the intensities. But also intensities can be inaccurate for 30 km/h roads.

Thus, within the master thesis research, use was made of the floating car data collected for the ‘Het Nieuwe 30’ research. In this way, the relationship between credibility and speed could be determined (see section 6.3). An attempt was also made to predict the HERE speed based on the road and environmental characteristics (section 7.3).

# 5 Survey design

As described earlier, the core of the study consists of a survey among car drivers in which the respondent was asked to fill in speeds for various photographs of roads. This chapter describes the process of devising, constructing and distributing the survey. Section 5.1 describes the choice of a survey and its overall content. Next, section 5.2 describes how credibility is quantified. The complete content of the survey is presented in section 5.3 and the distribution of the survey is described in section 5.4.

## 5.1 General concept

A questionnaire study with photos was chosen for a number of reasons. The main reasons are that the results of a survey are seen as a useful contribution to the study and that the implementation of a survey is feasible within the limited duration of the survey. Field experiments have not been assessed as suitable, because it takes too much time and resources that were not available during the investigation. Using a survey, it is relatively easy to reach a large group of respondents, creating a representative image of car drivers.

Photo's of roads are used in the survey like most previous studies on this subject. The advantage of using pictures in the survey is that they are relatively easy to assess for the respondents and for determining road characteristics. Previous studies also show that respondents can indicate their actual speed based on pictures (Goldenbeld, Van Schagen, & Drupsteen, 2006). Besides, photographs are easy to collect and can be edited as needed. Movies or animations may give a more complete picture of the road with more information. However, it would probably have been more difficult for the respondent to assess the video and choose a speed because more information needs to be processed. The speed of movement of the video may have a large influence on the answers. It is also more difficult to determine the road and environmental characteristics of a video compared to photographs. Because videos are dynamic, many characteristics may change throughout the movie, making it difficult to sketch an unambiguous profile of the road and to identify the specific characteristics that influence the speed.

The photos are taken from the public Google Streetview. Other options were using Cyclomedia's similar but not public Street Smart or taking the pictures personally. However, compared to the images from Google Streetview, the images from Street Smart often contain unrealistic colours and are taken throughout the year. The images of Streetview were generally much more realistic with natural colours. Also, these images are often made in spring and summer on brighter and drier days. An attempt was made to equalise the weather conditions of the photos as much as possible, to ensure that the weather conditions do not disturb the respondents' answers. Therefore, the Streetview images were better suited for the research because there was less need for photo editing. However, the Street Smart images were often more up to date, they are taken on every road every year. But also most of the Streetview images were up to date and came from 2018 or 2019. When the Streetview images came from 2018 or earlier, a comparison was made of the Street Smart images to assess the topicality of the road layout. On some roads, the Streetview images were no longer up to date because the road layout had changed. In that case, the road in question was not included in the research and another road was chosen. It was important that the road layout in the photographs corresponded to the road layout as it was in 2019 because of the measured speed data related to that year.

The recordings of Google Streetview and Street Smart were both made with a camera on the roof of a car driving on the roads. The disadvantage of these images is that they were taken from the perspective on the roof of a car. Drivers sit lower, giving them a different view of the road. The images of the roof are therefore slightly distorted and give a different perspective than drivers have. Some respondents also indicated that they experience the roads in the photographs narrower than is probably the case in reality. This narrower effect could, for example, lead to lower speeds.

However, it is assumed that the distorted effect was limited by these photographs. Moreover, taking pictures of the roads personally was not considered feasible, because the roads were scattered throughout the Netherlands. Also, specific favourable conditions are needed while taking the photographs, of which it is uncertain in advance whether these will be there. For example, it was decided to take photographs of roads on relatively clear and dry days with few or no other road users. As described earlier, certain dynamic characteristics such as the presence of other road users or weather conditions can also strongly influence speed.

However, the research aims to make roads more credible with the help of the layout of the road. The characteristics of the road and its surroundings are mainly important in this respect. The presence of other (dynamic) characteristics is, therefore, disruptive and undesirable. Of course, there are no speed limits on signs and marked on the road visible in the photographs, because otherwise the speed limit would already be revealed to respondents.

## 5.2 Quantification credible speed limit

The survey aimed to determine the credibility of 30 km/h roads. However, the credibility is not directly measurable and therefore needs to be quantified. Based on definitions and already existing quantifications of the credibility in the literature, the concept is made measurable and applied in the survey questions. In this way, the relative differences in credibility between the roads can ultimately be assessed and explained based on the differences in characteristics. It is also possible to use the absolute speed if it turns out that the used measure of credibility gives a realistic impression of reality.

### 5.2.1 Definitions

To investigate the credibility of roads, it is necessary to make the concept investigable, the concept must be operationalised. This implies that the abstract concept of 'credibility' is made measurable by non-abstract and observable phenomena through the selection of indicators that represent the concept. In this way, the concept can be used as a measurable variable in the research. In the literature review, several definitions of credible speed limits have been mentioned. An overview of these definitions is shown in Table 11.

*Table 11: Definitions credible speed limit from the literature review*

| Source | Definition credible speed limit |
|---|---|
| Yao et al. (2019) | ‘a limit that drivers consider logical or appropriate in light of the characteristics of the road and its immediate surroundings through specific consistency and continuity of road design, including the type of the road, road layout, road surface, road curvature, traffic density, weather conditions and a mix of traffic’ |
| Bellalite (2013) | ‘a credible speed limit corresponds to the operating speed of the vast majority of drivers (85$^{th}$ percentile speed); this is the speed that drivers consider to be suitable given the roadway features and the roadway environment’ |
| Goldenbeld et al. (2007) | ‘credibility means that drivers consider a speed limit as logical or appropriate in the light of the characteristics of the road and its immediate surroundings’ |
| Van Schagen et al. (2004) | 'a speed limit that matches the image that the road and the (traffic) situation evoke' |

From these definitions, it can be concluded that a speed limit is credible if it matches the image evoked by the road and the road environment. Both characteristics of the road itself and characteristics of the surroundings must make it logical and credible that a lower limit applies on one road than on the other. Assessing a limit as 'logical' and 'credible' can be interpreted in various ways. For example, it is described that a limit is logical if it is not exceeded by 85% of the drivers (V85). It is also described that the limit must match the image that the road and its surroundings evoke. The image of the road and its surroundings evokes a certain speed. This speed can be measured as well as questioned. The V85 speed is measurable and the difference between the V85 and the actual speed limit already shows something about the credibility. For example, if the V85 is 40 km/h and the limit is 30 km/h, then a considerable number of drivers do not comply with the limit. This is provoked by the road and environmental characteristics which do not match with the limit. As a result, the speed limit on the road in question can be regarded as not or less credible.

A credible speed limit is also defined as a limit that drivers find logical given the characteristics of both the road and its surroundings. Characteristics of the road that play a role are the road layout, road surface, road curvature and mix of traffic. Dynamic characteristics such as traffic density and weather conditions are also important. To find out which specific characteristics fit a certain road type and speed limit, it is necessary to be able to determine the influence of the characteristics on speed. This could be done by measuring the characteristics and then trying to make correlations between the characteristics and the speed.

Not all features are easily measurable. For example, there is a difference between the measurability of static characteristics and dynamic characteristics. Examples of static characteristics are markings, curves, buildings and trees. These characteristics can (partially) change over time, but are often fixed for a longer period. On the other hand, dynamic characteristics such as traffic density and weather conditions are very changeable, in the short term, large changes are possible that can influence the credibility of the limit. On highways, for example, dynamic limits can, therefore, be used that adapt to current road conditions. On urban 30 km/h roads, however, this is not (yet) the case. Besides, it is much more difficult to measure dynamic characteristics. That is why the main focus is on static characteristics of the road and its surroundings.

Within the group of static characteristics, however, not all characteristics are directly measurable. Characteristics such as the width of the road, the distance to trees and the distance to buildings are relatively easy to measure. These distances can be expressed with a number and have a fixed zero point (measurement level 'ratio'). However, other characteristics such as the type and colour of the pavement, the presence of trees and the presence of parking spaces cannot be directly expressed in a number but can be classified. Because in this case a distinction can only be made between items, there is a nominal/categorical measurement level. However, the influence of these characteristics on the credibility of speed can also be investigated.

### 5.2.2 Operationalisations from the literature

A few studies are available in the literature in which the credibility has been investigated and quantified in a survey. For example, in a study into the credibility of 80 km/h roads by Goldenbeld et al. (2006), the operationalization was based on various starting points. The first starting point was that it should be the driver's own estimation/view. Furthermore, it was assumed that credibility has a scale: a limit can be more or less credible. The questions 'Do you find the limit credible?' or 'Do you find the limit logical for this road?' were therefore not used, because no degree of credibility can be measured. The question 'Which limit do you find credible/logical for this road' has not been used either, although the question does meet the requirement that the answers result in a scale. However, this and the earlier questions assume that drivers have a notion of the concept credible/logical limit, which is probably not the case. It has therefore been decided to avoid these terms (Goldenbeld et al., 2006).

Two different operationalisations related to speed are used in the study of Goldenbeld et al. (2006):

- The credible limit is the limit that a driver considers being safe on a certain road section.
- The credible limit reflects the speed a driver wants to drive on a particular section of road.

The credibility of the speed limit was operationalised as the difference between the actual speed limit (which was 80 km/h) and the participants' preferred speed and perceived safe limit. By using these operationalisations, a limit is more credible if it is closer to the limit that drivers themselves consider to be safe or closer to their preferred speed (Goldenbeld et al., 2006).

In a study by Starkey et al. (2017), a similar questionnaire was used but extended with three additional questions (see Figure 7). During the first three questions, respondents were asked how comfortable, difficult and familiar the road is on a scale of 1 to 5. Then the same three questions were asked that were also used in the study by Goldenbeld et al. (2006).

So, respondents were then asked to indicate what speed they would choose to drive on this road, what they thought was a safe speed and what they thought was the speed limit. Before this questionnaire, respondents had to drive in a driving simulator on the same roads that came back later in the questionnaire. The speed participants drove in the simulator was used to calculate the observed credibility of the speed limit (posted speed limit – speed driven in the simulator) to identify roads that had poor speed limit credibility (Starkey, Charlton, & Malhotra, 2017).

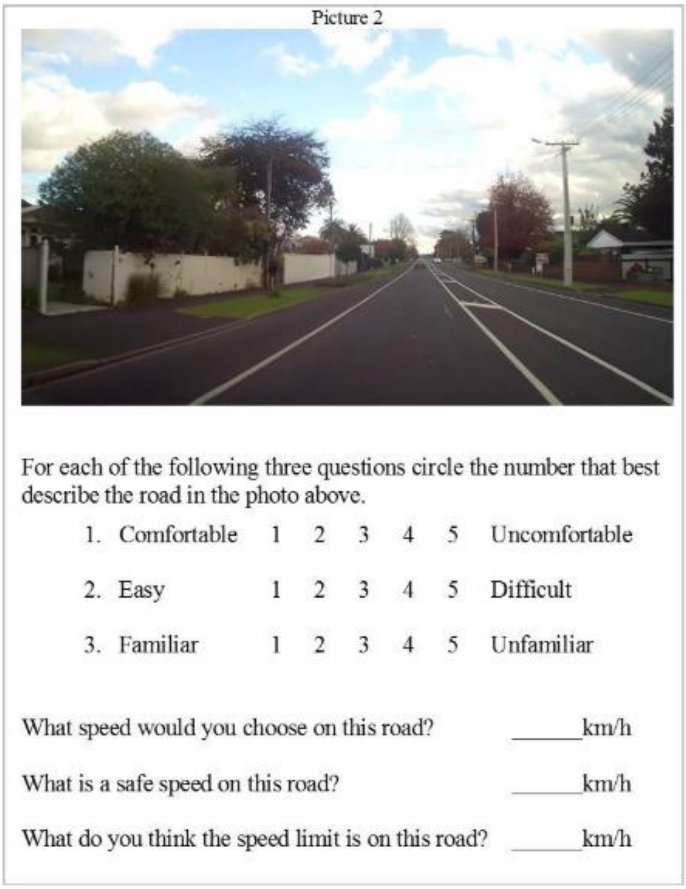


*Figure 7: Questions used by Starket et al. (2017)*

In a study of Yao et al. (2019), credible speed limits are defined as the speed limits which are accepted by most drivers (over 50% of the respondent drivers) without the need of enforcement in a given road layout. If most drivers have a commonly perceived speed limit and the choice of speed is less than or equal to that limit, it is assumed that the speed limit is credible for the road environment and drivers are compliant with the limit. Respondents were presented photographs of road situations with two questions based on research by Goldenbeld et al. (2006). The questions were:

- If there was no speed limit, how fast would you drive on the road section shown? The response could be any numerical value.
- What speed limit do you think would be safe here? Choose one: 10/20/30/40/50/60/70/80.

The mode value of the proposed safe speed limit is adopted as the most credible speed limit (Yao, Carsten, & Hibberd, 2019).

All in all, the literature contains a limited number of studies quantifying the credibility of speed limits by drivers. Goldenbeld et al. (2006) was the first study in which this concept is applied. Many follow-up studies have made minor adjustments or additions to the questions in this research. But the basis is almost the same in the studies. Drivers are asked with which speed they would drive on the road if they were not familiar with the speed limit or if there was no speed limit. Drivers are also asked what speed they would find safe and what they think the actual speed limit is. Next, the differences between these answers and the actual speed limit are often used to be able to quantify credibility.

### 5.2.3 Selected operationalisation

The operationalisation used in this study is based on the previous operationalisations described. Respondents are asked two questions with each picture:

1. What speed would you choose on this road?
2. What do you think the speed limit is on this road?

The first question is about indicating the speed the respondent expects to drive on the road in question, without the respondent is familiar with the speed limit (see Figure 8). The answer can be given by placing the ball (drag or click on the bar) on the speed the respondent expects to drive on the road. It was not necessary to give rounded answers (e.g. 30 km/h or 45 km/h), all speeds within the range of the bar were a possible answer. The choice was made to have the respondent give an answer with a scroll bar instead of, for example, having the respondent type in an answer himself/herself. As a result, respondents were probably less inclined to fill in rounded numbers or existing speed limits.

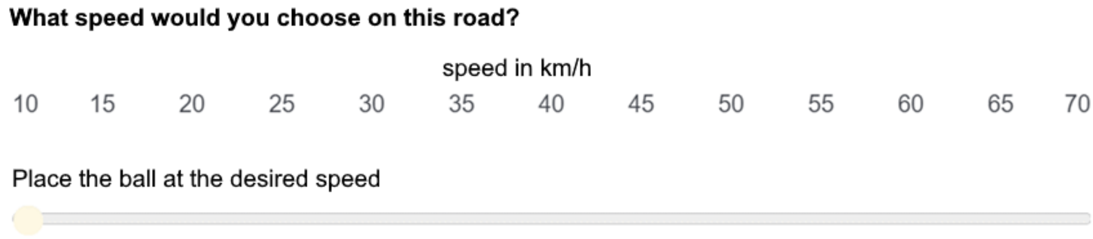


*Figure 8: First road photo question survey*

Concerning the second question, the respondent was asked about the speed limit of the road in the picture (see Figure 9). This speed did not have to correspond with the answer given earlier, differences were possible. There were some existing speed limits to choose from. This question has been added to check whether respondents can determine the speed limit at the location.

For this question, it was decided to offer the answer options to the respondent instead of the respondent filling in an answer herself/himself. The latter option requires respondents to be familiar with all speed limits, this is probably not the case. Also, being able to click on an answer requires less effort from the respondent than filling in an answer yourself. The respondent no longer has to think about the existing speed limits, but only has to choose between them.

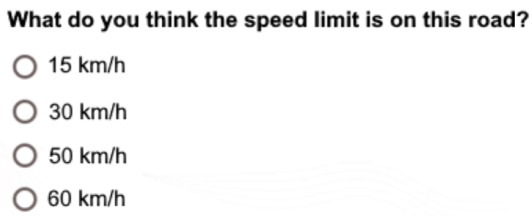


*Figure 9: Second road photo question survey*

The words 'speed' and 'speed limit' are deliberately used in the questions, because it is assumed that it is clear to everyone what is meant by this. Terms such as ‘credible limit’ or ‘logical limit’ have been avoided to avoid any confusion.

A question such as 'What do you think is a safe speed on this road' was not asked the respondents, in contrast to several previous studies described. These earlier studies show that there is a very strong positive correlation between the preferred speed and the safe speed limit. For example, research by Goldenbeld et al. (2006) shows that on almost all roads drivers want to drive 4-5 km/h faster than the limit they consider safe. Moreover, the differences are much smaller on 30 km/h roads. 30 km/h is almost three times as small as 80 km/h. This makes it more difficult for respondents to distinguish between three different speeds. In that case, the answers are expected to be much closer together or even the same. Previous research shows that the distance between the preferred speed and speed limit is the greatest, so these two questions are most suitable. It has been assumed that this also applies to 30 km/h roads.

Furthermore, an extra question about the safe speed means that respondents have to answer 33% more questions for an equal number of pictures and thus road characteristics. However, to increase the number of fully-completed surveys, it is limited in length. This means that when adding a question about the safe speed, fewer pictures can be shown to keep the length of the survey the same, resulting in fewer road characteristics. All in all, the importance of adding extra photos is considered to be greater than adding the question about the safe speed. Extra photographs lead to a large quantity and diversity of road characteristics, which are a crucial part of the research. Moreover, a question about the safe speed seems to yield limited valuable information given previous comparable studies.

### *Other question types*

In addition to asking about speeds, other types of questions would also have been a possibility. For example, two or more photographs of roads could be shown at the same time, after which the respondent could put them in order of the speed he expected to drive on the roads. In the end, a ranking could be created in which all pictures were sorted from low speed to high speed. However, in this case, only one kind of speed can be asked for, instead of multiple speeds. This method also lacks a quantification of credibility. Roads higher in the ranking with higher speed can be considered less credible, but to what extent is unknown. This question type is, therefore, judged to be less appropriate in comparison with the previous described questions type.

## 5.3 Composition of survey

The creation of the survey consisted of several parts. First, a selection of 30 km/h roads was made which were placed in the survey. Then, the further content of the survey was made and a pilot test was carried out to test the survey among a limited group of people.

### 5.3.1 Selection of roads

The research focuses exclusively on 30 km/h roads within built-up areas. Multiple road types or limits would make the size of the questionnaire too large. It was necessary to find photographs of road situations with sufficient variation in the road and surrounding characteristics, but with the same 30 km/h speed limit. But, to show sufficient variation in road situations, some roads with a speed limit of 15 km/h (residential areas) and 50 km/h were also added. In this way, an attempt was made to prevent that respondents would become bored too quickly due to a great monotony in the road situations to be assessed. All roads were taken from the list of roads included in the 'Het Nieuwe 30' study because speed data is known for these roads. The floating car data has already been used in the selection of 30 km/h roads by checking whether there was sufficient variation in actual driving speeds. In addition, an attempt was made to make a selection of roads with many different characteristics, in order to obtain a more complete picture of the influence of characteristics on credibility. The selection of roads was therefore not completely random. Also within the 'Het Nieuwe 30' research, there was no random selection of roads. Mainly busier roads (with a lot of traffic intensity) had been added. In general, it is probably more difficult to determine the speed limit for these roads (doubt can arise between 30 km/h and 50 km/h).

The pictures are taken from Google Streetview and are as far as possible within the road sections for which speed data is known. In this way, it possible to link the influence of road and surrounding characteristics on speed later on. The pictures always give a relatively calm traffic image with little or no other traffic. The study aims to investigate the influence of static road and surrounding characteristics, dynamic characteristics like other traffic can disrupt the answers. Moreover, the photographs are of relatively clear and dry days. When the original Google Streetview photo was darker, it was made lighter using photo editing, so that all photos have an approximately equal brightness (see Figure 10). Also, the street name labels that were originally visible in Google Streetview have been removed, as these labels may be able to distract respondents. Furthermore, the aspect ratio of all photos has been adjusted to widescreen (16:9), so that all photos are displayed at the same size in the survey. And because of this adjustment, photos have become narrower, making the two questions better visible at the same time as the photo.


*Figure 10: Example of original Google Streetview image (left) and result after editing (right). The state name labels have been removed, the brightness has been made lighter and the aspect ratio has been adjusted to widescreen.*

### 5.3.2 Content survey

The previously described two questions and the photos are the most important part of the survey. In addition, the survey also contains several smaller parts that are described in the overview below. A complete overview of the text and questions of the survey is given in Appendix A (except for all pictures because the same questions were asked for each picture). The survey was in Dutch as the target group of the survey were Dutch driving licence holders. The survey consists of the following main parts:

- Introduction
  In order not to influence the answers, the introduction does not mention that the study specifically concerns the design of 30 km/h roads. Respondents were given a limited amount of information by indicating that the study deals with speeds on roads and that it investigates how roads within built-up areas can be designed safely and attractively. Furthermore, it is described that the data is processed anonymously, there is a chance of winning a voucher after the survey has been completed, and the estimated time for completing the survey is about ten minutes.
- Personal questions
  Gender and age were asked to be able to investigate whether the respondents form a representative sample of the holders of a Dutch driving licence. They were also asked about the possession of a driving licence for driving passenger cars. If this was not the case, respondents were directly sent to the end of the survey. It was assumed that respondents should have sufficient experience in driving to be able to estimate the speed at which they would drive on various roads. Therefore, besides, respondents were asked about their annual mileage. People with low annual mileage (less than 500 kilometres) were also not included in the analysis. Furthermore, the characteristics of gender, age and annual mileage were used to create different classes of respondents, after which it was investigated whether and to what extent these characteristics influence the speed and credibility of roads. Section 7.4 explains the requested personal characteristics in more detail.
- Introduction to photo questions
  To familiarize respondents with the two questions described earlier, a sample picture was first shown and an explanation of the questions was provided. This was done because a lot of people probably never made these types of questions before. It was also important that the difference between the two requested speeds was well understood.
- Photo questions
  The photos with accompanying questions were offered to the respondents one by one. To exclude order effects, each respondent was shown the photos in random order. Each respondent was shown 20 of the 36 possible photos. Of the total of 36 photos available, 27 photos (75%) were 30 km/h roads, 7 photos (19%) were 50 km/h roads and 2 photos (6%) were 15 km/h roads. The average respondent thus received 15 photos of 30 km/h roads, 4 photos of 50 km/h roads and 1 photo of a 15 km/h road.
- Questions about driving behaviour
  After the photo questions, some questions were asked about the respondent's travel behaviour. These questions provide more insight into the travel motives for which the car is used, the use of other means of transport and the aspects that are important when choosing a transport mode. These questions provide more insight into the type of drivers and the background information might make it possible to better explain any differences in answers between respondents. The questions are based on previously conducted surveys into travel behaviour.
  The questions are deliberately placed at the back, behind the photo questions. If respondents leave the survey early during these questions, at least the answers to the photo questions have been collected. These answers make it possible to determine at least the credibility. Section 7.4 explains the questions in more detail.
- Final questions
  At the end of the survey, some final questions were asked. Respondents were asked whether they would like to participate in the raffle of vouchers and/or a possible follow-up survey. If this was the case, respondents could fill in their e-mail address. Finally, respondents could fill in any comments about the survey.

### 5.3.3 Pilot test

To test the survey, a pilot was carried out with about 10 people. These persons filled out the survey in the same way as respondents will have to fill it out later on. This way it was tested if the questions are clear and if the time for filling in the questions is suitable.

In general, the questions turned out to be clear. There were no comments about questions that were not understood. However, some remarks were made about how questions could become clearer and how answers could become more complete. That is why several questions and answers have been slightly modified. The explanation of the two questions that are asked with each picture of a road turned out to be clear. Everyone understood the difference between the two questions. However, sometimes it was not read that clicking on the scroll bar was also possible instead of dragging. In this way, answers can be given more easily and quickly. That is why this possibility is more emphasized in the explanation.

Almost every person indicated that the survey was too long. Especially the number of pictures was too much for many people, for some people it seemed like there was no end to it. Some indicated that they had dropped out if the survey was a normal one. Because it is important to collect completed surveys, it was decided to reduce the number of photos. Originally, 30 photos were presented in the survey, this number has been reduced to 20 photos. In this way, the time needed to complete the survey was reduced.

Finally, some respondents indicated that they were not always able to give their desired answer (expected speed) to the photos. For some 50 km/h roads respondents wanted to drive faster than the maximum answer of 70 km/h that can now be given. This may indeed be the case, but has little impact on the results. The data of 50 km/h roads is not analysed at a later stage, the research only focuses on 30 km/h roads. Extending the range to, for example, 10-90 km/h also gives a problem with the display of the slider on mobile phones. Because the width of these screens is limited, the numbers on the scroll bar will be very close together. Therefore, the original scale to indicate the preferred speed has been retained.

## 5.4 Survey distribution

The survey was created in an online survey tool (Qualtrics) and distributed via an anonymous link with a short description. The survey could only be completed online. Although less digital people may have been excluded with this method, a survey on paper (as a supplement) was not considered suitable. Given the many pictures in the questionnaire and the manual input of the data on the computer that is required afterwards, this was not a realistic option. The advantage of an online survey is that a large sample can be examined with relatively few resources. A survey at a specific location on the street is not suitable, because no specific target group was needed. In principle, every person in possession of a driving licence for passenger cars is already suitable to take part in the survey.

Respondents for the survey were collected in various ways. Within the study 'Het Nieuwe 30' 15 different municipalities participated, both larger and smaller municipalities in the Netherlands. Before the survey, all these municipalities were asked whether it would be possible to distribute the survey among their residents, for example via a panel or social media. Seven municipalities were willing to spread the survey, this was done in various ways. For example, some municipalities put a short description and link of the survey on their social media (e.g. Facebook and Twitter), see Figure 11 for some examples. Some other municipalities distributed the survey among their employees. The survey was also distributed among Goudappel Coffeng employees. Furthermore, one municipality referred to the survey within an existing panel survey. And one municipality shared the survey via various neighbourhood platforms. Several other municipalities indicated that they could not distribute the survey at the time (April 2020), but perhaps at a later time. These municipalities indicated that they only wanted to report on corona measures and temporarily did not allow any other messages on their social media. Furthermore, the use of an existing municipal panel was often not an option, because many municipalities only wanted to use this panel a limited number of times and only for their own policy.


*Figure 11: Examples of survey distribution on social media*

The distribution of the survey started on Monday 6 April. There was no specific end date linked to the survey in advance, as it was not yet certain when municipalities could distribute the survey. There was some delay between providing the link with description and placing it on the various platforms. The survey was closed on 30 April because the number of new responses in the time before that was very limited. In total 1,692 registered surveys were received.

A relatively large number of surveys (447 responses, 26% of all responses) were not fully completed. During the pilot test, it already appeared that the number of photos was too large, after which the number of photos was reduced from thirty to twenty. But it still turned out that this number was too large for some of the respondents. Also, many respondents who had filled in the survey completely said they thought the survey was too long and boring at a certain point because the same question was asked each time. But in the introduction of the survey, it was described that it will take about ten minutes to complete the survey. Without some extreme peaks to the top, the average time to complete the survey was eleven minutes. This duration therefore corresponded well with the expected duration indicated beforehand. Nevertheless, several respondents thought the survey was too long, possibly due to asking the same questions with each picture.

It was difficult to predict in advance how many respondents would complete the survey, partly because it was unknown how many people the survey would be distributed to. A maximum of a few hundred respondents was expected, however, it eventually turned out to be over 1,000. If this high number had been known in advance, more photos of roads would probably have been added to the survey (but with an equal or lower number of photos per respondent). In this way, greater diversity of roads could be obtained and larger clusters of roads with certain characteristics were possible. However, because it was difficult to predict the number of respondents as described, a safe prediction and a limited number of photos were chosen, so that it was more likely that sufficient data would be collected per photo.

One of the reasons for the relatively high number of respondents is probably the involvement with the subject. During the distribution of the survey, it was described, among other things, that the aim is to make roads in built-up areas safer and more attractive. Because in principle everyone benefits from this, there was probably a lot of involvement with this subject. Because of this, people were more willing to contribute to the survey. Especially if people live within the built-up area and suffer from unsafe traffic situations due to speeding traffic in their surroundings, there would have been an incentive to participate in the survey.

### 5.4.1 Representativity of the sample

The data is somewhat biased because it does not represent the opinions of everyone, but only those who have chosen to participate in the survey. In other words: they were informed about the survey, had access to the internet, went to the survey website and chose to complete the survey.

The survey was mainly distributed via the social media of several municipalities. Primarily residents of the municipality will follow these social media and may encounter the message. Because it was mentioned in the description that the survey is about speeds and safe and attractive road design, most people who are interested in these topics will probably have completed the survey. For example, people may feel involved and interested in the survey if they experience problems with exceeding the limit and unsafe traffic situations in their living environment. On the other hand, it is possible that a group of people did not complete the survey because they are not interested in the topic. Maybe these are the hard-drivers who generally do not keep to the speed limit and do not experience inconvenience from other fast road users.

Besides, the survey was distributed among employees of Goudappel Coffeng and some municipalities. For some of these people, the field of expertise is road design. These people probably have an above-average amount of knowledge about road design and the associated speeds. The answers of these respondents will therefore probably be less representative than the answers of people with less knowledge about road design.

To persuade people to take part in the survey and to complete it, it was decided to raffle off 5 vouchers worth 25 euros among participants who wanted to enter the raffle at the end of the survey. However, this small price could also have an influence, as people who need the money might be more inclined to complete the survey. However, given the limited amount of the reward and the limited number of rewards, the influence has been estimated to be very limited.

Based on the characteristics of the respondents who completed the survey, more information about the representativeness of the sample is described in section 6.2.

# 6 Data analysis

This chapter describes the data preparation and the first part of the data analysis. Section 6.1 describes the collection of road and environment characteristics. Next, the collection of the survey data and the representativeness of these data is discussed (section 6.2). Finally, several speed analyses are presented. The speeds were analysed on all roads combined (section 6.4) as well as per road (section 6.4). Subsequently, in chapter 7 the most important results are presented: the influence of road and environment characteristics on speed.

## 6.1 Collection road and environment characteristics

Various types of data have been collected as input for the data analysis. The results of the survey form an important part of these data. Based on the given speeds of the respondents, the credibility has been quantified per road. Besides, additional personal characteristics were examined to investigate the influence of certain characteristics on the given speeds. However, data from the road and road environment are also necessary to be able to determine which characteristics (and to what extent) contribute to credible road design.

Therefore, a list of characteristics has been drawn up, mainly based on the literature review described in chapter 3. When determining the relevant characteristics, it was important to keep the type of road in mind. Many studies described in the literature review related to speed limits higher than 30 km/h. However, some properties may be less applicable on 30 km/h roads, such as the number of lanes. On the other hand, properties such as parking may be important for 30 km/h roads, while this is not the case for some other road types with higher speed limits. Therefore, the characteristics are specifically established for 30 km/h roads. The characteristics can be divided into three different groups:

- Road characteristics: characteristics of the road itself, e.g. type of pavement
- Dynamic characteristics: characteristics that can change with time, such as the presence of other traffic
- Road environment characteristics: characteristics of the road environment, such as the height of buildings next to the road

To determine the influence of road and environmental characteristics on credibility, the 27 photos of the 30 km/h roads were assessed on the various characteristics. Appendix B gives a complete overview of the characteristics and categories with descriptions that were initially collected. However, some characteristics were not included in the data analysis due to a very skewed assessment of the observations. For other characteristics, this led to the merging of several categories to increase the number of observations per category. The final remaining characteristics and corresponding categories are shown in Table 12.

*Table 12: Road characteristics and categories*

| Characteristic | Categories |
|---|---|
| Road width | [m] |
| Lane width | [m] |
| Pavement | Grey asphalt / clinkers / otherwise |
| Road marking | Yes/no |
| Driving direction separation | Yes/no |
| Speed decelerators | Yes/no |
| Location cyclists | Roadway / bicycle (suggestion) lane / separated bike path |
| Other traffic | Yes/no |
| Parked cars | Yes/no |
| Trees | Yes/no |
| Tree density | Small/large |
| Hedges | Yes/no |
| Buildings | One side / two sides |
| Building density | Large / small |
| Distance to buildings | [m] |
| Type of environment | Shopping/ living / otherwise |
| Clarity of the situation | Clear /average or complex |

## 6.2 Survey data

In total 1,692 registered responded have been received (see Figure 12). However, as mentioned earlier, a relatively large proportion (447, 26%) of the surveys were not fully completed. Only the fully completed respondents were used for further analysis. If the number of respondents was low, the use of unfinished respondents might have been necessary. But due to the relatively high number of fully completed respondents, this was not the case.

Within the fully completed respondents, there was a small group of respondents without a driver's license. They did not answer the photo questions and were sent straight to the end of the survey. As a result, their answers were registered, but not usable. However, part of the data from respondents with a driving licence was also incomplete. These respondents were classified as invalid. For example, some respondents had not entered a valid age. Besides, a few dozen respondents had filled in no or very low mileage data. It is assumed that a certain number of kilometres per year must be driven to have sufficient driving experience and to be familiar with the situations in the photographs. If this is the case, it is assumed that respondents are better able to determine the speeds. This is why the data of respondents with mileage lower than 500 kilometres was not used for the analysis. Eventually, 1145 completed surveys were leftover that were used for the data analysis.

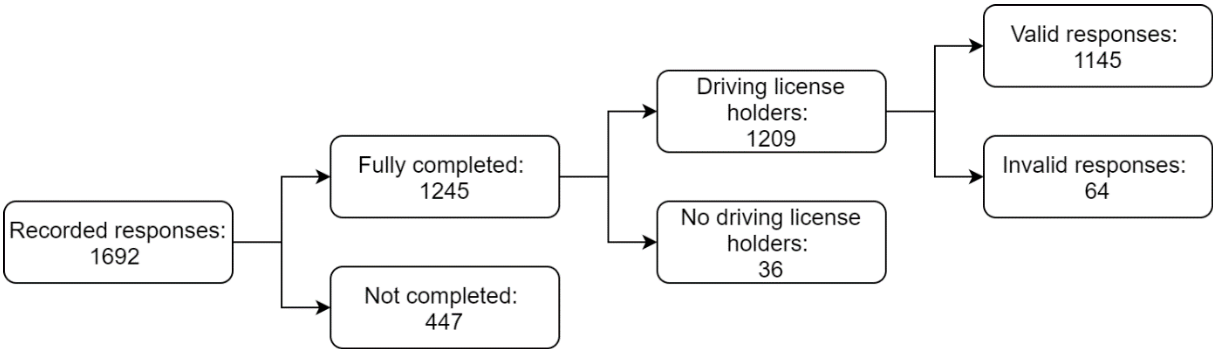


*Figure 12: Selection of the responses*

*Representativity of the sample*

The survey represents all persons in possession of a Dutch driving licence (driver's license B). At the beginning of 2019, almost 11.2 million people had this driving licence. This is 80 per cent of the population aged 17 years or older. Driving license possession is highest in the age groups between 30 and 70 years. Of these, 85 to 90 per cent have a driving license. This percentage is much lower among 17 to 30-year-olds and people older than 70 years. In all age groups, possession of a driving licence is higher among men than among women. Of Dutchmen aged 17 or older, 85 per cent have a driving licence and 75 per cent of women (CBS, 2019a).

To assess whether the sample of 1,445 respondents was representative of all driving licence holders in the Netherlands, the current distribution of driving licence possession among men and women for the various age groups was calculated and compared with the distribution within the sample. This was done based on men's and women's driving licence holdings per age category (CBS, 2019a) and the number of people with a driving licence per age category (CBS, 2019b). Both figures relate to 1 January 2019. It has been assumed that the number of men and women per age category is equal.

The intended distribution of driving licence possession is shown in Table 13. The distribution of respondents following from the sample has been juxtaposed for comparison purposes. Given the proportions between men and women, it is noticeable that men are over-represented. There are 5.8% more male respondents than targeted and thus 5.8% too few female respondents than targeted. In addition, it is interesting to note that most of the respondents are in the age category 40-49 or 50-59, both among men and women. Women aged 50-59 are even over-represented. Respondents in the lower age classes are slightly underrepresented, both among male and female respondents.

In comparison with the national CBS figures, there is some deviation between both age and gender distributions of driving licence holders. However, the respondents were not specifically targeted to obtain a representative sample, but anyone who read the message about the survey could participate. Therefore, the distribution within the sample is considered reasonably representative as the differences within the age classes are at most a few percentage points.

*Table 13: Number of respondents by age group, intended distribution of driving licence holders and realised sample distribution. Positive differences greater than 1 per cent are marked red and negative differences less than 1 per cent are marked blue.*

| **Age group** | **Men** | | | | **Women** | | | | **Total** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *#* | *Sample (%)* | *Desired (%)* | *Difference (%)* | *#* | *Sample (%)* | *Desired (%)* | *Difference (%)* | *#* | *%* |
| 16 - 17 | 0 | 0 | 0.1 | -0.1 | 0 | 0 | 0.1 | -0.1 | 0 | 0 |
| 18 - 19 | 3 | 0.3 | 0.9 | -0.6 | 3 | 0.3 | 0.9 | -0.6 | 6 | 0.5 |
| 20 - 24 | 25 | 2.2 | 3.4 | -1.2 | 12 | 1.0 | 3.3 | -2.3 | 37 | 3.2 |
| 25 - 29 | 36 | 3.1 | 4.0 | -0.9 | 35 | 3.1 | 3.9 | -0.8 | 71 | 6.2 |
| 30 - 39 | 101 | 8.8 | 8.1 | +0.7 | 76 | 6.6 | 7.7 | -1.1 | 177 | 15.5 |
| 40 - 49 | 131 | 11.4 | 9.2 | +2.2 | 115 | 10.0 | 8.7 | +1.3 | 246 | 21.5 |
| 50 - 59 | 151 | 13.2 | 10.4 | +2.8 | 146 | 12.8 | 9.6 | +3.2 | 297 | 25.9 |
| 60 - 64 | 91 | 7.9 | 4.5 | +3.4 | 46 | 4.0 | 4.0 | 0 | 137 | 12.0 |
| 65 - 69 | 74 | 6.5 | 4.1 | +2.4 | 20 | 1.7 | 3.5 | -1.8 | 94 | 8.2 |
| 70+ | 62 | 5.4 | 8.3 | -2.9 | 18 | 1.6 | 5.1 | -3.5 | 80 | 7.0 |
| **Total:** | **674** | **58.9** | **53.1** | **+5.8** | **471** | **41.1** | **46.9** | **-5.8** | **1145** | **100** |

## 6.3 Overview speeds

For all 27 roads with a speed limit of 30 km/h, the average preferred speed was 38.34 km/h (see Table 14). Respondents, therefore, indicated that they wanted to drive more than 8 km/h faster than the limit. The estimated limit was even higher with an average of 39.17 km/h. The average measured speed is also shown in the table. This value is lower at 33.42 km/h. This speed is based on the V85 speeds of the roads, so the majority of the actual measured speeds are below this speed.

It is explainable that the measured speed is lower than the preferred speed. This is because the measured speed was measured during normal road conditions, so in general with the presence of other traffic. However, other road users can influence the speed very much, it will mostly decrease during the presence of other traffic. The preferred speed was determined by using photos of roads on which deliberately no or very little other traffic was visible. In this way, it was easier to determine the influence of road and surrounding characteristics on speed, the presence of other traffic could be disruptive. In that respect, it is explainable that the measured speed is lower than the preferred speed. There may also be differences between the road section from which the speed was measured and the photograph. A road section can be several tens of meters long, while only a limited part of the road section is visible in the photo. Because of this, speed bumps in a road segment, for example, may not be visible in the photo, while they are in the road segment and affect the measured speed.

*Table 14 Speeds all roads*

| | **Preferred speed limit** | **Estimated limit** | **Measured speed** |
|---|---|---|---|
| *Average* | 38.34 | 39.17 | 33.42 |
| *Standard deviation* | 7.00 | 6.71 | 6.61 |

Averaged over all roads, the estimated limit is above preferred speed. However, it was perhaps expected that the preferred speed will be higher than the estimated limit. This is because on many 30 km/h roads the speed is higher than the limit. When people are aware of the speed limit, they know that they consciously or unconsciously drive faster than the limit. However, the speed limit is often not correctly estimated, making the preferred speed lower on average. The tendency to give socially desirable answers can also play a role (see the discussion in chapter 9).

To further investigate the relationship between the preferred speed and the estimated limit, the average of all preferred speeds was calculated for each estimated limit. For example, for the 30km/h limit, this means that all responses from respondents with an estimated limit of 30km/h were used. The average of all preferred speeds given at this estimated limit has been calculated. The results per speed limit are shown in Table 15.

*Table 15 Average speed per estimated limit*

| Estimated speed limit | Average preferred speed (km/h) | Standard deviation (km/h) |
|---|---|---|
| 15 km/h | 19.2 | 6.7 |
| 30 km/h | 32.0 | 6.2 |
| 50 km/h | 45.0 | 7.2 |
| 60 km/h | 55.8 | 8.2 |

The table shows that for the lower speed limits of 15 km/h and 30 km/h the corresponding preferred speed is higher than the limit. For the higher speed limits of 50 km/h and 60 km/h, this is just the other way around and the average preferred speed is on average below the estimated speed limit. For the lower speed limits, respondents seem to be able to afford to drive faster than the limit. In some cases, the limit may not be credible enough on these roads. For the higher speed limits, on the other hand, respondents are more careful with their speed, which is on average about 5 km/h below the estimated limit. In all cases it concerns 30 km/h roads, so an estimated limit of 50 km/h or 60 km/h was always wrong. It is therefore interesting that for these respondents the limit was overestimated (30 km/h was not credible), but that the road did not invite them to drive at least the speed of the limit. However, there may be a partial artificial selection effect. Respondents thought they saw mainly 30 km/h roads (this was also the case), so even on non-30 km/h roads (according to the respondents), the tendency to respond in the direction of 30 km/h may be greater. If the 30 km/h roads were part of a survey in which, for example, mainly 50 km/h roads were shown, then the given speeds for the 30 km/h roads were probably higher in comparison to the current situation.

The differences between speed limits also explain why, on average over all given speeds, the estimated limit is higher than the preferred speed (see Table 14). The higher estimated limit is thus mainly caused by the preferred speeds given at higher estimated limits of 50 km/h and 60 km/h. For the lower speed limits, the preferred speed is higher than the estimated limit.

The correlation between the preferred speed and the estimated limit was investigated via a Pearson product-moment correlation. As can be expected, there is a significant, very high positive correlation between the preferred speed limit and estimated speed limit ($r$ = 0.986; $p$ = 0.000; $N$ = 27), see Figure 13. This correlation shows that when the preferred speed limit deviates more from the limit, the estimated speed limit also deviates more from the limit in the same direction.

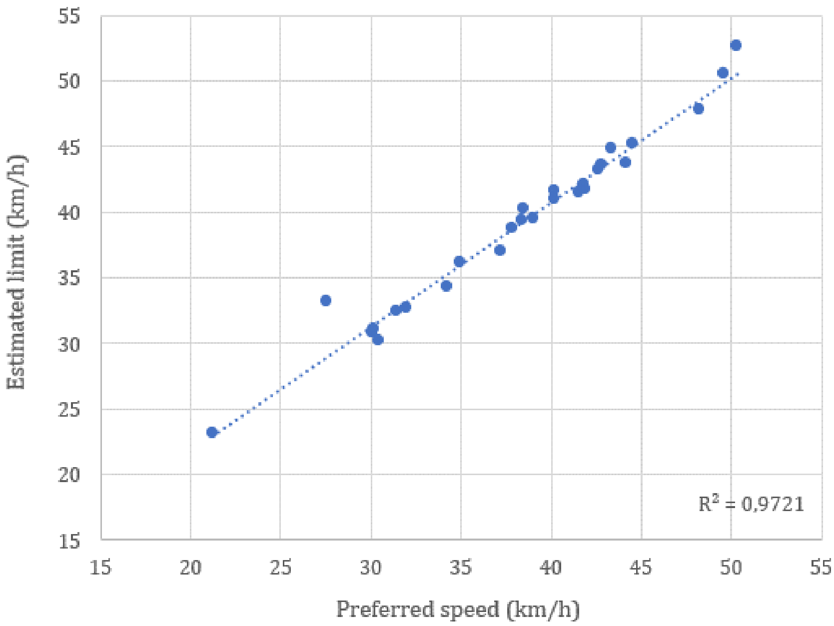


*Figure 13: Correlation between preferred speed and estimated limit.*

About the 30 km/h roads, there was also a positive correlation between the preferred speed and measured speed (HERE speeds from the 'Het Nieuwe 30' study, but to a lesser extent ($r$ = 0.551; $p$ = 0.003; $N$ = 27), see Figure 14. This correlation could be assessed as 'moderate', there is some correlation between the preferred speed and measured speed. Some correlation was also expected. If there would be no correlation, then the chosen method (estimating speed based on pictures) would probably not be suitable. The fact that this correlation is not very strong can also be explained. As described earlier, most photos contain little or no other traffic, probably in contrast to the situation during the measurements. Also, the measurements are related to an entire section of the road, while the photo only shows a limited part of the road. Therefore, these two speeds can be different.

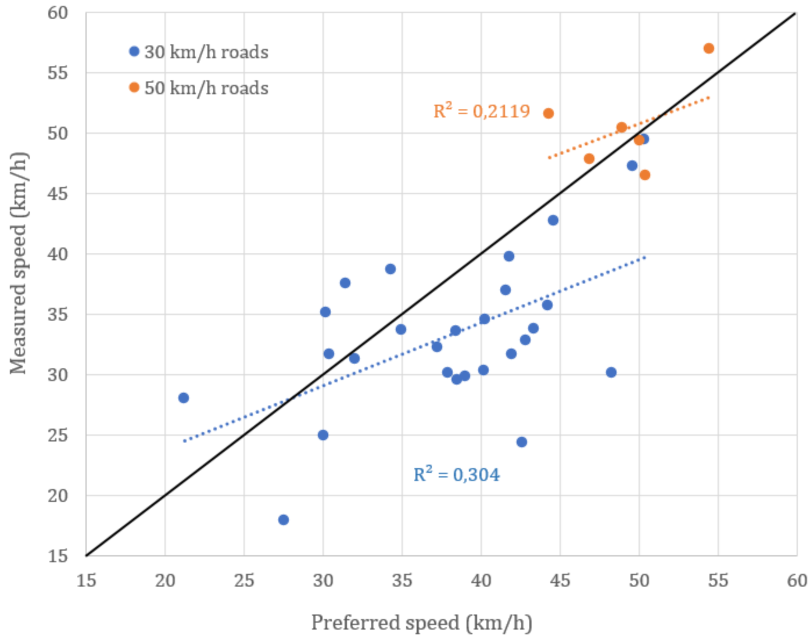


*Figure 14: Correlation between preferred speed and measured speed 30 km/h and 50 km/h roads. Points below the black line indicate that the preferred speed is higher than the measured speed.*

The blue dots in Figure 14 indicate per road the preferred speed and the measured V85 speed. If these points are on the black line, this indicates that the preferred speed is equal to the measured speed. Points above the black line are roads where the preferred speed is lower than the measured speed. At points below the black line, the preferred speed is higher than the measured speed. Also, the general trend of the relation is shown with a dotted blue line.

Since it is clear that most blue points are below the black line, it can be concluded that for most roads the preferred speed is higher than the measured speed. For all roads with a preferred speed above 35 km/h, this is the case. Roads with a preferred speed lower than 35 km/h show a more diverse picture with roads where the preferred speed is both higher and lower than the V85 speed. The trend line reveals a tipping point at 28 km/h. From that preferred speed, the speed is generally higher than the V85 speed.

The 50 km/h roads from the survey are also shown in Figure 14. In contrast to the 30 km/h roads, in the majority of these roads, the measured speed was above the preferred speed. For two roads, the measured speed is below the preferred speed. However, the number of roads is too low to give reliable results about the correlation between the preferred speed and the measured speed on 50 km/h roads. The two 15 km/h roads could not be shown in the figure, because no measured speed of these roads was known.

Figure 15 shows the average preferred speed and measured speed for each 30 km/h road, illustrating the differences. As shown in Figure 14, the preferred speed for most roads is higher than the measured speed. There are some roads where this difference is very large, such as road 2 and road 5. On some other roads, the differences are also relatively large, such as roads 16, 26, and 27. A possible explanation for these differences in speed is a difference between the location of the road section belonging to the speed measurement and the location or direction of the picture. For example, it is possible that there is a speed bump within the road section of the speed measurement, but that this speed bump is not visible in the picture. Sometimes a road section is tens of meters long or the photo can show the other direction of the road, away from the speed bump.

Moreover, there is a difference in the way in which both speeds are determined. The measured speed indicates the V85, so 85% of the measured speeds are below this speed. The preferred speed is an average and therefore determined differently. However, determining the V85 for the preferred speed leads to a

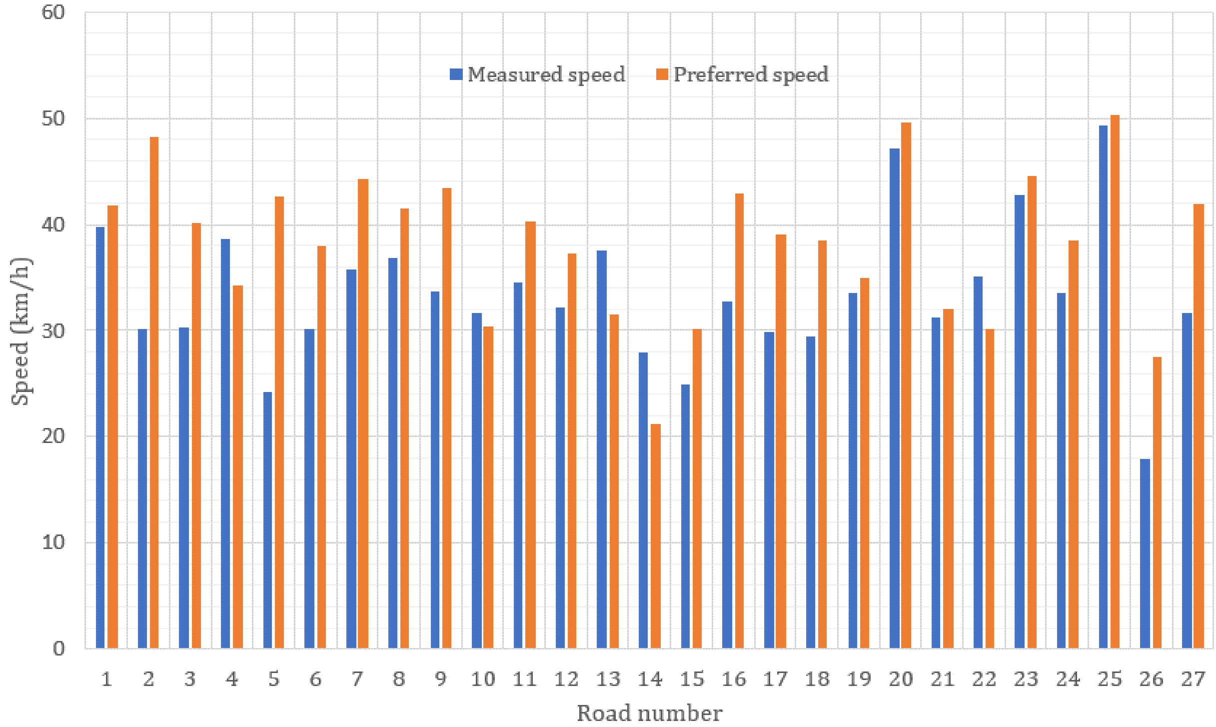


*Figure 15: Measured speed and average preferred speed per road*

wrong image of this speed. The majority of the respondents chose a speed close to 30 km/h or 50 km/h (see section 6.4). This leads to the fact that when all given preferred speeds are sorted by size, the V85 is often in the vicinity of 50 km/h since the last part of the answers is around this value. Therefore, the V85 gives a distorted image is not suitable to indicate the preferred speed.

All in all, there are differences between the preferred speed indicated by respondents and the measured speed. However, these differences are unavoidable due to the different ways of measuring and processing the data. It was also not the aim to equalize both speeds as much as possible.

Figure 16 shows the effect of the estimated limit on speed by plotting per road the percentage of people who opted for a limit of 30 km/h against the average preferred speed of the road. This percentage and the speed are strongly correlated ($r$ = -0.866; $p$ = 0.000; $N$ = 27). Only road number 14 deviates from the pattern that follows from the other roads. Without this road, the correlation would have been even higher. From the graph, it can

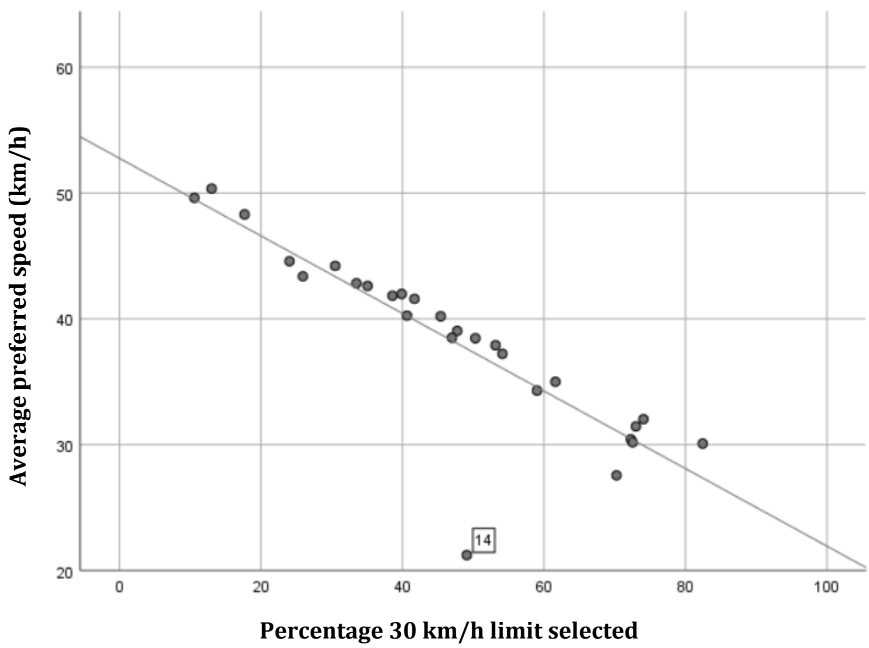


*Figure 16: Correlation between preferred speed and percentage 30 km/h limit selected*

be concluded that when 70% of people choose 30 km/h as the limit, the average preferred speed is about 30 km/h. And when 40% of people choose 30 km/h as the limit, the average preferred speed is about 40 km/h. All in all, given the high correlation, it has little added value to do further research into the influence of characteristics on the percentage of people who have chosen a 30 km/h limit. The use of the preferred speed will suffice and will give comparable results.

## 6.4 Speeds per road

To illustrate the differences between roads, Table 16 shows the averages and standard deviations of the speeds per road. The numbering of the roads corresponds to the numbering of the photographs in Appendix C. This appendix shows an overview per road in which the distribution of selected speed limits and selected preferred speeds are shown in graphs. These graphs provide more insight into the formation of the averages per road in Table 16. Besides, more information on the spread of the preferred speed is given in Appendix D using box plots. These graphs clearly show the distribution in the preferred speeds per road. On some roads, 50 per cent of the answers are given within a range of 5 km/h, while on other roads this range is 20 km/h.

The figures in the table show that there are large differences between the roads. On some roads (road 2, 20 and 25), drivers indicate that they drive about 20 km/h faster than the limit, while there is also a road where respondents indicate that they drive almost 9 km/h slower than the limit (road 14). Also, there are some roads (roads 10, 13, 15 and 22) where the preferred speed is almost equal to the limit. However, for most roads, there is a relatively large positive difference between the preferred speed and the limit. On about half of the roads, this difference is even 10 km/h or more.

It is remarkable that on almost all roads the difference between the preferred speed and the estimated limit is very small. On the majority of the roads, this difference is less than 1 km/h. Only on road 26, there is a relatively large difference between both speeds of 5.5 km/h. Besides, the difference is often negative, which means that the indicated preferred speed is on average lower than the estimated limit.

The standard deviations are also large at individual road level. Drivers, therefore, differ a lot, both in the speed they want to drive and in the estimation of the local limit.

For the sake of completeness, averages are also given for roads with limits of 15 km/h and 50 km/h (see Table 17). Again, the numbering corresponds to the numbering used in Appendix C. But as described earlier, these roads have not been used in further analyses.

Concerning the 50 km/h roads, it is noteworthy that both the preferred speed and the estimated speed limit are much closer to the real limit than was the case for the 30 km/h roads.

*Table 16: Averages and standard deviations (SD) of speed differences per road (in km/h)*

| Road | Difference between preferred speed and limit | | Difference between estimated limit and limit | | Difference between pref. speed and est. limit |
|---|---|---|---|---|---|
| | *Average* | *SD* | *Average* | *SD* | |
| 1 | 11.8 | 9.8 | 12.1 | 10.2 | -0.3 |
| 2 | 18.3 | 8.7 | 17.7 | 8.9 | 0.6 |
| 3 | 10.2 | 10.1 | 11.0 | 10.5 | -0.8 |
| 4 | 4.3 | 10.9 | 4.2 | 11.5 | 0.1 |
| 5 | 12.6 | 9.8 | 13.2 | 10.0 | -0.6 |
| 6 | 7.9 | 9.9 | 8.7 | 10.5 | -0.8 |
| 7 | 14.2 | 10.1 | 13.7 | 10.3 | 0.5 |
| 8 | 11.6 | 9.9 | 11.5 | 10.2 | 0.1 |
| 9 | 13.4 | 9.0 | 14.8 | 8.9 | -1.5 |
| 10 | 0.4 | 9.0 | 0.2 | 9.2 | 0.2 |
| 11 | 10.3 | 9.5 | 11.5 | 10.2 | -1.3 |
| 12 | 7.2 | 10.7 | 6.9 | 11.2 | 0.3 |
| 13 | 1.5 | 8.3 | 2.4 | 9.3 | -1.0 |
| 14 | -8.8 | 7.9 | -6.8 | 8.5 | -1.9 |
| 15 | 0.1 | 7.5 | 0.8 | 7.5 | -0.7 |
| 16 | 12.8 | 10.7 | 13.5 | 10.4 | -0.7 |
| 17 | 9.0 | 11.4 | 9.5 | 11.2 | -0.5 |
| 18 | 8.5 | 9.4 | 10.2 | 10.3 | -1.7 |
| 19 | 5.0 | 9.5 | 6.1 | 10.4 | -1.1 |
| 20 | 19.6 | 9.1 | 20.5 | 8.3 | -0.9 |
| 21 | 2.0 | 8.3 | 2.7 | 9.2 | -0.7 |
| 22 | 0.2 | 9.0 | 1.0 | 9.3 | -0.8 |
| 23 | 14.6 | 8.7 | 15.2 | 9.0 | -0.6 |
| 24 | 8.5 | 9.4 | 9.4 | 10.5 | -0.9 |
| 25 | 20.3 | 11.6 | 22.6 | 10.5 | -2.3 |
| 26 | -2.4 | 8.0 | 3.1 | 9.8 | -5.5 |
| 27 | 12.0 | 10.2 | 11.7 | 10.6 | 0.3 |

However, also for these roads, the differences between the preferred speed and estimated speed limit are small. About the two 15 km/h roads, there is a road (34) where the indicated speeds are close to the limit and a road (35) where the indicated speeds are further away from the limit.

*Table 17: Averages and standard deviations (SD) of speed differences per road (in km/h) with speed limit 15 km/h or 50 km/h*

| **Road** | **Speed limit (km/h)** | **Difference between preferred speed and limit** | | **Difference between estimated limit and limit** | | **Difference between pref. speed and est. limit** |
|---|---|---|---|---|---|---|
| | | *Average* | *SD* | *Average* | *SD* | |
| 28 | 50 | 0.4 | 7.7 | -0.6 | 6.5 | 1.0 |
| 29 | 50 | -1.0 | 6.8 | -1.4 | 6.0 | 0.4 |
| 30 | 50 | -3.1 | 8.1 | -3.2 | 7.9 | 0.1 |
| 31 | 50 | 0.1 | 8.0 | -0.1 | 7.0 | 0.2 |
| 32 | 50 | 4.4 | 9.6 | 3.6 | 7.9 | 0.8 |
| 33 | 50 | -5.7 | 9.3 | -5.1 | 9.0 | -0.6 |
| 34 | 15 | 1.8 | 6.1 | 2.7 | 5.9 | -0.8 |
| 35 | 15 | 7.0 | 8.2 | 7.7 | 8.7 | -0.6 |

All in all, in many cases the respondents had difficulty determining the correct limit on 30 km/h roads. There was no uniform pattern in the roads so that a limit of 30 km/h was recognized. One of the probable reasons for this is that the roads were not chosen randomly, but a search was made for specific types of roads (see section 5.3.1). There was a lot of difference between the respondents' answers. The 50 km/h roads were easier to distinguish. On these roads, the estimated limits are close to the actual limit.

### *Differences between respondents*

The results described earlier show that in many cases the 30 km/h limit was not correctly determined. The analysis of estimated speed limits on 30 km/h roads shows that only 7 out of 1,145 respondents had filled in all the limits correctly. Besides, 613 respondents (53.5%) had estimated less than half of the limits correctly. Because it appeared that the preferred speed and estimated limit were very correlated, the correct estimation of the limit probably also depends on the height of the preferred speed. To gain insight into this, the respondents were divided into three groups:

1. Good estimators: respondents who had answered more than 65% of the questions about the 30 km/h limit correctly (206 respondents, 18%).
2. Average estimators: respondents who had answered 35-65% of the questions about the 30 km/h limit correctly (605 respondents, 53%).
3. Bad estimators: respondents who had answered less than 35% of the questions about the 30 km/h limit correctly (334 respondents, 29%).

Table 18 shows the average differences between the preferred speed and limit for the various groups. There are large differences between the groups. Whereas for the 'good estimators' the preferred speed differs on average 4.5 km/h from the limit, for the 'average estimators' this is 7.6 km/h and for the 'bad estimators' even 12.0 km/h. However, this outcome is to be expected, since it has been shown before that the preferred speed and estimated limit are very much related. In general, this means that respondents who are better able to determine the correct limit also have lower preferred speeds that are closer to the limit.

*Table 18: Averages and standard deviations of differences between preferred speed and limit by respondent groups*

| **Group** | **Difference between preferred speed and limit** | |
|---|---|---|
| | *Average* | *Standard deviation* |
| *Good estimators (> 65%, n = 206)* | 4.5 | 4.5 |
| *Average estimators (35-65%, n = 605)* | 7.6 | 4.7 |
| *Bad estimators (< 35%, n = 334)* | 12.0 | 5.1 |
| *Total (n = 1145)* | 8.4 | 5.4 |

*The relation between preferred speed and limit*

The previously described results consistently show a strong correlation between the preferred speed and estimated limit. However, the data do not give a clear reason for this relationship. Respondents may have adjusted the estimate of the limit to their preferred speed. On the other hand, it is also possible that the preferred speed has been adjusted to the estimated limit. It is difficult to investigate this correlation. However, it is possible to determine to some extent what the influence is of the fact that after asking for the preferred speed, respondents are asked for the limit. It is possible that respondents immediately think of a limit when they see a photo and adjust their preferred speed accordingly. In this way, a strong correlation can be found between the limit and the preferred speed.

To what extent this may be the case has been briefly examined by analysing the answers of the example question. A picture of a 50 km/h road and the two speed questions were given as examples to explain the questions to the respondents. It was also possible to answer the questions, so respondents could test how this works. The fact that the limit was also asked was only mentioned after the question about the preferred speed. Respondents were therefore not aware of the limit question when they gave their first preference speed. That is why the answers to this question give some insight into the relationship between the order of the questions and the final answers.

The average speed of the road at the example question was 46.5 km/h. The average given limit was 46.7 km/h. Although it is only based on one question, it may be deduced from this that asking a question about the limit after the preferred speed has little influence on the given answers. In the example question, respondents were not aware of this and the same pattern can be seen in the answers. The preferred speed is lower than the limit and both values are close together.

*Influence estimated limit on preferred speed*

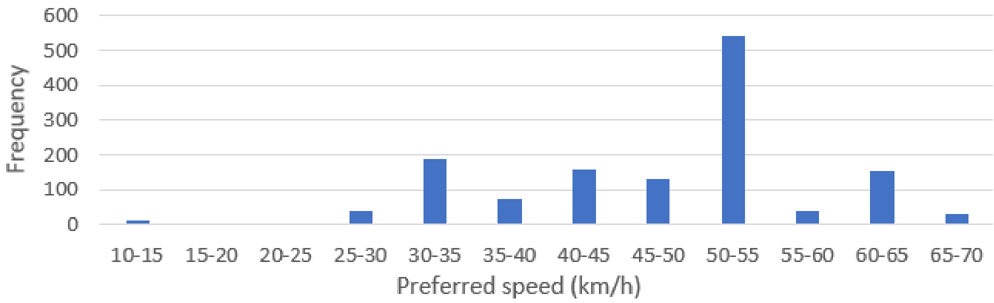


*Figure 17: Answers preferred speed example question survey*

Likely, the preferred speed is unconsciously influenced by the limit that respondents have in their heads. Figure 17 shows the frequencies of several answer classes of the preferred speed, based on the answers of the first example question. What is striking is that the answers between 30-35 and 50-55 are given the most. This is not only the case for this first example question but almost all roads (see Appendix C). For almost all roads, answers between 30-35 and 50-55 km/h are given most often. Exceptions are some roads where according to the respondents, the road has a limit of 30 km/h or 50 km/h. Respondents, therefore, seem to (unconsciously) adjust their preferred speed to the available limits. The question is to what extent this is, in reality, the case.

Therefore, previous measurements of speed on similar roads have been used to explore the distribution in speeds. These roads do not originate from the survey and therefore no preferred speeds are known. Similar roads were used because no data on speed distribution was (yet) available for the roads from the survey, but only the V85 value. From the measurements (see Figure 18 and Figure 19) it appears that both roads have a peak at a certain speed class, which was measured most often. Subsequently, a decrease in frequencies is visible on both sides. This pattern does not correspond with the histograms of the preferred speed. The peaks were always around the speed limits (30-35 and 50-55 km/h) and not, for example, at 40-45 km/h, as shown in Figure 18.

The preferred speed chosen by the respondents thus seems to have been strongly influenced by the possible speed limits, and the choice of a certain limit is based on the characteristics of the road and its surroundings. Based on the chosen limit, the preferred speed seems to be determined, sometimes with a small deviation from the limit. However, when driving on the road, the speed limit seems to have a less strong influence on the speed. Whether drivers are familiar with the limit or not, they do not adjust their speed so that it is close to the limit and seem to keep their logical speed. This speed may be lower than the limit, for example, because drivers have to drive more slowly due to congestion. Or the speed may be higher than the limit if drivers are tempted to drive faster while driving. Therefore, a speed limit has a limited influence on speed. Characteristics of the road and its surroundings and other road users probably have an important influence on the speed. That is why it is important to design the road in such a way that the characteristics result in the speed limit being credible and being exceeded less often.

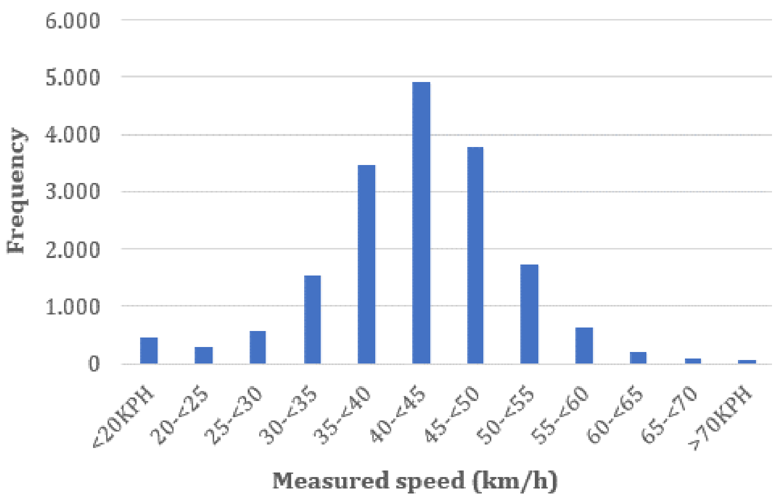


*Figure 18: Speed distribution 'Sportlaan' (Schoorl) based on measurements 11 April – 22 May 2019*

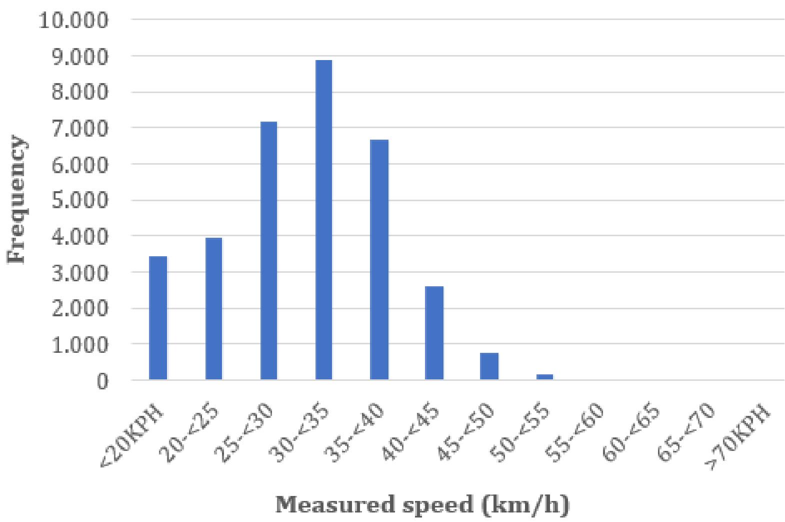


*Figure 19: Speed distribution 'Laanweg' (Schoorl) based on measurements 11 April – 22 May 2019*

# 7 Results

In sections 6.3 and 6.4, the speed of all roads together and per road was examined. In this chapter, the effect of the road and environmental characteristics of the roads on the speed is investigated. This analysis consists of two steps. First, the individual effect of each characteristic on speed is analysed. Concerning the categorical variables (non-measurable properties, such as type of pavement), the difference between the averages of the categories within a characteristic has been determined (section 7.1). Regarding the continuous variables (measurable properties, such as lane width), the correlation between the variable and the speed has been determined (section 7.2).

Next, all characteristics with influence on speed are taken together to determine the individual effect per characteristic again, but then taking the combination other characteristics into account (by using regression analysis), see section 7.3. Also, the influence of personal characteristics on speed was investigated (section 7.4).

## 7.1 Non-measurable characteristics

The effect of non-measurable characteristics on speed was determined by calculating the average speed for the different categories within a characteristic and then determining to what extent these speeds differ from each other. For example, the average speed was determined for all roads without and with markings on the road. Subsequently, it was investigated whether the difference between these averages is statistically significant. In this case, it can be said with 95% certainty that the averages differ from each other and that the chance of an accidental difference is very small.

The independent samples T-test was used with the statistical computer program SPSS. This test compares the means between two unrelated groups on the same continuous, dependent variable. A condition for the use of this test is that the samples are independent of each other. This was the case, the samples contain different roads that did not influence each other. Also, the dependent variable has to be measured at an interval or ratio level. This is also the case, the speed is measured on a continuous scale in km/h. Another condition is that if the sample contains less than 30 observations, the dependent variable must be normally distributed. The sample contains less than 30 observations (27 roads), so it has been tested whether the dependent variables are normally distributed. This was done using the Shapiro-Wilk test in SPSS for the different categories of characteristics. In all cases, the data was found to be normally distributed. Besides, the independent samples T-test is only suitable for comparing the averages of two samples. If more than two samples are used, a different test must be used or multiple samples must be combined.

The data met the above conditions, so it was possible to use the independent samples t-test. Since within some categories of the characteristics there were only a limited number of observations, several categories with a comparable average speed were merged to obtain better results. For example, the characteristic 'presence parked cars' was divided into two categories (parked cars/no parked cars) instead of the original four categories (no/left + right/left parked cars).

The final result of the test is statistical significance, represented by a number between 0 and 1. This number indicates the probability that the null hypothesis is true, in this case, the probability that there is no difference between the averages. For example, a statistical significance of 0.05 indicates that the probability that the averages do not differ from each other is 5%. So the probability that the averages do differ from each other is relatively high at 95%.

Appendix E shows for each characteristic the distribution of the observations about speed and categories. The average speed and the number of observations are also given per category (sometimes combined). Besides, the significance of the difference between the averages of both categories is shown. For some characteristics there were too few observations per category and/or it was not possible to combine several categories. This concerns the following characteristics: pedestrian/cyclist crossing visible, intersection visible, location pedestrians and distance hedges/green. These characteristics were therefore not usable and have not been included in Appendix E and further analyses.

Table 19 shows the characteristics with the most statistically significant differences. The p-values smaller than 0.010 are dark green marked, indicating a very significant difference. Light green marked values are those 0.01-0.05, indicating a significant difference. Marked yellow are the values 0.05-0.1, indicating a moderately significant relationship. Also, some characteristics with a p-value larger but close to 0.1 have been added to the table (red marked). These characteristics have a weak significant relationship. For each characteristic, the average speeds per category are also shown and a possible explanation is given for the differences between the averages.

*Table 19: Characteristics with the most statistically significant differences between averages*

| **Characteristic** | **Category** | **Avg. speed (km/h)** | **Sig.** |
|---|---|---|---|
| Main function environment | Shopping | 31 | 0.001*** |
| | Otherwise | 41 | |
| *On roads with shops, the average speed is about 10 km/h lower in comparison with other streets. One explanation for this is that in shopping streets there are often more objects and there is more information to process. Examples of objects are parked cars, parked cyclists and street furniture such as benches. There are also often other road users, such as cyclists and pedestrians. The presence of cyclists and pedestrians in the vicinity of the road generally reduces the speed because the risk of a dangerous situation is estimated to be higher.* | | | |
| Clarity of the situation | Clear | 43 | 0.007*** |
| | Average/complex | 36 | |
| *The clarity of the situation was assessed mainly based on visibility in all directions, both forward and both sides. This view is influenced by the presence of objects such as parked cars and street furniture. An increase in the number of objects leads to a less clear view and therefore to a less clear overview of the situation. As a result, it is more difficult to recognise the danger in time and drivers tend to reduce their speed.* | | | |
| Building density | Contiguous | 35 | 0.014** |
| | Interruptions/freestanding | 41 | |
| *The difference between continuously present buildings and buildings with gaps or freestanding buildings is 6 km/h. An explanation for this is that buildings increase the cognitive load of people and the road environment is more closed when buildings are present. Many buildings along the road create a busy environment where more visual information is present. Therefore, drivers need to process more visual information.* | | | |
| Parked cars | Yes | 36 | 0.018** |
| | No | 42 | |
| *Parked cars provide a reduced overview of the road, a narrower (perception) of the roadway and an increase in possible danger when people enter/exit the car and enter/exit the road. This has led to a difference of 6 km/h between roads with or without parked cars.* | | | |
| Buildings | Both sides | 37 | 0.021** |
| | One side | 45 | |
| *In situations where buildings are only located on one side, the other side of the road is usually more open. If drivers have a wider view, they tend to drive faster. In this case, the difference between the two situations is 8 km/h.* | | | |
| Location cyclists | Roadway/separated path | 37 | 0.049** |
| | Bicycle (suggestion) lane | 42 | |
| *Although the locations of cyclists on the road and a separate bike path do not appear to be related to each other, the average speed was approximately the same in both situations. Therefore they have been taken together in one category. When cyclists have their lane, the speed is higher. Probably because in this case cyclists are separated from the lanes of cars to a greater extent, giving drivers more space and thus being able to drive faster. With the presence of bicycle lanes, car drivers experience less hindrance from cyclists limiting speed.* | | | |
| Other traffic | Yes | 36 | 0.071* |
| | No | 41 | |
| *The amount of other traffic on photos was deliberately limited. In this way, it was easier to measure the effect of road and environmental characteristics. Nevertheless, some photos showed other road users, both drivers, cyclists and pedestrians. Other traffic was most present in shopping streets and resulted in a 5 km/h lower speed.* | | | |
| Tree density | Small | 37 | 0.079* |
| | Large | 42 | |

| | | | |
|---|---|---|---|
| *Although it was expected that smaller trees lead to higher speeds than larger trees, just the opposite is the case. A possible explanation is that with larger trees the view to the sides next to the road is more blocked, resulting in less view of buildings and other objects. As a result, less potential danger could be perceived, resulting in a higher speed.* | | | |
| Trees | Yes | 40 | 0.084* |
| | No | 34 | |
| *It was expected trees reduce the average speed by increasing the cognitive load on drivers. They need to process an additional amount of information. However, it turns out that in general, the speed is higher when there are trees next to the road. A possible explanation for this is a correlation with other characteristics that do lead to higher speeds. An example is the distance to buildings, the larger the distance to buildings, the higher the speed. But a larger distance also leads to more space for trees. The same goes for the shape of the road. On straight roads, the speed is higher than on roads with many curves, but more trees may be placed next to straight roads.* | | | |
| Pavement | Grey asphalt | 42 | 0.133 |
| | Clinkers | 37 | |
| *Clinkers reduce driving comfort by increasing vibration and noise due to a less flat surface in comparison to asphalt. As a result, lower speeds are more likely to be perceived by drivers in comparison with grey asphalt.* | | | |
| Marking | Yes | 41 | 0.142 |
| | No | 37 | |
| *Marking is strongly related to the location of cyclists, as in almost all cases the marking consists of bicycle lanes. Marking in the middle of the road occurred only once on the roads investigated. Bicycle lanes lead to higher speeds as cyclists are more separated from cars, as a result of which drivers are less hindered by cyclists and have more space to drive faster.* | | | |
| Hedges | Yes | 38 | 0.161 |
| | No | 43 | |
| *The presence of hedges is slightly related to the presence of trees and their effect on speed can be explained in the same way. Hedgerows are probably more often present next to roads with a wider profile and larger distances from buildings, thus negating a possible delaying effect of the presence of hedges.* | | | |

Notably, many of the most significant differences relate to the characteristics of the environment. However, these characteristics are often difficult to adjust. For example, the character of an environment cannot simply be changed from a residential street to a shopping street, but this characteristic turns out to have a very strong influence on the speed. Also, the clarity of the situation has a great influence on speed. This characteristic is assessed based on the number of obstacles in the form of parked cars, street furniture, buildings and other objects on the photo. This characteristic is therefore determined by the objects present and can indirectly be influenced.

The presence and density of the buildings also have a strong influence on the speed, but both characteristics of the environment are difficult to adjust. Although the environmental characteristics are not easy to adjust, they can be used to determine in which streets 30 km/h are most suitable. The characteristics could be used to test whether a 30 km/h road fits into its surroundings. If the surrounding area largely meets the characteristics that have a positive influence on credibility, then it is probably also easier to implement new 30 km/h roads credibly.

Characteristics of the road that are relatively easy to influence during road design and have a significant influence on speed are the presence of parked cars and the location of cyclists. To a lesser extent, this applies to the type of pavement.

*Comparison with results 'Het Nieuwe 30'*

Although both surveys were conducted in different ways (the use of measured speeds or the use of respondents' preferred speeds), it is interesting to what extent the results match or differ. In the 'Het Nieuwe 30' study, too, the average of a category within a characteristic was calculated and it was determined whether the difference between the averages is significant. Table 20 shows all characteristics with a significant difference between the averages (p-value ≤ 0.05). Under each characteristic, the similarities and/or differences with the previously shown results in Table 19 are described. To make the distinction between the two studies clear, this study is always referred to as 'the regular study' and the study by Goudappel Coffeng and DTV Consultants is called 'Het Nieuwe 30' study.

*Table 20 Characteristics with statistically significant differences between averages from ‘Het Nieuwe 30’ study and comparison with previously described results of the regular study.*

| **Characteristic** | **Category** | **Avg. speed (km/h)** |
|---|---|---|
| Main function environment | Shopping | 32 |
| | Otherwise | 38 |
| *A similar difference between the two categories follows from the regular research. The presence of shops next to the road, therefore, seems to have a considerable influence on speed.* | | |
| Parked cars | No parking | 36 |
| | Both sides | 34 |
| *The difference in speed between the two categories (2 km/h) is limited compared to the previous results. However, in that case, it was about the difference between parked or no parked cars, now it is about the difference between no parked cars or cars parked on both sides. Moreover, the ‘Het Nieuwe 30’ study considered the possibility of parking and the regular study considered the actual presence of parked cars.* | | |
| Building height | Two layers or lower | 36 |
| | More than two layers | 33 |
| *Although the height of buildings was also investigated in regular research, no significant difference was found in the speed at different heights. However, a difference may occur if more photos with tall buildings are added. It is also possible that the height of buildings is experienced much more in reality, for example, because high buildings are partially not visible in photographs. In addition, higher buildings will probably lead to more traffic on the street, which will reduce the speed.* | | |
| Lampposts | No or standard | 37 |
| | Special lampposts | 32 |
| *In regular research, no distinction was made between different types of lampposts, as the number of observations per category would then become too small. However, the difference in speed was investigated if lampposts are or are not next to the road. No statistically significant difference was found between the averages.* | | |
| Pavement | Asphalt | 38 |
| | Clinkers | 32 |
| *The regular research shows a similar speed difference between both types of pavement. However, both speeds are at a lower level (about 5 km/h lower), presumably due to the influence of other road users which is limited in the regular research* | | |
| Location cyclists | Roadway | 33 |
| | Bicycle lane/separated path | 37 |
| *Also in the 'Het Nieuwe 30' research, there is a clear difference in speed between roads where cyclists do not have separate facilities and roads where cyclists have their lane. The fact that drivers are less hindered by cyclists seems to increase speed. However, also on roads where cyclists had separate paths, a higher speed was measured comparable to roads with bicycle lanes. This was not the case in the regular study, probably because certain other characteristics were often present on roads with separate bicycle lanes causing a decrease in speed.* | | |
| Load/unloading location | Yes | 31 |
| | No | 37 |
| *In the regular survey, no loading and unloading locations were visible on the photos, so no comparison is possible. However, the characteristic does seem to have a considerable influence on the speed given the difference between the averages. However, it is questionable to what extent this is true for the whole road, as the loading/unloading site is only present at one location. Maybe there is a strong correlation with shopping streets where there are shops that need to be supplied.* | | |
| Parking with many changes | Yes | 31 |
| | No | 37 |
| *This characteristic has not been specifically investigated in regular research. Presumably, the characteristic has a strong correlation with shopping streets, as there are many parking changes in these streets.* | | |
| Driving direction separation | Yes | 38 |
| | No | 34 |

<table>
<tr><td colspan="3">The results of the regular survey show hardly any difference in speed between the presence and absence of separate driving directions. Different definitions may have been used for separation of driving directions. Within the regular study, another type of (overridable) surfacing was also seen as a separation of driving directions in addition to physical separation. Also, there were only three roads with a physical separation, so it may be a coincidence that there is no difference in speed.</td></tr>
<tr><td rowspan="2">Large trees/hedges/high buildings/parked cars/high lampposts</td><td>Yes</td><td>36</td></tr>
<tr><td>No</td><td>30</td></tr>
<tr><td colspan="3">Although the combination of characteristics has not been investigated within the regular research, the individual characteristics do partially show the same patterns. The results of the regular research show higher speeds in combination with trees, large trees and hedges. This pattern is in line with these results.</td></tr>
<tr><td rowspan="2">Right of way</td><td>Priority road</td><td>39</td></tr>
<tr><td>Equivalent</td><td>33</td></tr>
<tr><td colspan="3">This characteristic has not been investigated in the regular research, so a comparison is not possible. On the pictures hardly any intersections were visible. Moreover, traffic signs about priority rules are more difficult to recognize on the photographs, which makes this characteristic less suitable for testing on the basis of photographs.</td></tr>
<tr><td rowspan="2">Parking type</td><td>On road/parallel</td><td>35</td></tr>
<tr><td>At right angles or at an angle</td><td>33</td></tr>
<tr><td colspan="3">Due to the limited number of roads, no distinction was made between parking methods in the regular investigation. The difference between the two modes seems small. Probably the speed is slightly higher with parallel parking, because this parking method requires fewer actions to park. This makes it easier to park and other traffic is less disturbed.</td></tr>
</table>

Given the similarities and differences between the two studies, some conclusions can be drawn. Some characteristics show to have a significant influence on the speed in both the regular and the 'Het Nieuwe 30' research. Examples are shopping streets, parked cars, type of pavement, location of cyclists and the presence of trees and hedges. Since these characteristics appear in both studies as characteristics with influence on speed, it is plausible that this is the case.

However, several characteristics seem to have a significant influence on speed in one study and not in the other. For example, within 'Het Nieuwe 30' study, building height, lamp posts and driving direction separation seem to influence the speed, but this influence did not appear in the regular study. A possible explanation for this is the different ways in which the speed was determined. It is also possible that, due to coincidence, no significant influence of certain characteristics was found within the regular investigation. Because of the limited number of roads, the number of observations per characteristic was sometimes limited. This increases the chance that due to coincidence there seems to be no influence on speed, while in reality there may be.

Some characteristics were only investigated in one of the two studies. Examples are loading/unloading locations and right of way. This can partly be explained by the fact that both investigations determined the speed in different ways. For the regular study, photos have been used, therefore the number of characteristics that can be deduced is limited. For the 'Het Nieuwe 30' study, the measured speed at road section level was used. A road segment often has a much larger length than visible on a picture, so more characteristics could be taken into account.

## 7.2 Measurable characteristics

For the continuous variables (road width, lane width and distance to buildings), the correlation between the variables with speed has been calculated and visualised.

The data show that the correlation between road width and speed is limited ($r = 0.22$; $p = 0.270$; $N = 27$), see Figure 20. Although there is no strong correlation, a wider road generally leads to a higher speed. Probably, a wider road gives more space for drivers and a larger distance from possible obstacles, resulting in a higher speed.

On the contrary, a wider lane generally leads to a lower speed, but here too there is no strong significant correlation ($r = -0.226$; $p = 0.256$; $N = 27$), see Figure 21. A possible explanation for a lower speed in combination with a wider lane is the definition of a lane used. For example, physical or minor separation of lanes and marking of bicycle lanes has been considered to be the boundary of a lane. This means that with narrower lanes cyclists and other cars are often separated, which makes a higher speed possible.

Contrary to the aforementioned characteristics, there is a strong significant correlation between distance to buildings and speed ($r = 0.456$; $p = 0.017$; $N = 27$), see Figure 22. A larger distance from buildings leads to a less closed road image and a better view of the surroundings, resulting in higher speeds. However, other characteristics related to the distance to buildings can also contribute to this correlation in the background.

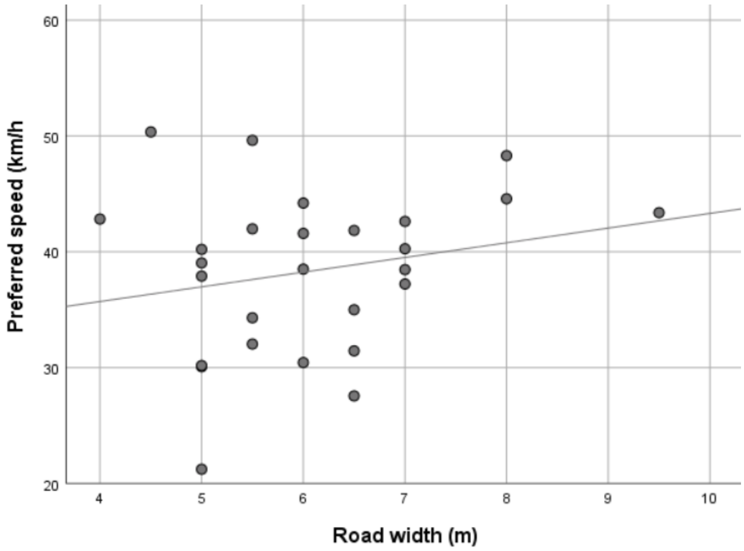


*Figure 20: Correlation preferred speed and road width. R-squared = 0.048.*

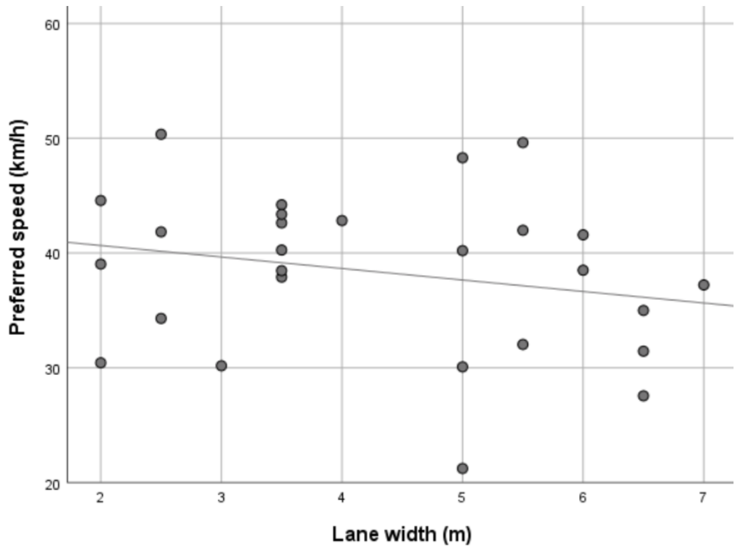


*Figure 21: Correlation preferred speed and lane width. $R^2 = 0.051$.*

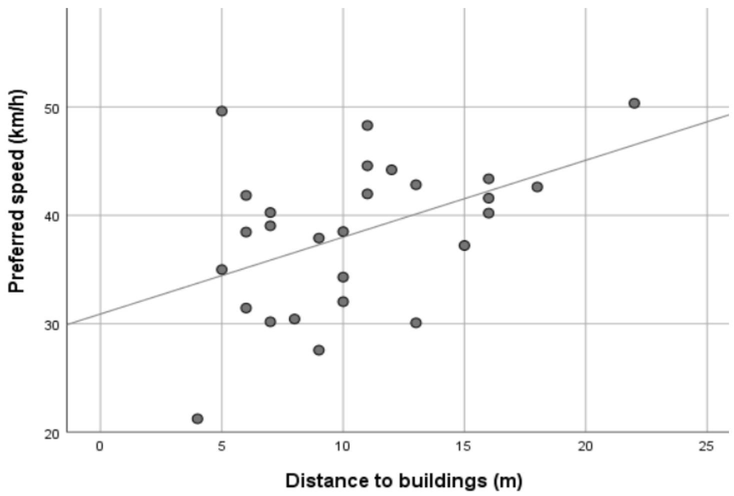


*Figure 22: Correlation preferred speed and distance to buildings. $R^2 = 0.208$.*

*Comparison with results 'Het Nieuwe 30'*

The 'Het Nieuwe 30' study also investigated the effect of two continuous variables on speed: road width and distance between buildings. The influence of both characteristics on speed seems to be limited in this research. The distance between buildings next to the road hardly seems to contribute to the speed ($r$ = 0.146; $p$ = 0.038; $N$ = 203), although the contribution is statistically significant. In the regular study, the effect of the distance to buildings was much larger. The difference may be caused by different measurement methods. In the regular study, the distance to the nearest building was determined from the middle of the road. In the 'Het Nieuwe 30' study, the distance between buildings on both sides of the road was used. And if there were only buildings on one side, the distance to this building was multiplied by two.

In addition, the correlation between road width and speed is also very limited in the 'Het Nieuwe 30' study ($r$ = 0.141; $p$ = 0.073; $N$ = 162). However, an exact comparison is also difficult with this characteristic, because a different definition of the road width has been used. On roads with a central reservation, this reservation has been included in the road width, but this was not done during the regular research. The shown correlation therefore only applies to roads without a central reservation.

The results of both studies, therefore, show similarities and differences. Probably some of these differences can be explained by the different measurement methods used. In general, there are more influencing factors in reality than visible in photographs. For example, if the influence of a certain characteristic is related to another characteristic that is not visible in photographs (but is present), this can also lead to differences in results.

## 7.3 Regression analysis

As described in section 7.1 and 7.2, by comparing the averages for categorical variables and determining the correlation of the continuous variables, it was determined to what extent the characteristics influence speed. The results of the previous paragraphs have thus been used to make an initial selection of characteristics that are important for application in the regression analysis. Many characteristics of the roads are known. The regression analysis would contain a lot of superfluous characteristics and would become unnecessarily complex if all characteristics were used.

Mainly the characteristics that turn out to have a statistically significant influence on the speed were used as input for regression analysis. In this regression analysis, an attempt was made to create a model with which the preferred speed (dependent variable) can be predicted from multiple characteristics of the road and environment (independent variables). Since it concerns multiple characteristics with influence on the speed, a multiple regression analysis was performed.

### 7.3.1 Assumptions regression analysis

To arrive at a good estimation of the regression coefficients using linear regression, the data must meet some conditions:

- The dependent variable should be measured on a continuous scale.
  This is the case, the speed (dependent variable) is measurable in km/h
- The independent variables must have an appropriate level of measurement.
  Some variables (e.g. distance from buildings) are measurable and suitable for input into the regression analysis. However, many categorical variables are not measurable, such as the presence of parked cars. Therefore dummy variables were used, these are indicator variables that can have a value of 0 or 1. The assumption has been made that the value 0 means 'not present/not applicable' and the value 1 means 'present/applicable'. Concerning the parked cars variable, this means that for all roads with parked cars the value 1 is assigned to the variable and for all other roads the value 0. In this way also non-measurable, categorical variables can be included in a regression analysis. There are also characteristics with more than two categories, in which case multiple dummy variables have been created.
  During the description of the regression analyses on the following pages, the result is given using a formula and an explanation of how the variables are coded is added. Goal is to make clear how the results can be interpreted and applied.

- The relationship between the explanatory variable and dependent variables is linear.
  This has been tested by presenting the three measurable variables in a scatter diagram (see section 7.2). Based on these diagrams, a linear relationship seems appropriate to represent the relationship between the characteristics and the speed.
- The explanatory variables included in the regression do not have a strong linear correlation.
  This has been tested by calculating all correlations between the variables. Two pairs of characteristics appeared to be strongly correlated (Pearson Correlation > 0.8). The correlation between parked cars and the clarity of the situation was 0.84. This correlation can be explained as the presence of parked cars has a major influence on the clarity of the situation. However, because the correlation is strong and the presence of parked cars can be determined more objectively than the clarity of the situation, the clarity of the situation was not used in the regression analysis.
  Also, there was a strong correlation (-0.83) between the presence of markings and the location of cyclists. This correlation can also be explained logically since only one road contained markings in the middle of the road separating the lanes. In all other cases, the presence of markings was used to indicate bicycle lanes. Based on this correlation, the presence of marking was also not included in the regression analysis.
- The variance of the error term is the same for all values of the explanatory variable (homoscedasticity).
  The variance of the error term must be the same for all values of the explanatory variable. Thus, there should be no more or less variation in the error term for larger or lower values of the explanatory variable. In the case of the opposite (heteroscedasticity), the regression coefficient is purely estimated, but the significance is unreliable. This can be over- or underestimated. To test for homoscedasticity, the residues were plotted against the predicted speed after performing a regression analysis. From these diagrams, it appeared that for both higher and lower predicted speeds the residues were about the same, so there is homoscedasticity.

Four different regression analyses were carried out with different methods and combinations of characteristics. The execution of these analyses and the results are described per analysis.

### 7.3.2 Regression 1: Prediction of preferred speed based on all significant characteristics

First, all variables that individually had a statistically significant relationship ($p \leq 0.05$) were included in the regression model. By including all these variables at the same time, it was investigated which variables still have a significant contribution to the speed. The forced entry method was used. Within this method, all predictors (characteristics) are forced into the model at the same time.

Multiple regression was calculated to predict the preferred speed from main function environment, distance to buildings, building sides, parked cars, building density and location of cyclists. A significant regression equation was found ($F(6,20) = 7.292$, $p = 0.000$) and $R^2 = 0.686$. Therefore, overall, the regression model statistically significantly predicts the outcome variable.

R Squared provides the relative measure of the percentage of the preferred speed that the model explains. R Squared = 0.686, so almost 70% of the variation in speed can be explained using the model. Besides, the standard error of the regression is equal to 4.471. This number provides the absolute measure of the typical distance that the data points fall from the regression line and is in the units of the dependent variable. Therefore, the average error of the predicted speeds is equal to 4.5 km/h.

Table 21 shows the contribution per variable, including how the variables have been coded/measured. The table shows that the preferred speed per road is equal to 41,070 - 5,773 (Shopping street) + 0,342 (Distance to buildings) + 4,236 (Buildings) - 5,259 (Parked cars) - 0,369 (Building density high) - 3,196 (Location cyclists). Both 'shopping street' and 'parked cars' were significant predictors of speed ($p \leq 0.05$) and they have the largest impact on speed with a reduction of more than 5 km/h.

The contribution of 'buildings two sides' is not statistically significant (taking into account a limit of $p \leq 0.05$), but is close. The same goes for the variables 'distance to buildings' and 'location cyclists', although their p-value is greater than 0.10. The 'building density high' no longer appears to play a significant role in combination with the other variables.

*Table 21: Results per variable regression analysis 1*

| Variables | Unst. B | Std. Error | St. B | Sig. |
|---|---|---|---|---|
| Constant | 41,070 | 3,515 | | 0,000 |
| Shopping street *(1 = shopping street, 0 = otherwise)* | -5,773 | 2,220 | -0,368 | 0,017 |
| Distance to buildings *(measured in meters from middle of road)* | 0,342 | 0,218 | 0,220 | 0,131 |
| Buildings *(1 = buildings one side, 0 = buildings two sides)* | 4,236 | 2,371 | 0,239 | 0,089 |
| Parked cars *(1 = parked cars, 0 = no parked cars)* | -5,259 | 1,930 | -0,370 | 0,013 |
| Building density high *(1 = contiguous, 0 = interruptions/freestanding)* | -0,369 | 2,080 | -0,027 | 0,861 |
| Location cyclists *(1 = roadway/separated path, 0 = bicycle lane)* | -3,196 | 1,945 | -0,219 | 0,116 |

Figure 23 shows the preferred speed on the y-axis, with the black dots indicating the average preferred speed per road. The error bars provide insight into the spread of the answered preference speeds and range from the 25th percentile (Q1) to the 75th percentile (Q3). The error bars, therefore, indicate the bandwidth within which 50% of the provided answers fall. On the x-axis the predicted speed is displayed, this value is the result of the regression analysis. The black dotted line indicates the correlation between the preferred speeds and the predicted values. The further the points deviate from this line, the greater the deviation from the prediction. Roads above the line have a predicted value that is too low and points below the line have a predicted value that is too high.

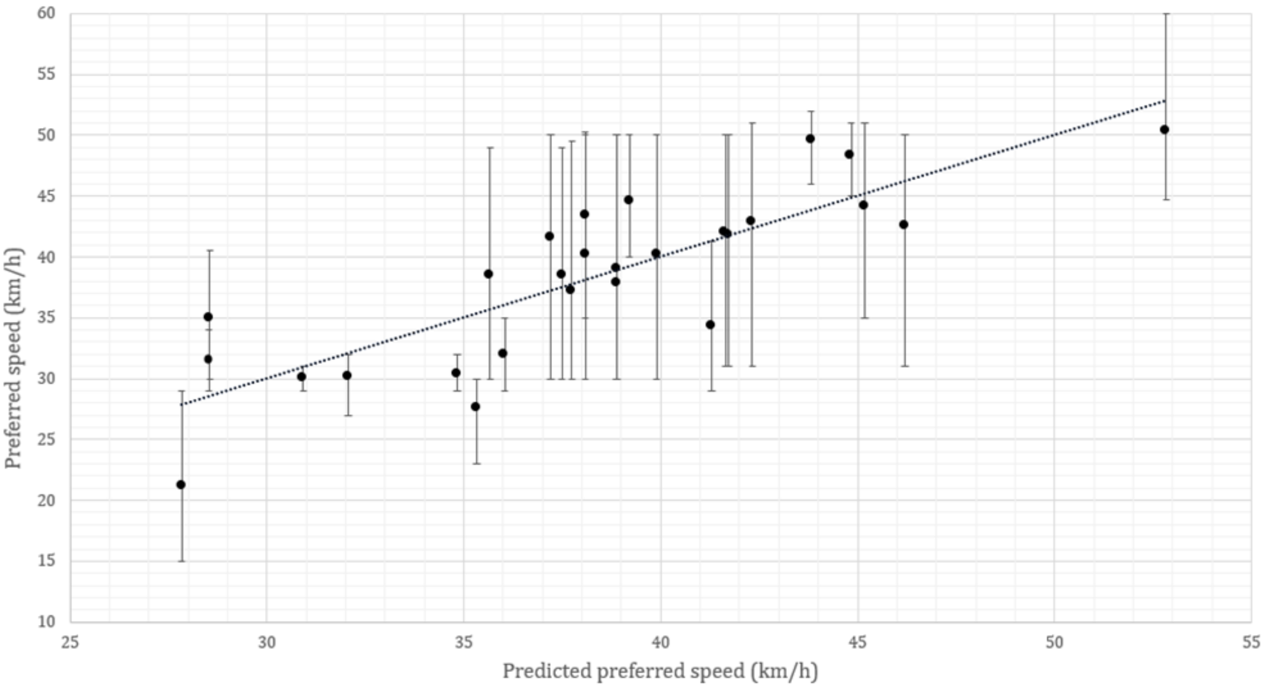


*Figure 23: Correlation between preferred speeds and predicted speeds, R Squared = 0.686. The error bars indicate the spread of the preferred speed (Q1 - Q3).*

As can also be seen in appendix D, for most roads there is a relatively large spread in the preferred speeds. However, assuming the average, the speed of most roads can be predicted reasonably well. Many points are not further than a few km/h from the trend line, which means that for many roads the speed can be predicted with limited deviation. Some points are further away from the trend line. These roads do not meet the general trend that emerges from the other roads and turn out to be more difficult to predict. The deviation may be caused by certain characteristics that do occur on these roads but are (wrongly) not included in the regression equation. To investigate whether this is the case, the residues (the difference between actual preferred speed and predicted preferred speed) of roads that turn out to be poorly predicted were examined. Analysis of the residues shows that the predicted value of roads 4, 14, 19 and 26 deviates most from the preferred speed (more than 6 km/h deviation). However, no correlations could be found between the height of the residues and characteristics excluded from the regression equation.

### 7.3.3 Regression 2: Prediction of preferred speed bases on significant road characteristics only

The previous regression analysis shows that some variables are environmental characteristics that are difficult or cannot be adjusted. The density of the buildings next to the road and the main function of the environment appear to be important variables for explaining the variance in speed. However, these variables are not properties of the road, but the environment. This makes the variables difficult to adjust and take into account during road design. Therefore, a regression analysis was also performed without environmental characteristics, but only with more adaptable road characteristics. All road characteristics with a p-value ≤ 0.10 regarding the significance of the difference between averages (see Table 19) are included in this analysis. Although they are not characteristics of the road itself, trees have also been included as adaptable features.

A significant regression equation was found ($F(4,22) = 3.433$, $p = 0.025$) with $R^2 = 0.384$. Therefore, overall, the regression model statistically significantly predicts the outcome variable. However, compared to previous models, the R Squared is low, only a limited percentage of the variation in speed can be explained by the road characteristics. In addition, the standard error of the regression is equal to 5.97, so the average deviation increased by 1.5 km/h.

Table 22 shows the contribution per variable, including how the variables have been coded/measured. The table shows that the preferred speed per road is equal to 43.974 – 5.914 (Parked cars) + 1.419 (Tree density high) + 1.072 (Trees) - 5.064 (Location cyclists). 'Parked cars' is a significant predictor of speed (p <= 0.05) and 'location cyclists' is close by. Trees density' and 'Trees' do not appear to play a significant role in combination with other variables.

*Table 22: Results per variable regression analysis 2*

| **Variables** | **Unst. B** | **Std. Error** | **St. B** | **Sig.** |
|---|---|---|---|---|
| Constant | 43,974 | 4,598 | | 0,000 |
| Parked cars *(1 = parked cars, 0 = no parked cars)* | -5,914 | 2,662 | -0,416 | 0,037 |
| Tree density high *(1 = yes, 0 = no or no trees)* | 1,419 | 2,875 | 0,103 | 0,627 |
| Trees *(1 = yes, 0 = no)* | 1,072 | 3,291 | 0,065 | 0,748 |
| Location cyclists *(1 = roadway/separated path, 0 = bicycle lane)* | -5,064 | 2,742 | -0,347 | 0,078 |

So it turns out to be difficult to estimate a good model based on road characteristics alone. The quality is less compared to a model in which the environmental characteristics are taken into account. This is also shown by analysis of the residues. Both the characteristics 'buildings' and 'shopping street' have a significant correlation with the residues. Adding these characteristics to the regression equation would, therefore, mean that more variance in speed can be explained. This was also to be expected since the earlier results consistently show that certain environmental characteristics have a major influence on speed. The influence of most road characteristics on speed is limited, therefore only a limited part of the variation in speed can be explained when using road characteristics only.

### 7.3.4 Regression 3: Prediction of preferred speed bases on all characteristics

During the first regression, only all variables with an individual statistically significant contribution were included in the regression analysis. In this analysis, a larger group of variables is included to investigate the effect of these variables on the quality of the model. However, because it concerns a larger group of variables that individually do not all contribute statistically significantly to the speed, another regression method was used. In this regression analysis, the stepwise method was used instead of the forced entry method. During the stepwise method, at each step, the independent variable not in the equation that has the smallest probability of F is entered, if that probability is sufficiently small. Also, variables already in the regression analysis equation are removed if their probability F becomes sufficiently large. The method terminates when no more variables are eligible for inclusion or removal (IBM, 2020). One of the advantages of this method is the ability to manage large amounts of potential predictor variables and it is possible to fine-tune the model to choose the best predictor variables from the available options. However, the use of stepwise regression also has several drawbacks (see the discussion in Chapter 9).

So once again a multiple regression analysis was performed, but now using the stepwise method. The regression was calculated to predict the preferred speed from all variables shown in Table 19. The correlation between the predicted speed and preferred speeds is shown in Figure 24. A significant regression equation was found ($F(6,20) = 12.256$, $p = 0.000$,) with $R^2 = 0.786$. Therefore, overall, the regression model statistically significantly predicts the outcome variable. The standard error of the regression is equal to 3.691. Just as with the first regression analysis, no correlation could be found between the residues and other characteristics of the road and environment that are not included in the regression equation.

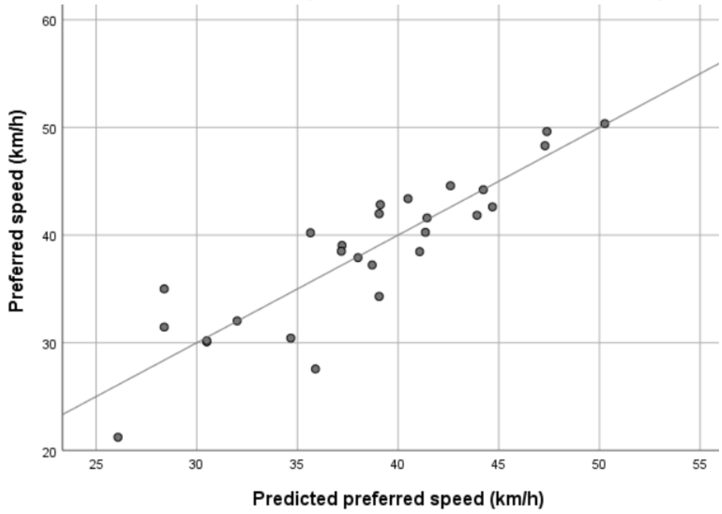


*Figure 24: Correlation between preferred speed and predicted speed. $R^2 = 0.786$.*

Table 23 shows the contribution per variable, including how the variables have been coded/measured. The table shows that the preferred speed per road is equal to 35.040 – 1.532 (Road width) – 7.051 (Parked Cars) + 5.973 (Buildings) - 5.153 (Shopping street) – 4.409 (Location cyclists) + 2.358 (Pavement). All variables except pavement are significant predictors of speed. The results of this regression analysis were used as the basis for the construction of the credibility indicator (see section 8.3).

*Table 23: Results per variable regression analysis 3*

| **Variables** | **Unst. B** | **Std. Error** | **St. B** | **Sig.** |
|---|---|---|---|---|
| Constant | 35,040 | 4,190 | | 0,000 |
| Road width *(measured in meters)* | 1,532 | 0,635 | 0,266 | 0,026 |
| Parked cars *(1 = parked cars, 0 = no parked cars)* | -7,051 | 1,547 | -0,496 | 0,000 |
| Buildings *(1 = buildings one side, 0 = buildings two sides)* | 5,973 | 1,955 | 0,338 | 0,006 |
| Shopping street *(1 = shopping street, 0 = otherwise)* | -5,153 | 1,800 | -0,329 | 0,010 |
| Location cyclists *(1 = roadway, 0 = bicycle lane/separated path)* | -4,409 | 1,462 | -0,321 | 0,007 |
| Pavement *(1 = grey asphalt, 2 = otherwise)* | 2,358 | 1,563 | 0,162 | 0,147 |

### 7.3.5 Regression 4: Prediction of measured speed based on all characteristics

In the previous regression analyses, the preferred speed was used as a dependent variable and predicted based on various characteristics. In this analysis, the measured HERE speed is analysed as a dependent variable and it is examined to what extent this speed can be predicted based on the characteristics. However, it was not possible to use the same variable as in the previous analyses. Some characteristics could not be used because they are specifically based on the photo of the road while the HERE speed is based on the speed on a road section. This means that the following characteristics could not be used: the presence of other traffic, the presence of parked cars and the visibility of speed bumps. These characteristics have been specifically determined for the photographs of the roads.

For example, it does not mean that if there are no speed bumps visible in the picture, the road itself (and the road section of the speed measurement) does not contain any speed bumps. It may be that the speed bumps are too far from the location of the photo or that the photo was taken just in the opposite direction to the speed bump. The same applies to parked cars and the presence of other traffic. Both characteristics are dynamic and may vary over time. That is why these variables have not been taken into account for now.

Because it was unknown to what extent the variables individually contribute to the HERE speed (as was the case with the preferred speed), all variables were included in the analysis. But due to a large number of variables, the stepwise method was used.

A significant regression equation was found ($F(3,23) = 3.185$, $p = 0.043$,) with $R^2 = 0.294$. Therefore, overall, the regression model statistically significantly predicts the outcome variable. However, compared to previous models, the R Squared value is low, only a limited percentage of the variation in speed can be explained by the road characteristics. Besides, the standard error of the regression is equal to 5.91.

Table 24 shows the contribution per variable, including how the variables have been coded/measured. The table shows that the measured speed per road is equal to 31.839 + 4.256 (Pavement grey asphalt) – 6.080 (Hedges) + 5.755 (Buildings two sides). None of the characteristics contributes statistically significantly to speed, although the p-value of the variables is less than 0.10. In conclusion, it is only to a limited extent possible to predict the HERE speed.

*Table 24: Results per variable regression analysis 4*

| **Variable** | **Unst. B** | **Std. Error** | **St. B** | **Sig.** |
|---|---|---|---|---|
| Constant | 31,839 | 1,512 | | 0,000 |
| Pavement grey asphalt *(1 = yes, 0 = no)* | 4,256 | 2,442 | 0,309 | 0,095 |
| Hedges *(1 = yes, 0 = no)* | -6,080 | 3,240 | -0,333 | 0,073 |
| Buildings *(1 = one side, 0 = two sides)* | 5,755 | 2,938 | 0,345 | 0,062 |

Table 25 shows the results of the 'Het Nieuwe 30' study in which the HERE speed was also predicted based on various characteristics using multiple regression analysis. Only road characteristics that can be adjusted were included in this analysis. The R Squared of the model was 0.370, so 37% of the variance in speed could be explained using the model. Loading and unloading zones, clinkers and car traffic intensity are significant predictors of speed (p-value ≤ 0.05). Loading and unloading zones and car traffic intensity were not included in the regular study, because these characteristics cannot be determined based on a photograph. A comparison with these variables is therefore not possible. However, a comparison can be made with the pavement. In the 'Het Nieuwe 30' study, clinkers lead to a significant reduction in speed. In the regular study, a moderately significant increase in speed was observed when grey asphalt was used as paving. Possibly this difference is caused by the difference between judging a picture and driving on the road. When drivers drive on a road, they experience reduced driving comfort on clinkers due to an increase in vibration and noise. In a picture only the visual aspect is visible, so the effect on speed may be less than in reality. Many parking changes and priority intersections have a moderately significant effect on speed. Priority intersections have not been researched in regular research. Many parking changes have not been studied specifically either but is probably strongly correlated with shopping streets. Also in the regular research, a strong effect of shopping streets on speed was observed.

*Table 25 Results regression analysis 'Het Nieuwe 30'*

| Variable | Unst. B | St. B | Sig. |
|---|---|---|---|
| Constant | 36,925 | | 0,000 |
| Loading and unloading zone | -3,506 | -0,239 | 0,001 |
| Parking | -0,398 | -0,024 | 0,716 |
| Many parking changes | -2,242 | -0,148 | 0,063 |
| Separation of driving directions | 1,255 | 0,073 | 0,339 |
| Speed brakes present on road section | -1,611 | -0,087 | 0,141 |
| Speed brakes present on side roads | 0,385 | 0,027 | 0,654 |
| Clinkers | -3,506 | -0,242 | 0,000 |
| Bicycle lane | 1,484 | 0,093 | 0,138 |
| Bicycle path | 1,551 | 0,071 | 0,267 |
| Priority intersections | 2,098 | 0,101 | 0,099 |
| Road width | -0,051 | -0,022 | 0,754 |
| Car traffic intensity | 0,000 | 0,215 | 0,000 |

## 7.4 Personal characteristics

The main aim of the survey was to investigate which road and environmental characteristics influence the credibility of 30 km/h roads and to what extent. The survey, therefore, consisted of photographs of roads that respondents could judge and reply to with a speed. However, in addition to the photo questions concerning the credibility of roads, some personal characteristics were also asked. This was done for two different reasons.

Firstly, some data from the respondent were asked to determine the representativeness of the sample (as described in section 5.1). Since the survey was aimed at the holders of a Dutch driving licence, the real distribution of driving license holders was compared with the distribution of the respondents who completed the survey. For this purpose, use was made of the national statistics of driving licence holders in which a distinction was made between gender and age to describe the driving licence holders. For this reason, these characteristics have been requested in the survey to assess the representativeness of the sample.

In addition, some additional personal characteristics were asked in order to explain possible differences between respondents' answers. As expected, there is a lot of variation in the given speeds of the respondents, possibly some (part) of this variation can be explained with some personal characteristics. For this purpose, the data already requested were used, among other things: age and gender. But also the number of kilometres driven per year was requested. This mileage was also used for the selection of respondents for the data analysis. It was assumed that respondents should have sufficient experience in driving to be able to estimate the speed at which they would drive on various roads. Therefore, people with low annual mileage (less than 500 kilometres) were not included in the analysis.

Furthermore, some questions were asked about the respondent's travel behaviour. These questions provide more insight into the travel motives for which the car is used, the use of other means of transport and the aspects that are important when choosing a transport mode. The questions are based on previously conducted surveys into travel behaviour.

### 7.4.1 Data preparation

This analysis was carried out similarly as the analysis of road and environmental characteristics with a multiple linear regression analysis. Also in this analysis, the preferred speed is the dependent variable. However, the average speed per respondent was used instead of the average speed per road. The aim was to determine the influence of various personal characteristics on the speed of respondents. Therefore, the independent (explanatory) variables in this analysis are the personal characteristics instead of the characteristics of the road and its surroundings.

The analysis is not connected to the previous analyses concerning characteristics of the road and its surroundings. Research has only been done into the influence of personal characteristics on speed, without taking into account the possible influence of road characteristics. This influence can differ per type of person. However, because the main aim of the research was to investigate the influence of road and environmental characteristics on credibility, no in-depth research into the influence of personal characteristics was conducted.

Concerning the speed per respondent, it is obvious to use the average of all preferred speeds on 30 km/h roads given by the respondent in question. However, not every respondent was given the same 30 km/h roads, as a random selection was made of the 27 available 30 km/h roads during the survey. Using the average given speed per respondent may, therefore, give a wrong image of the respondent. The type of roads the respondent was given (e.g. many fast roads) affects the average speed.

Therefore, the extent to which taking the average speed per respondent is justified and leads to an acceptable inaccuracy was tested. For this purpose, the average given speed per road was determined and per respondent per given speed the deviation with the average given speed of the road in question was determined. Next, the sum of all differences and the mean of all differences were calculated for each respondent. These values give a good indication of the extent to which a respondent deviates from other respondents and whether this deviation is negative (lower speed than average respondent) or positive (higher speed than average respondent).

Correlation between the two calculated values and the previously calculated average speed was then determined (see Table 26). In this way it can be concluded to what extent using the average speed gives a correct representation of the respondent, given the fact that respondents have been shown different roads.

*Table 26 Correlation between deviation values and average speed per respondent*

| | **Sum of deviations** | **Average of deviations** |
|---|---|---|
| *Correlation* | 0.975 | 0.977 |
| *Sig.* | 0.000 | 0.000 |
| *N* | 1145 | 1145 |

The results show that both the sum and the mean of the deviations are very strongly correlated to the average speed. The correlation with speed is also clearly visible in Figure 25 and Figure 26. These figures show the relationship between the preferred speed with the sum of the deviations from the mean and the mean deviation from the mean. Each point in the graph refers to a respondent. This clear relation is probably caused by the relatively high number of respondents. Given the very high correlation, it seems fair to use the average preferred speed instead of the other two values. The advantage of using the average speed is that it is much easier to interpret.

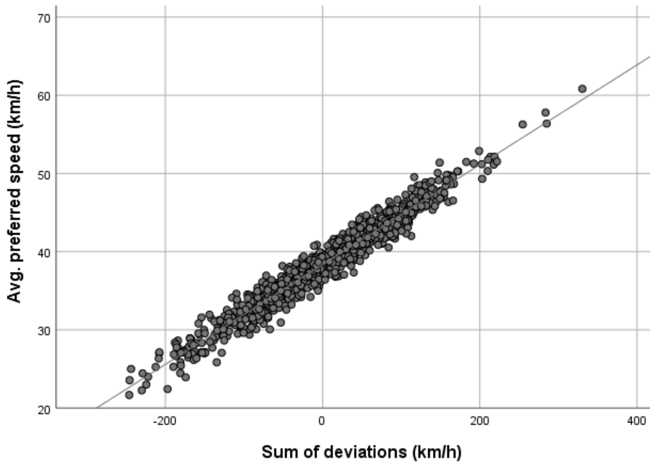


*Figure 26: Correlation preferred speed and sum of deviations. $R^2 = 0.950$. Given the strong correlation it is justified to use the preferred speed.*

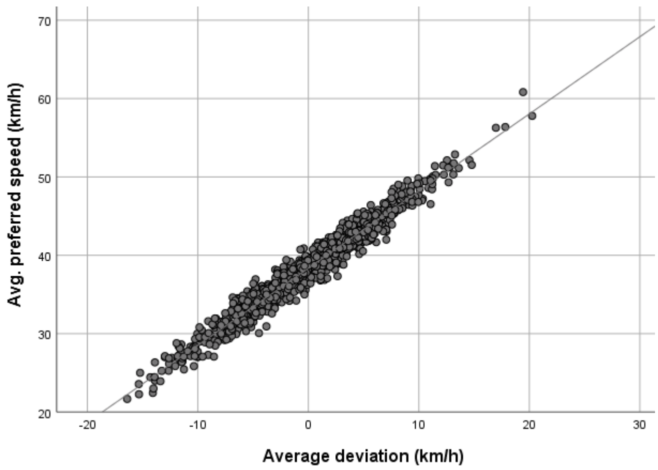


*Figure 25: Correlation preferred speed and average of deviations. $R^2 = 0.955$. Given de strong correlation it is justified to use the preferred speed.*

### 7.4.2 Influence personal characteristics on speed

Different types of variables are known from the respondents, therefore the influence of these variables on speed has been investigated in different ways. A distinction was made between categorical variables (e.g. gender), continuous variables (e.g. age) and ordinal variables (e.g. frequency of car use).

*Categorical variable: Gender*

Gender is the only categorical variable asked about the persons. As described in section 6.2, the majority of the respondents were male. The average speed of men was slightly higher compared to women, but the difference is small, see Table 27. Using an independent samples T-test, it was determined whether the differences were also statistically significant, that is not the case: $t(1143) = 1.160$, $p = 0.246$. So the influence of gender on speed does not seem to be present.

*Table 27*

| Gender | N | Avg. preferred speed | Std. Deviation |
|---|---|---|---|
| *Male* | 674 | 38.51 | 5.40 |
| *Female* | 471 | 38.13 | 5.51 |

Also in a similar study in which the preferred speed was asked, no difference was found between men and women with regard to the speed they would like to drive. However, when looking at the reported speed other studies, in general, a difference in speed was found between men and women (Goldenbeld et al., 2006). The similar answers may be caused by the question type, the preferred speed was asked. If actual speeds are measured at 30 km/h roads and it is known who drives the car, then speed differences may be found between the two sexes.

*Continuous variables: age and mileage*

During the survey, the age and the number of kilometres driven per year were also questioned. Figure 27 and Figure 28 show the correlation between the speed with age and mileage. Both graphs show that there is a lot of dispersion and that the variables have hardly any influence on the speed. This is also shown by the calculated correlations for age ($r = 0.103$; $p = 0.000$; $N = 1145$) and mileage ($r = 0.112$; $p = 0.000$; $N = 1145$). Although both correlations are statistically significant, there is no correlation.

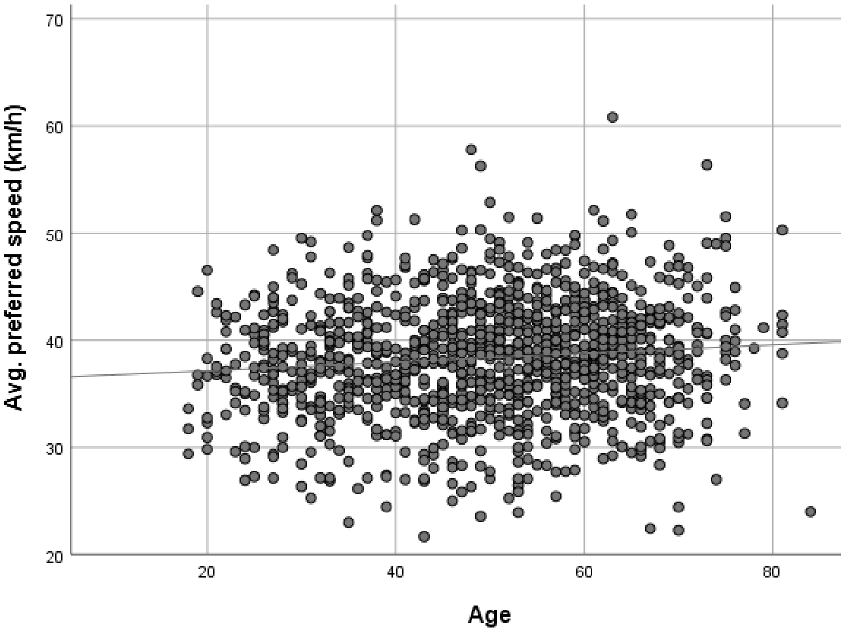


*Figure 27: Correlation speed and age. $R^2 = 0.011$.*

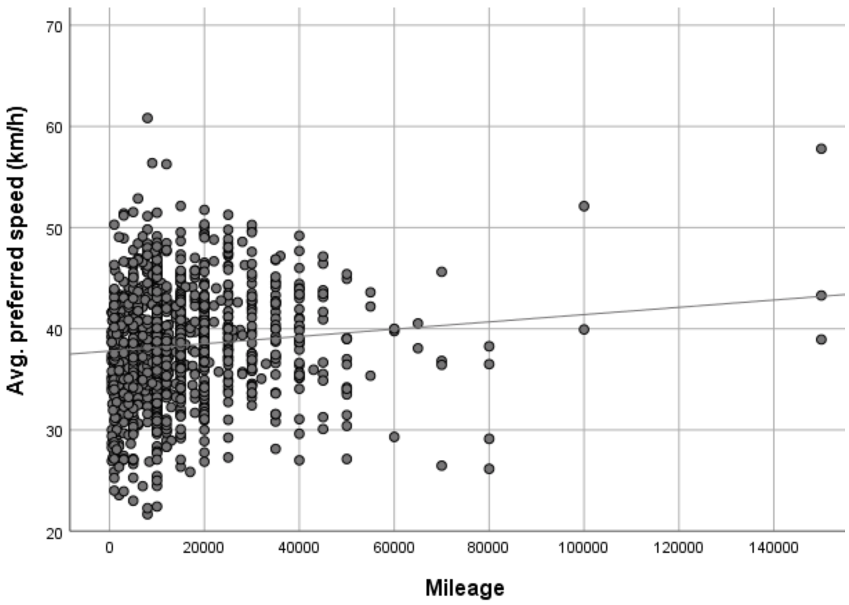


*Figure 28: Correlation speed and mileage. $R^2 = 0.013$.*

Younger respondents were expected to answer higher speeds compared to older respondents. But this is not the case, rather the opposite. Earlier studies have shown that especially young, inexperienced drivers drive faster and also take more risks than older, more experienced drivers. This occurs because young people consciously accept a higher risk or because young people are insufficiently able to assess the dangers of their own (still limited) driving skills (Goldenbeld et al., 2006). However, the survey answers do not show a correlation between higher speeds and younger drivers.

### *Ordinal variables: Use of transport modes and travel preferences*

The last part of the survey consisted of some questions asking about car use, use of other means of transport and travel preferences. The questions asked and possible answer options are shown in Table 28.

*Table 28 Questions about the use of transport modes and travel preferences*

| Questions | Answer possibilities |
|---|---|
| 1. How often do you use the car for the activities below?<br>a) Commuting<br>b) Business<br>c) Education<br>d) Daily shopping<br>e) Shopping<br>f) Visit someone<br><br>2. How often do you use the following transport modes?<br>a) Train<br>b) Bus/tram/metro<br>c) Motor/moped<br>d) Bicycle/e-bike<br>e) Walking | 1. 4 or more day per week<br>2. 1-3 days per week<br>3. 1-3 days per month<br>4. 6-11 days per year<br>5. 1-5 days per year<br>6. Never |
| 3. How important are the following aspects for you to choose a transport mode? I want…<br>a) to travel in a healthy way<br>b) as little as possible travel expenses<br>c) to travel comfortably<br>d) to spend at as little travel time as possible<br>e) to be environmentally friendly | 1. very unimportant<br>2. unimportant<br>3. neutral<br>4. important<br>5. very important |

For all questions, the answer options are ordinal, as there is an order in the answers. For the first two questions, the answers range from very frequent use of a means of transport to never using a means of transport. In the last question about travel preferences, the answer options range from very unimportant to very important. Both answer scales can be treated as a continuous variable. However, in this case, the differences between the answer options are assumed to be equal. For example, the difference between 1-3 days per week and 1-3 days per month is not equal to the difference between 1-3 days per month and 6-11 days per year.

Therefore, for application in regression analysis, multiple answer options have been merged. For the first two questions, the options 1: '4 or more days per week' and 2: '1-3 days per week' have been merged into a category 'often'. Besides, option 5: '1-5 days per year' and option 6: 'never' have been merged into one category 'never'. So two dummy variables have been created. The same has been done for the answer options of question 3. Options 1: 'very unimportant' and option 2: 'unimportant' have been combined into one category 'unimportant'. Furthermore, option 4: 'important' and option 5: 'very important' are combined into one category 'important'.

Using the Spearman correlation coefficient, it was investigated to what extent the various variables are related to each other. Correlations higher than +/- 0.3 are shown in Table 29. For all correlations, the p-value was 0.000 (i.e. a statistically significant correlation).

*Table 29: The highest correlations between individual characteristics*

| Relation | Coefficient |
|---|---|
| The more often the car is used for going to work, the more often the car is used for business travel. | 0.538 |
| The more often the car is used for commuting, the less the bicycle is used | -0.477 |
| The more often the car is used for commuting, the more important it is to minimise travel time | -0.300 |
| The more often the car is used for daily shopping, the more often the car is used for shopping | 0.505 |
| The more often the car is used for daily shopping, the more often the car is used to visit someone | 0.436 |
| The more often the car is used for shopping, the more often the car is used to visit someone | 0.484 |
| The more often the train is used, the more often other public transport (bus/tram/metro) is used | 0.622 |
| The more often the bicycle is used, the more important it is found to travel in a healthy way | 0.339 |

These correlations show that when people use their car to go to work, short travel time is important and they also use the car more often for other travel motives. On the other hand, people who use the train frequently also use other public transport more often. Finally, people who often use the bicycle also find it important to travel healthily. However, all correlations are moderate, which means that there are no strongly correlated variables. That is why all variables are included in the regression analysis. No variables have been excluded due to a too strong correlation.

### 7.4.3 Regression analysis

A regression analysis was carried out for the personal characteristics to determine the effect of the characteristics on speed. For this purpose, all variables are entered into the regression model and a stepwise regression is used to determine which characteristics have the most influence on the speed.

A significant regression equation was found ($R^2$ = 0.061; $F(5,1139)$ = 12.268; $p$ = 0.000). The results per variable are shown in Table 30.

*Table 30: Results regression analysis individual characteristics*

| | Unst. B | Std. Error | St. B | Sig. |
|---|---|---|---|---|
| Constant | 36,220 | 0,904 | | 0,000 |
| Important to travel in a healthy way | -0,860 | 0,376 | -0,076 | 0,022 |
| Unimportant to have low travel costs | 0,864 | 0,469 | 0,054 | 0,066 |
| Important to travel comfortably | 0,755 | 0,446 | 0,052 | 0,091 |
| Important to have reduce travel time | 0,656 | 0,396 | 0,052 | 0,098 |
| Important to travel environmentally friendly | -0,595 | 0,361 | -0,054 | 0,100 |
| Never use a car for business travel | -0,586 | 0,341 | -0,054 | 0,086 |
| Often walk to destinations | -1,280 | 0,463 | -0,081 | 0,006 |
| Age (per year) | 0,058 | 0,012 | 0,149 | 0,000 |
| Mileage (per 1,000 kilometers) | 0,020 | 0,010 | 0,062 | 0,046 |

Only a limited part of the variance in speed between persons appears to be explained by the requested variables. Walking frequently to destinations has the largest impact on the speed (-1.3 km/h), followed by finding it unimportant to minimise travel costs (+ 0.9 km/h). Age and mileage are also included in the regression model. For every 20 years the speed increases by about 1 km/h. Besides, every 20,000 kilometres driven also results in a higher speed of 1 km/h.

In conclusion, due to the very low R squared value as a result, it is not possible to explain the variance in speed between the respondents using the variables studied. It is therefore likely that there are other (unrequested) variables that can better explain the differences between respondents.

*Comparison with other studies*

In general, previous studies show that a higher speed is associated with, for example, younger drivers, the male gender, a high level of education, paid work, a company car or a leased car and a high annual mileage. The influence of some characteristics (level of education and paid work) has not been examined. The fact that younger drivers and male drivers drive faster did not emerge from the research. However, the speed of drivers with a high annual mileage seems to be higher. And although the type of car ownership has not been specifically asked for, the speed of business drivers seems to be higher than that of people who never drive for business.

Also in comparison with the results of Goldenbeld et al. (2006), there are similarities and differences between the results. The results of this study showed that younger drivers who often get speed tickets drive faster than older drivers who get speed tickets less often. A regional effect was also found, drivers from the north and east of the Netherlands want to drive faster than the other drivers. However, within the regular study aimed at 30 km/h roads, the number of speed tickets received and the region from which the respondent came was not asked. Comparison with these results is therefore not possible. However, a comparison with the other results is possible. Goldenbeld et al. (2006) found no effects of gender and annual mileage on the assessment of speed. These results are in line with the results of the regular survey.

Another possible variable explaining more variation in speed is the sensation seeking. Several studies have shown that sensation seeking is related to accident involvement and driving behaviour. Zuckerman introduced the concept of sensation seeking in the 1960s. A sensation seeker is described as someone with a strong need for different and new experiences in different areas, someone who does not easily adapt to social norms and values and who wants to be independent of others. Various studies in the field of traffic behaviour have shown that a greater need for excitement goes hand in hand with, among other things, a higher driving speed. For example, observed differences in speed behaviour between men and women and between young and older drivers are also attributed to an underlying difference in sensation seeking between these groups.

To measure the degree of sensation seeking, use was made of a shortened version of Zuckerman's original 'Sensation Seeking' questionnaire. The questionnaire consisted of 20 statements on specific or general activities. Examples are: 'I'd like to parachute jump once' and 'If I have to do the same job for a long time in a row, I get restless'. Respondents had to indicate on a five-point scale to what extent they considered the statement to apply to themselves. In the end, this led to an absolute score (0-100) per respondent, indicating the sensation-seeking score. The degree of sensation seeking was also found to contribute to the assessment of the speed. Drivers who need more excitement want to drive faster and also find a higher limit safe (C. Goldenbeld et al., 2006).

All in all, there are similarities, but certainly also differences between the results of various studies in which the effect of personality traits on speed has been investigated. These differences are partly due to the different research methods used and the focus of the research. But certain characteristics of the respondents play a role in determining the speed. A driver's speed is therefore not only influenced by the characteristics of the road and its surroundings, but also by the characteristics of the respondent. Making a limit on a particular road credible for everyone by adapting the characteristics of the road and its surroundings is therefore not possible because personal characteristics also always contribute to credibility. However, since respondents are often influenced by the same road and environmental characteristics, it is possible to make a limit more credible for everyone.

# 8 Application

In this chapter, the results obtained are applied to determine the credibility of 30 km/h roads. First, an already existing method is described and tested (section 8.1 and 8.2). This method is then adapted to the results obtained in Chapter 7 to improve the method for 30 km/h roads (section 8.3). Finally, other measures that may contribute to credibility are described (section 8.4).

## 8.1 Existing method to determine credibility

Over the years, various methods/tools have been developed within the Netherlands to increase traffic safety. One of the most used methods is called 'safe speeds and credible speed limits' (VSGS, 'Veilige Snelheden Geloofwaardige Snelheden'). This method focuses on the credible design of roads and can be used to determine whether the desired speed limit matches the design of the road. The VSGS method is based on the idea that there is unsafety if the speed limit, road layout and types of road users are not properly attuned to each other. It is assumed that road users will more easily keep to the limit on a road with a credible speed limit. The method helps to determine a safe speed for road design.

In a study by Van Nes et al. (2007), a start was made with the development of the method by making a checklist for the assessment of credible speed limits. Based on various characteristics, it was determined to what extent a specific speed limit on a road is credible. Later, this method was developed into an instrument for determining 'safe speeds and credible speed limits': VSGS. The VSGS method identifies the potential unsafety of situations using a step-by-step plan (Jansen et al., 2018).

The method can be used to determine a safe speed given the layout of the road (step 1: VSafe) and to determine to what extent the current speed limit is credible (step 2: VCredit). The third and final step consists of influencing the behaviour of drivers. These steps will be explained in the following section.

### *Step 1: Safe speed limit*

The first step relates to the safe speed. By considering the alignment of function, shape and use, it is possible to determine which speed limit is safe (the VSafe). The 'weakest link' determines which speed limit is safe. This means that the speed that is considered safe is determined by the least safe characteristic of a road. Table 31 shows the factors that determine which speed limit is considered safe in built-up areas. In general, below 50 km/h limits, fast traffic and vulnerable road users can be mixed, while at 50 km/h it is desirable for vulnerable road users and fast traffic to be separated (Jansen et al., 2018).

*Table 31: Proposal for safe speeds given the potential conflicts between different road users and design characteristics of the road. Changes concerning the row above are shown in italics (Jansen et al., 2018).*

| Potential conflict situations and related conditions | Safe speed |
|---|---|
| Possible conflicts with vulnerable road users in residential areas (no pavements, pedestrians use the entire carriageway) | 15 km/h |
| Possible conflicts with vulnerable road users *on roads, intersections, also in situations with bicycle or advisory lanes* | 30 km/h |
| *No conflicts with vulnerable road users, excluding motorised two-wheelers with helmets* (moped on the carriageway). Possible cross conflicts between motor vehicles, possible frontal conflicts between motor vehicles. | 50 km/h |

### *Step 2: Credible speed limit*

The second step concerns the determination of the credibility of the speed limit (the VCredit). The starting point is that if the road design matches the experience of the drivers, a safe speed limit will partly be maintained automatically. To determine the VCredit, the road characteristics of a road or road section have to be collected. Initially, Van Nes et al. (2007) identified five characteristics that influence the credibility of the speed limit. These characteristics are subdivided into accelerators and de-accelerators (see Table 32). Accelerators are elements of the road or road environment that intuitively provoke a higher speed regardless of the limit. De-accelerators are elements of the road or road environment that intuitively stimulate a lower speed irrespective of the limit (Van Nes, Houwing, et al., 2007).

*Table 32: Accelerators and de-accelerators (Van Nes et al, 2007)*

| | Accelerators | De-accelerators |
|---|---|---|
| Road type | Long straights (straight road) | Short straights (many curves or intersections) |
| Physical speed limiters | No physical speed limiters | Physical speed limiters present |
| Visibility | Open, clear road environment | Closed, confusing road environment |
| Road width | Wide road | Narrow road |
| Road surface | Smooth road surface | Rough road surface |

Based on the road layout, for each of the characteristics, it is assessed whether they may have an accelerating or decelerating effect on speed and thus on the credibility of the limit. Each characteristic is scored on a three-point scale: 'accelerating effect', 'neutral effect' and 'decelerating effect'. Moreover, it is assumed that a (net) neutral score equals a credible limit. The presence of many accelerators or decelerators means that the limit is considered incredible. The final credibility score can be determined by determining the number of accelerators and decelerators present (see Figure 29). If a characteristic is a decelerator, then a -1 score will be assigned. Accelerators are given a score of +1 and neutral characteristics a score of 0. If the total score for all characteristics is -2 or lower, then a deceleration effect will be expected based on the road and environment characteristics. If the total score for all questions is +2 or higher, then an acceleration effect will be expected based on the characteristics. Also, if the score is -1, 0 or 1, then no effect on the speed is expected and the road is considered credible (L Aarts & van Nes, 2007).

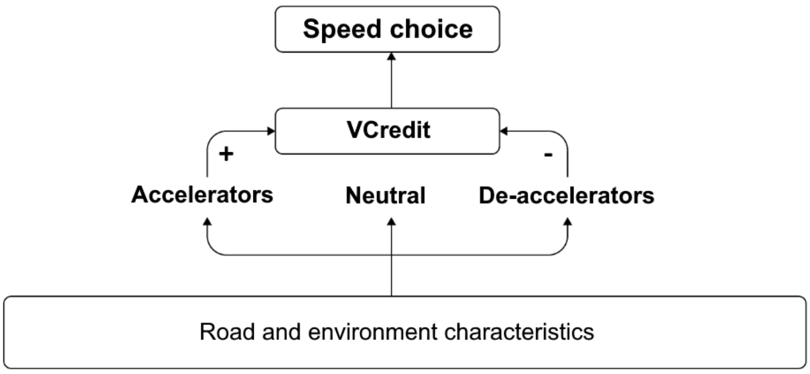


*Figure 29: Determinination of the VCredit*

Over time, adjustments have been made, and new characteristics were added to this method. Also, different scoring schemes have been drawn up for each speed limit because the guidelines for each speed limit differ. As an example, for 50 km/h roads, two road characteristics and the corresponding scores are shown in Table 33.

*Table 33: Two examples of scores on 50 km/h roads (Bax et al., 2018)*

| Characteristic | De-accelerator (-1) | Neutral (0) | Accelerator (+1) |
|---|---|---|---|
| *Lane width* | < 3.1 m | 3.1 – 3.7 m | > 3.7 m |
| *Driving direction separation* | No separation | With road marking | Fully separated |

This method assumes that accelerators and decelerators can neutralise each other. For example, with two accelerators and two decelerators, the total score is 0, and no effect is expected. However, it is possible that in practice, the impact of the characteristics is not equal. This problem can be solved by assigning a certain weight to different effects, but weights are not yet applied within the method.

### *Step 3: Influencing the behaviour of drivers*

The third and final step of the VSGS method consists of assessing the possible influence of the behaviour of drivers, such as enforcement and education. For example, speed can be influenced by speed checks. However, it is questionable to what extent speed controls apply on 30 km/h roads (see section 8.4).

*Relation VSafe en VCredit*

The characteristics that are considered to be most favourable for VSafe and VCredit are sometimes contradictory. For example, a large obstacle-free space is favourable for VSafe. If a road user loses steering wheel control, the chance of colliding with an object is smaller with a larger obstacle-free area. However, for VCredit, a large obstacle-free space, especially in combination with a wide view, can have the effect of an accelerator. An open road environment invites to drive faster, often faster than the applicable speed limit of the road. That is why a balance is needed between these two measures. The characteristics of VSafe are related to biomechanics, those of VCredit to psychology. Setting up the road according to the safe speed limit is seen as the most important, complemented by a credible design (Bax et al., 2018).

*Validity*

The validity of the method relates to the question to what extent the outcome of the method gives a correct representation of reality. A higher positive VCredit score is expected to result in a higher exceeding of the limit and a higher negative VCredit score is expected to result in a higher undershooting of the limit. Whether this also happens in practice is not well known. The GS score has been validated to a very limited extent with empirical results. The validity of the method can be determined by analysing to what extent VCredit scores from different locations are a good predictor of the actual speed driven at those locations. In a study by Jansen et al. (2018), this has been investigated whether this is the case for 50 km/h roads in Amsterdam. The main conclusion of the study was that, for the time being, caution is needed when interpreting the VCredit as an indicator of safety. Although the scope of the study was limited, no clear relationship was found between the score and speed.

Therefore, additional research (also on other road types) is necessary to gain more insight into the validity of the method. That is why the method has been applied to all 30 km/h roads within the study and recommendations are made to improve the method specifically for 30 km/h roads.

## 8.2 Application 'Safe speed and credible speed limits' method

As described, the first step of the method is the assessment of the VSafe. Based on the road and environmental characteristics, a safe speed is linked to the road. The lowest speed belonging to a certain characteristic (weakest link) is decisive for the final VSafe. An overview of the characteristics used to determine the VSafe is shown in Table 34. For each of the 27 roads within the study with a speed limit of 30 km/h, the VSafe is determined based on this table. Table 34 shows under 'access' that the access for every road user leads to a VSafe of 30 km/h. For 23 of the 27 roads, cyclists are allowed to use the same lane as cars. As this characteristic leads to a 30 km/h VSafe, this means that these roads could directly be given a 30 km/h VSafe. Relating to road number 8, the obstacle-free distance is less than 0.8 meters, which means that this road also has a 30 km/h VSafe. For roads 12 and 16, a 30 km/h VSafe could also be granted based on the level junctions without a plateau which are present. For one road (number 18), the allocated VSafe is 50 km/h instead of 30 km/h. This road does not contain the aforementioned characteristics that allowed the allocation of a VSafe of 30 km/h.

*Table 34: Criteria for determining the VSafe, considering the weakest link (category with the lowest speed) as the leading link (Bax et al., 2018).*

| ***Characteristic*** | **Categories** | **Speed limit** |
|---|---|---|
| *Driving direction separation* | Not possible to drive over | Maximum limit |
| | Difficult to drive over | 80 km/h |
| | No / only markings / tram/bus lane that can be driven over | 70 km/h |
| *Obstacle-free distance* | Obstacle distance > 13.0 m or guide rail | Maximum limit |
| | Obstacle distance 11.5 – 13.0 m | 110 km/h |
| | Obstacle distance 10.0 – 11.5 m | 100 km/h |
| | Obstacle distance 8.0 – 10.0 m | 90 km/h |
| | Obstacle distance 6.0 – 8.0 m | 80 km/h |
| | Obstacle distance 5.5 – 6.0 m | 70 km/h |
| | Obstacle distance 2.5 – 4.5 m | 60 km/h |
| | Obstacle distance 0.8 – 2.5 m | 50 km/h |
| | Obstacle distance < 0.8 m | 30 km/h |
| *Connections* | 0 per 100 m | Maximum limit |
| | 1-2 per 100 m | 70 km/h |
| | 3 or more per 100 m | 50 km/h |
| *Intersections* | No intersection or grade separation | Maximum limit |
| | Roundabout or level crossing with a platform | 50 km/h |
| | Level crossing without platform or intersection with a bike path | 30 km/h |
| *Intersection density* | No intersections | Maximum limit |
| | 0-2 intersections per km | 100 km/h |
| | 2-3 intersections per km | 70 km/h |
| | 4 or more intersections per km | 50 km/h |
| *Access* | No access for cyclists and mopeds or no access for all slow traffic | Maximum limit |
| | No access for cyclists | 50 km/h |
| | Access for every road user | 30 km/h |

As described in section 8.1, the second step consists of determining the credibility (VCredit) for the roads. This has been done based on the characteristics and corresponding scores as shown in Table 35. This scorecard has been specifically drawn up within the method for 30 km/h roads. For each 30 km/h road within the study, the corresponding score was determined for each characteristic. Subsequently, all scores per road have been added together. All characteristics can be assessed as accelerators, resulting in a maximum score of +8. Four characteristics cannot be assessed as a de-accelerator, making a minimum score of -4.

*Table 35: Scorecard VCredit 30 km/h roads (Bax et al., 2018)*

| | Decelerator (-1) | Neutral (0) | Accelerator (+1) |
|---|---|---|---|
| *Road width* | < 4.5 m | Between 4.5 and 5.5 m | > 5.5 m |
| *Lane width* | < 3.1 m | Between 3.1 and 3.7 m | > 3.7 m |
| *Number of lanes* | | No separate driving directions | Separated driving directions and/or one or more lanes per driving direction |
| *Driving direction separation* | | No separation of driving directions | Separation of driving directions |
| *Straight* | < 40 m | Between 40 and 100 m | > 100 m |
| *Access* | | No limitations | No access for cyclists and mopeds |
| *Junctions* | Speed reduction | | No speed reduction or no junctions |
| *Road environment* | | Closed | Open or semi-open |

The final scores per road are shown in Table 36. As described earlier, a total score of 2 or higher is considered incredible and is expected to lead to higher speeds on the road. Most examined roads have a score higher or equal to 2, only seven roads have a score of -1, 0 or 1 which is rated as credible. The average score of all roads is 2.6. There is no road with a negative score with an expected slowing effect on speed.

Subsequently, through the graphs in Figure 30, the relationship between both the measured speed and preferred speed with VCredit is shown. Both graphs show that there is no correlation between VCredit and speed. The VCredit, therefore, does not appear to be suitable for determining the credibility and speed of a road based on the roads investigated.

*Table 36: Calculated VSafe and VCredit scores per road. Roads assessed as 'incredible' are marked red.*

| Road | VSafe | Vcredit | Road | VCredit | Vsafe |
|---|---|---|---|---|---|
| **1** | 30 km/h | 2 | **15** | 30 km/h | 3 |
| **2** | 30 km/h | 2 | **16** | 30 km/h | 2 |
| **3** | 30 km/h | 1 | **17** | 30 km/h | 4 |
| **4** | 30 km/h | 1 | **18** | 50 km/h | 5 |
| **5** | 30 km/h | 0 | **19** | 30 km/h | 4 |
| **6** | 30 km/h | 2 | **20** | 30 km/h | 4 |
| **7** | 30 km/h | 1 | **21** | 30 km/h | 3 |
| **8** | 30 km/h | 4 | **22** | 30 km/h | 3 |
| **9** | 30 km/h | 5 | **23** | 30 km/h | 4 |
| **10** | 30 km/h | 3 | **24** | 30 km/h | 3 |
| **11** | 30 km/h | 3 | **25** | 30 km/h | 0 |
| **12** | 30 km/h | 4 | **26** | 30 km/h | 4 |
| **13** | 30 km/h | 3 | **27** | 30 km/h | 1 |
| **14** | 30 km/h | 0 | | | |

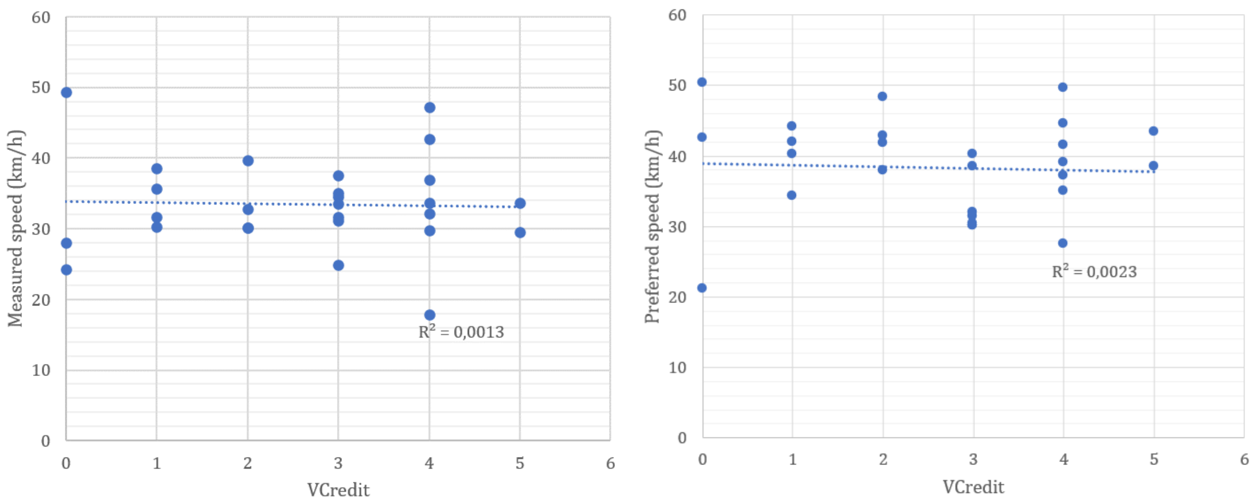


*Figure 30: Correlation between measured speed and preferred speed with VCredit*

One of the probable reasons for this is that the method has been developed mainly for roads outside built-up areas such as 80 km/h roads. As a result, some characteristics do not fit well with 30 km/h roads. Table 37 discusses each characteristic. Also, the correlations of the scores of the characteristic (-1, 0, 1) with the preferred speed are shown. Some characteristics have a weak correlation with the preferred speed, such as the road environment. However, most characteristics do not correlate with the speed and are therefore unsuitable predictors for application in the method.

*Table 37: Discussion of characteristics VSGS method and correlation with preferred speed*

| **Characteristic** | **Cor.** | **Issues** |
|---|---|---|
| *Road width* | 0.06 | Does not affect the speed and is therefore not suitable to be included in the method. |
| *Lane width* | -0.14 | Definition of lane width for 30 km/h roads is unclear and characteristic has almost no influence on speed. |
| *Number of lanes* | -0.05 | Roads with a higher speed limit can have several lanes, but for 30 km/h this is rarely the case. This is why the scorecard distinguishes between 'no separate driving directions' and 'separate driving directions'. However, this characteristic has already been asked for once. |
| *Driving direction separation* | -0.05 | Has already been asked once and there is little distinction between roads (almost all roads have no separation). Because of this, the effect on predicting speed is very limited. Moreover, it is unclear what exactly is meant by 'separated driving directions'. Some 30 km/h roads, for example, have a slight separation from other pavements (e.g. clinkers instead of asphalt). It is not clear whether this is seen as separate driving directions or not. Because physical separation seldom occurs on 30 km/h roads, a light separation is also classified as driving direction separation. |
| *Straights* | 0.33 | Influence on speed is limited. |
| *Access* | 0.04 | There is little diversity among 30 km/h roads in terms of access to cyclists. On almost all roads cyclists can ride on the same road as cars. |
| *Junctions* | -0.23 | Influence on speed is limited. |
| *Road environment* | 0.41 | Characteristic with the most influence on speed, but depends on several characteristics that influence the view of the environment. |

All in all, the current set-up of the method is not at all suitable to judge the credibility of 30 km/h roads. Many characteristics do not fit with 30 km/h roads and have an insufficient distinction between roads and no influence on speed. However, both the measured speeds and the preferred speeds show clear differences between roads. Therefore, there is potential to improve the existing VSGS method, in this case specifically for 30 km/h roads. This could include the use of characteristics with sufficient diversity on the roads and influence the speed. This improvement is described in section 8.3

## 8.3 Design credibility indicator

As described in section 8.1, there exists a method to determine the credibility of roads, including 30 km/h roads. However, as shown in section 8.2, the outcome of this method is in no way related to the respondents' preferred speed and the measured speed. Therefore, a new tool has been developed based on the results described in section 7.3. The tool differs on some aspects of the method described in section 8.1. The result is expressed as a speed in km/h and not as a score between -4 and +8. The use of this scoring system requires results to be transformed into the scoring system. Characteristics have to be split into two or three categories and these categories should be linked to a score (-1, 0 or 1). By expressing credibility in km/h, results are fully used without loss of results.

The tool is built in Microsoft Excel and is called the 'Credibility Indicator', see Figure 31. This tool aims to obtain an indication of the credibility of the road and its surroundings in a simple way after filling in several characteristics. The tool is only suitable for roads with a speed limit of 30 km/h and consists of some steps:

1. First of all, one or more roads must be chosen of which one wants to determine the credibility. Also, a clear overview of these roads is needed, for example by using programs such as Google Streetview and Cyclomedia Streetsmart. In both programs, 3D recordings of roads can be looked up and measurements can be made.
2. After determining the roads, some characteristics of the road and its surroundings have to be filled in. These characteristics are based on the results of the regression analysis described in section 7.3.4. By clicking on the input fields of the characteristics, the available options are shown and the correct option can be chosen. A description of the options will also appear to help with making the right choice.
3. After entering all requested characteristics, the result is automatically displayed using a speedometer in which various colour scales and the speed are displayed. The speed is calculated in the background based on the results of the regression analysis and the given input. Using four colours, an indication of the credibility is given:
    - Green: very credible (25-31 km/h)
    - Yellow: credible (31-37 km/h)
    - Orange: incredible (37-43 km/h)
    - Red: very incredible (43-60 km/h)

   The boundaries between the colour scales have been determined based on the distribution of estimated speeds of the roads. The minimum and maximum speeds are the lowest and highest values that can be obtained from the regression equation.
   By using colours, it becomes immediately clear how the given speed can be interpreted. This is because the indicated speed is not directly comparable with the actual speed since other road users were not taken into account in the design of the tool. As a result, the score will generally be higher than the actual speed driven. For this reason, a road with a credibility indication of, for example, 35 km/h does not immediately have to be considered 'incredible', since the actual speed driven is probably lower. The data analysis described earlier showed that the measured speed is about 5 km/h lower. Therefore, some speeds higher than 30 km/h are also considered credible.

Various applications are available with the tool. For example, several existing 30 km/h roads can be filled in to compare the credibility of these roads. Roads with a poor score, as a result, may require further investigation and more attention. It is also an option to test designs of 30 km/h roads, for example when modifying roads that are currently still 50 km/h or existing 30 km/h roads that are being improved. In all cases, various combinations of characteristics can be tested and the effect of the modifications on the credibility is immediately visible. The main target group for the tool are Dutch municipalities, as they are responsible for the control of 30 km/h roads. Consultancies that advise municipalities on the design of roads can also make use of the method.

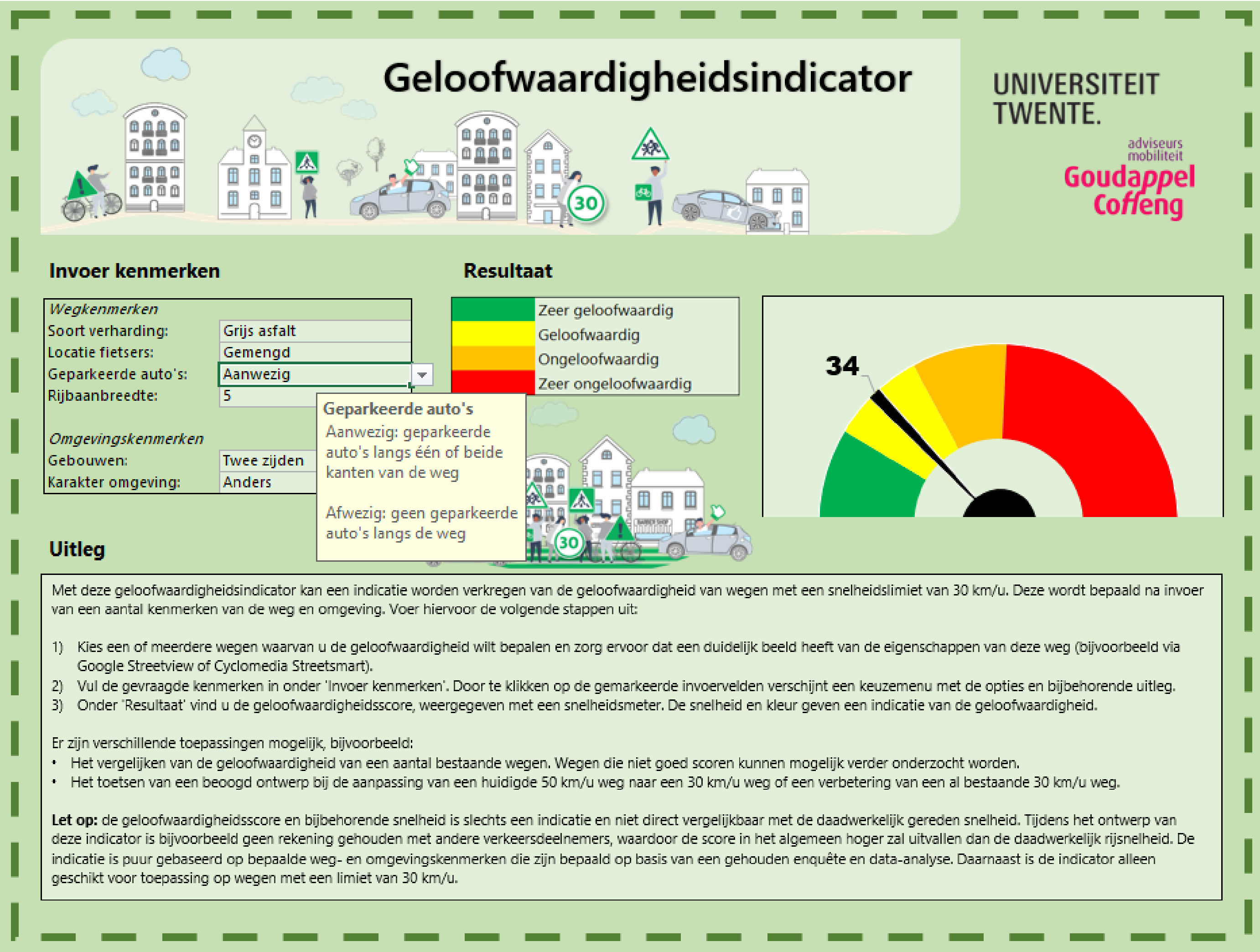


*Figure 31: Overview of the credibility indicator. After filling in the requested characteristics (under 'Invoer kenmerken'), the result is directly displayed (under 'Resultaat') by means of a speedometer with colour scales and speed. The functioning and possible applications of the indicator are explained under 'Uitleg'.*

## 8.4 Other measures in favour of credibility and compliance

In addition to changing the layout of the road to make the limit more credible, the literature also discusses some other examples of measures that could reduce the speed on 30 km/h roads. A number of these measures are discussed in the overview below. These measures are aimed at influencing the behaviour of car drivers.

### 8.4.1 Enforcement

In the final step of the VSGS method, enforcement has been mentioned as a possible option to reduce speed. However, for 30 km/h roads this option does not seem suitable. A survey of 203 municipalities shows that 67% of municipalities feel that there is a lack of enforcement in 30 km/h zones. Figures from the Central Judicial Collection Agency (CJIB) also show that speeding fines are very rarely issued in 30 km/h zones. In 2016 only 0.1% of all speed tickets were issued in 30 km/h zones. Police also indicate that they hardly ever give speed tickets in 30 km/h zones. In addition to the lack of capacity, the police find that the roads are often not well designed and therefore do not meet the design requirements. The police want to be cautious about the use of traffic enforcement on roads that are not properly equipped. By doing so, errors in road layout are corrected and the police do not consider this desirable (Adriaens, 2017).

The police believe that roads should be 'self-maintaining'. The road layout should be such that it is not possible to drive faster than the speed limit. If a road zone is self-enforcing, the police do not have to enforce it. However, if a zone is not self-enforcing, it will not be enforced either, because according to the police the road should be self-enforcing. That is why there was a proposal to give municipalities the power to take action against speeding offences themselves if the police do not enforce it. However, this proposal did not go through, because taking action against speeding offences is typically a matter for the police, not for the municipality (Teunissen, 2017).

All in all, enforcement on 30 km/h roads is a difficult discussion. Due to lack of capacity and inappropriate road layout, there is rarely enforcement on 30 km/h roads. Although municipalities sometimes want to intervene themselves, this is not possible because they are dependent on the police for enforcement. The main solution, therefore, seems to be to improve road design and make it more credible, so that the road invites slower driving and enforcement by the police is no longer necessary.

### 8.4.2 Rewarding

Speeding offenders are traditionally punished by fines. But research shows that the opposite of punishment, namely rewarding, can also be effective. In a study by Duivenvoorden et al (2013), a pilot study was conducted to investigate whether speeding at 30 km/h and 50 km/h roads can be prevented by rewarding drivers if they adhere to the speed limit. Two types of reward strategies were investigated: a collective reward (traffic education package or materials for the primary school in the neighbourhood) and an individual reward (a flan). In the province of Limburg, twelve different neighbourhoods were selected that were divided into three groups: four neighbourhoods in the collective reward group, four neighbourhoods in the individual reward group and four neighbourhoods in the control group. In each district, measurements were taken at four locations before the pilot started and during the campaign. These measurements were used to calculate three variables: the average speed, the percentage of vehicles that broke the limit and the percentage of vehicles with a small speed limit exceedance (10 km/h or lower). During the pilot, several campaigns were used to alert drivers to their speed behaviour. For example, flyers were distributed and social media was used (Duivenvoorden et al., 2013).

At some locations, a small decrease in the average driving speed was found. A total of 43 (sometimes very small) decreases in average speed were found. An increase in average speed was also found at 35 locations. The differences measured were not large and not statistically significant. Also, the decrease in the percentage of vehicles exceeding the limit was not significant. It was therefore concluded that the various reward scenarios did not affect speed. This applies to both the individual and the collective reward scenario. This result is partly explained by the limited attractiveness and visibility of the action. (Duivenvoorden et al., 2013). However, even if the rewards in this study would have had the desired effect on speed, the question remains to what extent the results can be used. Rewards on a larger scale do not seem realistic. Campaigns with rewards on a small scale may temporarily draw attention to the problem, but rewards on a larger scale and in the longer term do not seem feasible.

### 8.4.3 Nudging

In research by Goldenbeld et al. (2017) the effect of Dick Bruna signs along 30 km/h roads on the speed of car drivers has been investigated. Dick Bruna was a Dutch author, illustrator and graphic designer known for the children's books he authored and illustrated. His most famous creation is Miffy. The idea behind the placement of these signs is that Dick Bruna images evoke a strong association with children and childhood and through this association unconsciously slow down the speed. In this way, a measure has been researched that can positively influence the speed without drivers being aware of it. This is also called nudging and involves giving a push in the right direction by making the desired behaviour attractive, natural or logical without restricting people's freedom (C. Goldenbeld et al., 2017).

A practical study was carried out in which the speeds were measured on five 30 km/h roads with and five 30 km/h roads without a Dick Bruna sign. The measurements had a small positive effect on the speed in the first week after installation, the average speed decreased by 0.75 km/h and the V85 by 1.5 km/h. However, follow-up measurements indicated that the effect was short-lived. In the second week after placement of the sign, the effect had almost disappeared and then completely. The conclusion was therefore that placing Dick Bruna-signs as a stand-alone measure did not seem sufficient to structurally and positively influence the speed behaviour of car drivers. A possible explanation for this is that a Dick Bruna-sign is only one relatively small part of the total road environment and in that sense, it is not surprising that the speed effect is limited (C. Goldenbeld et al., 2017).

# 9 Discussion

Section 9.1 addresses the validity and reliability of the research by discussing the research design and research methods used. Subsequently, in section 9.2, recommendations are made for possible follow-up research.

## 9.1 Evaluation and limitations

The core of the research consisted of a survey in which respondents were shown photos of 30 km/h roads. With each photo, the respondent was asked to fill in a preferred speed and estimated limit. The degree of credibility was quantified by determining the difference between the speeds answered and the speed limit. The preferred speed was mainly used, as the preferred speed and estimated limit appeared to be strongly related. The use of the estimated speed limit would probably have yielded the same results.

A disadvantage of photographs, however, is that they give a static view of the situation. In reality, car drivers will base their opinion about the desired speed partly on dynamic information about the situation, such as other traffic or the characteristics of earlier sections of the road. By opting for photographs, this dynamic aspect of speed choice was not addressed. It is, therefore, possible that the speeds give a distorted picture, especially when looking at absolute speeds. It also turned out that in many cases the measured speeds were about 5 km/h lower. However, a deliberate choice was made to show a limited amount of other traffic on the pictures. In this way, the effect of the road and surrounding characteristics could be better determined, without interference from other factors.

Besides, the choice was made to use a survey. The advantage of a survey is that it is relatively easy to obtain a large sample and thus a representative view of the Dutch car drivers. Moreover, a survey involves a controlled environment. Each respondent answered the same questions in the same way and the same environment. The use of measured speeds (for example collected with floating car data) would have been possible, but the quality of these measurements on 30 km/h roads is often uncertain due to a lack of vehicles. Moreover, these measurements take place in an uncontrolled environment where the influence of dynamic factors such as the presence of other road users is unknown. The pictures from the survey were the same for each respondent, so no dynamic factors in the background played a role that could be different for each respondent.

However, although field experiments have not been assessed as suitable, they do have some advantages compared to a survey. For example, a survey measures claimed behaviour, whereas a field experiment measures actual driving behaviour. A survey has to do with the possible tendency for socially desirable answers, while this tendency does not play a role during field measurements. It is therefore questionable to what extent the survey answers correspond to the actual speeds driven, even when corrected for other traffic. The distribution of preferential speeds per road showed that these are particularly close to the speed limits, in contrast to reality. The difference between the preferred speed and estimated limit was often limited. In reality, this difference is probably greater, which is why respondents seem to have given somewhat socially desirable answers.

Given the limited number of 30 km/h roads (27), it was not possible to test the influence of all characteristics. Because it was difficult to predict in advance how many respondents would be collected, the selection of roads was limited to obtain a sufficient number of respondents per road. However, because of this limited selection, it was not possible to collect a complete overview of all characteristics. Some characteristics only appeared to a limited extent in the photographs and with insufficient variation, making it difficult to determine the influence of these characteristics. On the other hand, because the number of roads was limited and the number of respondents was much higher than expected, relatively many answers were given per road (about 650). This partly compensated for characteristics with a limited number of observations, since many respondents filled in a lower speed limit for the limited number of roads with the characteristic in question.

By making a comparison with the national figures of driving licence holders, a limited deviation was found between the distribution of the sample and the national distribution of men and women in various age groups. Men in the age categories from 40 to 70 years are over-represented. There are several possible causes for this. For example, men in the age group in question may find the subject more interesting than other driving licence holders, which made them more inclined to complete the survey. It is also possible that how the survey was disseminated attracted more attention among men. The survey was distributed through various channels to collect as many respondents as possible. The distribution did not specifically take into account possible representativeness of the sample. For example, the survey was distributed among employees of Goudappel Coffeng, within this company male employees are in the majority. The same may apply to the social media followers of municipalities, male followers may be in the majority.

If possible, it would have been better to carry out a sample representative of the Dutch B driving licence holders in terms of gender and age. In this case, a database with people from a research agency who have indicated that they wish to regularly participate in an investigation may be needed. However, within the limited scope of the survey, this was not a realistic option, so it was necessary to collect a sufficient number of respondents. However, the influence of a slightly different sample seems to be limited, as the analysis of personal characteristics hardly showed any difference in speed between men/women and different age groups.

Various regression analyses were carried out during the data analysis, including stepwise regression. The advantage of this method is that a relatively large number of explanatory variables can be added to the model. Based on some pre-specified criteria, a variable is added (forward regression) or removed (backward regression) at each step. Ultimately, a model remains in which only variables with a significant contribution to the dependent variable are included. However, the use of stepwise regression has been criticised in science.

For example, the stepwise procedure may choose nuisance variables rather than true variables. In this case, some real explanatory variables that have causal effects on the dependent variable may happen to not be statistically significant, while nuisance variables may be coincidentally significant. As a result, the model may fit the data well in-sample, but do poorly out-of-sample. These problems are more likely to be serious when there are a large number of potential predictors (Smith, 2018). It is therefore important to take account of any inaccuracies when interpreting the results of this regression analysis. That is why the forced entry method was also used. This method is more widely accepted. Within this method, all independent variables are entered into the equation at the same time. This is an appropriate analysis when dealing with a small set of predictors, therefore, this method was used when the number of explanatory variables was limited. However, in some cases, there were many explanatory variables and then the stepwise method was used.

Based on the results of the regression analysis, a tool (the credibility indicator) has been built with which an indication of the credibility can be obtained. The tool only indicates the credibility, this speed is not directly comparable to the actual speed driven. However, the results can be used for the first selection of roads that require modifications or a quick review of the design. The boundaries of the colour scales may be subjective, but give a clear interpretation of the result. Because the number of characteristics requested is limited, a result can be obtained within a very short period. All characteristics are easy to assess when photos or 3D images of the road are available. Only determining the road width takes more time, but this can easily be measured digitally in some programs.

Finally, the study assumed that better credibility leads to a lower speed. It is assumed that a speed reduction of up to 30 km/h is desired on a 30 km/h road. However, it is questionable to what extent this is the case. On a road, for example, the limit can be lowered from 50 km/h to 30 km/h to improve road safety or livability. But if the majority of car drivers then drive 30 km/h but some continue to drive 50 km/h or 60 km/h, this probably does not improve road safety. From this point of view, a more constant speed of, for example, 40 km/h may be more desirable. Reducing speed to the limit, therefore, does not always have to be an end in itself, a more constant speed may be more desirable. A more credible limit can also contribute to this.

Besides, it was implicitly assumed that a lower speed leads to improved road safety and quality of life. However, the results of the 'Het Nieuwe 30' research do not show that lower speeds lead to fewer accidents. On the contrary, a significant correlation has been found between a lower speed and more accidents. Probably this correlation is caused by the fact that on streets where there are many activities (e.g. shops, crossings, parking movements) the speed is lower, but because of the environmental influences (e.g.

vulnerable cyclists and pedestrians), more accidents occur as well. All in all, therefore, it cannot simply be assumed that more credibly designed roads always lead to fewer traffic accidents. Many factors play a role in this and it is important to understand the relationships between these factors.

## 9.2 Directions for further research

The research carried out can be classified as exploratory research. The literature review has shown that the current knowledge about the credibility of 30 km/h roads is very limited. At the start of the study, there was little knowledge about the expected results. Therefore, a lot of information was collected, both road and environmental characteristics as well as personal characteristics. By combining these data with the speeds of the respondents, a first step was taken to gain more insight into the credibility of 30 km/h roads.

The study offers sufficient starting points for follow-up research. As mentioned earlier, the number of 30 km/h roads in the survey was limited. As a result, the diversity of some characteristics was also limited, leading to insufficient insight into the influence of some characteristics on credibility. Therefore, in a possible follow-up study, a larger group of 30 km/h roads could be used in which more characteristics are represented. In this way, a more complete overview of the influence of various characteristics can be obtained.

In addition to the survey, experiments with a driving simulator are a possible next step. The research proposal already discussed the possibilities of a driving simulator. However, due to a lack of time and the corona outbreak, it was not used. Various types of 30 km/h roads can be recreated in a 3D environment, after which car drivers can drive these roads in the driving simulator. Besides, it is possible to vary the relevant road and environmental characteristics to determine the effect of the characteristics on the speed. This allows the results of the survey to be validated.

Currently, both the influence of road characteristics and the influence of the personal characteristics on credibility have been investigated independently. However, the analysis can be extended by examining the influence of possible interactions between road characteristics and personal characteristics on credibility. For example, the influence of the road characteristics may depend on personal characteristics. Earlier research described in the literature analysis showed, for example, that young people allow themselves to be influenced by fewer characteristics than older car drivers. By carrying out analyses for different types of persons, new insights can be obtained.

Work can also continue on the application of credibility on 30 km/h roads. At this moment, a credibility indicator has been drawn up based on the results of the study. Because the number of characteristics to be filled in is still limited, an indication of the credibility can be obtained very quickly. However, when more information on the influence of characteristics on credibility is found, the existing credibility indicator can be expanded by adding more characteristics. It is expected that credibility can then be determined more accurately. Moreover, comparable indicators can be made for other themes, such as a speed indicator and a liveability indicator based on the results of the 'Het Nieuwe 30' study. Eventually, all indicators could be combined into one complete indicator in which, based on the characteristics of a 30 km/h road, a complete overview can be made of the expected consequences on themes such as speed, credibility and liveability. The described tool is only a first step in an attempt to make it applicable to the results, there is sufficient potential to improve the tool in the future.

# 10 Conclusion and recommendations

This chapter provides the conclusion (section 10.1) and recommendations (section 10.2) based on the results of the study.

## 10.1 Conclusion

The main question of the study was: 'How can existing 50 km/h roads within built-up areas be efficiently transformed into credible 30 km/h roads, thereby reducing speed in favour of road safety?'. Three different sub-questions have been drawn up, which together answer the main question.

The first sub-question is aimed at determining the credibility of the existing 30 km/h roads. First, it is determined how credibility can be quantified. The literature contains a limited number of studies quantifying the credibility of speed limits by drivers. In most studies, drivers are asked with which speed they would drive on the road if they were not familiar with the speed limit or if there was no speed limit. Drivers were also asked what speed they would find safe and what they think the actual speed limit is. The operationalisation used in this study is based on the previous operationalisations in the literature. Drivers were shown pictures of various 30 km/h roads in a survey, each time asking the same two questions: 'What speed would you choose on this road' and 'What do you think the speed limit is on this road'. Next, the difference between the respondents' answers and the speed limit was used as an indication of credibility.

Respondents' answers show that the preferred speed and measured speed are often very much related to each other. For all 30 km/h roads in the survey, the average given preferred speed was 38.3 km/h and the average estimated limit was 39.2 km/h. So both speeds are close to each other and the estimated limit is on average slightly higher than the preferred speed. A further analysis per estimated speed limit shows that this difference is mainly caused when an estimated limit of 50 km/h or 60 km/h was chosen, in these cases the preferred speed was often lower than the limit. If the limit was estimated at 15 km/h or 30 km/h, the preferred speed was generally higher than the estimated limit. When comparing the average preferred speeds and estimated limits per road, there are large differences between roads. The preferred speed ranges from 21 km/h to 50 km/h, while in all cases the applicable speed limit is 30 km/h.

Therefore, there was sufficient potential to explain these differences in credibility by investigating the influence of road and environmental characteristics on speed. This was investigated together with the influence of personal characteristics on speed in the second sub-question. First, the individual influence of each characteristic on speed was investigated. The results show that environmental characteristics have the most influence on credibility. Roads with shops, connected buildings and buildings on both sides of the road are characteristics that contribute most to credibility and reducing speed. The distance to buildings next to the road also has a significant influence on speed. In general, the greater the distance, the higher the speed. Additionally, various characteristics of the road have a significant influence on credibility, especially the presence of parked cars and the location of cyclists (mixed with other traffic instead of bicycle lanes).

Using various regression analyses, different combinations of characteristics were combined to investigate the joint effect on speed. Using the most significant characteristics of the road and its surroundings from the previous data analysis, a considerable part of the variation in speed can be predicted (about 70%). When only more adjustable road characteristics are used to predict speed, less than 40% of the variation in speed can be predicted. Environmental characteristics, therefore, play an important role in determining the credibility of a road.

The answers given by the respondents show that there is a lot of difference between speeds. Therefore, the survey also asked for some personal characteristics to be able to explain the spread in answers, examples are age, gender, car use and use of other means of transport. Analysis of the influence of these characteristics on speed, however, shows that it is not possible to explain the speed of respondents with the requested characteristics. It may be due to the method used (questions of preferred speed in a survey) that no correlation has been found. It is also possible that other, unrequested characteristics can (partially) explain the dispersion, such as the need for sensation.

Subsequently, the third sub-question examined how roads can be made more credible by combining the results of the previous sub-questions with existing methods and other information. An existing method for comparing the credibility of roads ('Safe speeds and credible speed limits') was tested. However, the credibility scores of roads turn out to have no relation whatsoever with both the speeds of respondents and the measured speeds. For this reason, a new credibility indicator tool has been developed that can be used to determine the credibility of 30 km/h roads more accurately. This indicator is based on the results of the data analysis and requires some road and environmental characteristics to be entered. After the entry of these characteristics, an indication of the credibility is directly displayed on a speedometer.

The impact of several other measures (enforcement, rewarding and nudging) on speed and credibility was also examined. Rewarding and nudging are not suitable for application on a large scale and the effect appears to be very limited on a small scale. If there is an effect, it appears to be short-term only. Enforcement is seldom applied on 30 km/h roads because the police have too little capacity and do not give priority to these roads. This is because the police believe that the layout of the roads should be improved first (more credible layout) before the police take any measures.

All in all, many factors are important in making roads more credible, whether it concerns the improvement of 30 km/h roads or the conversion of 50 km/h roads to 30 km/h roads. Since various environmental characteristics seem to have the greatest impact on credibility, it is first of all important to investigate whether the street fits in with its surroundings. When the characteristics of the environment contribute to credibility, it will become much easier to improve credibility. Next, the described characteristics of the road with the most influence on credibility can be applied to improve the credibility efficiently.

## 10.2 Recommendations

There is no simple solution to make roads with a 30 km/h limit more credible. Many characteristics of both the road and its surroundings affect credibility. Furthermore, several interactions between the characteristics need to be taken into account. Moreover, dynamic characteristics (such as other road users and weather conditions) and personal characteristics (of which there is currently insufficient insight) play a role in assessing the credibility of a certain car driver at a certain moment in time on a certain road. Therefore, there is an interplay of all kinds of interrelated characteristics. As a result, it is practically impossible to design a road in such a way that it is credible for everyone. It is, however, possible to make the road more credible for (almost) everyone with the help of certain modifications, because car drivers largely allow themselves to be influenced by the same road and environmental characteristics.

Based on the results, the environmental characteristics seem to have the most influence on credibility. Shops, contiguous buildings and buildings on both sides of the road contribute most to improving credibility and reducing speed. Distance to buildings also has a significant impact on credibility, greater distance leads to a higher speed. Although these characteristics are not easy to change, it is recommended to take them into account. They can be used to determine in which streets a transition to a 30 km/h limit seems most likely given the characteristics of the environment. Using the characteristics of the environment, it can be tested whether these characteristics fit a credible 30 km/h road. If the characteristics of the environment match the characteristics that also contribute positively to the credibility, it is much more likely that a possible new speed limit of 30 km/h will later also be assessed as credible by drivers. In addition, some more easily applicable road characteristics may be applied to enhance credibility, such as the addition of parking spaces for cars, the use of clinkers, and allowing cyclists to ride mixed between cars on the same lane.

The created credibility indicator is a first step towards the application of the results and can give the road administrator more insight into the roads that deserve extra attention concerning credibility and speed. The design of existing roads and potential designs of new roads can be tested. Ultimately, this can lead to adjustments to the limit or adjustments to the road and its surroundings in favour of credibility.

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# Appendix A: Survey content

Beste meneer/mevrouw,

Universiteit Twente en verkeersadviesbureau Goudappel Coffeng doen onderzoek naar snelheden op wegen. Met uw antwoorden kan worden onderzocht welke factoren invloed hebben op de snelheid, hiermee kan uiteindelijk de verkeersveiligheid worden verbeterd.

De vragenlijst bestaat uit drie delen. In het eerste deel worden enkele persoonlijke vragen gesteld. Vervolgens worden in het tweede deel vragen gesteld bij foto's van wegen. Ten slotte bevat het laatste deel enkele vragen over de door u gebruikte vervoermiddelen.

Het invullen van de antwoorden duurt ongeveer tien minuten. Door het invullen van de enquête maakt u kans op één van de vijf VVV Cadeaubonnen van € 25,-. Uw antwoorden worden anoniem verwerkt.

Alvast hartelijk dank voor uw medewerking!

Volgende

UNIVERSITY OF TWENTE.

Wat is uw geslacht?

- ◯ Man
- ◯ Vrouw
- ◯ Anders / wil ik niet zeggen

---

Wat is uw leeftijd?

---

Ben u in het bezit van een rijbewijs voor het besturen van personenauto's (rijbewijs B)?

- ◯ Ja
- ◯ Nee

---

Hoeveel kilometer per jaar rijdt u gemiddeld als bestuurder met een auto? Als u het niet precies weet, dan kunt u een schatting maken.

→

In dit deel van de enquête worden foto's van verschillende wegen getoond. Probeert u zich bij elke foto voor te stellen dat u de bestuurder van een auto bent die op deze weg rijdt. Bij elke foto worden steeds dezelfde twee vragen aan u gesteld.

Eerst volgt een voorbeeldfoto met daaronder uitleg over de vragen. **Let op**: deze vragen zijn een voorbeeld en de antwoorden tellen nog niet mee voor de resultaten.

---

Met welke snelheid zou u hier rijden?

*Het gaat bij deze vraag om het aangeven van de snelheid die u verwacht te rijden op de betreffende weg, zonder dat u bekend bent met de snelheidslimiet. De snelheid kunt u aangeven door het bolletje te plaatsen (klikken op balk i.p.v. slepen is ook mogelijk) op de snelheid die u ongeveer verwacht te rijden op de weg. U hoeft niet precies op vijf- of tientallen uit te komen, alle snelheden zijn een mogelijk antwoord.*

snelheid in km/u

10 15 20 25 30 35 40 45 50 55 60 65 70

Plaats het bolletjes op de gewenste snelheid

Welke snelheidslimiet denkt u dat hier geldt?

*Bij deze vraag kunt u aangeven wat u denkt dat de snelheidslimiet is van de weg op de foto. Deze snelheid hoeft niet overeen te komen met uw eerder gegeven antwoord, verschillen zijn mogelijk. U kunt steeds kiezen uit een aantal bestaande snelheidslimieten.*

- ○ 15 km/u (woonerf)
- ○ 30 km/u
- ○ 50 km/u
- ○ 60 km/u

Probeer steeds weer zo goed mogelijk uw antwoorden te bepalen. Teruggaan naar eerder ingevulde antwoorden is niet mogelijk en ook niet nodig. Het is de bedoeling dat u elke foto apart beoordeeld op het moment dat u de foto ziet. Probeer steeds uw eerste indruk te volgen.

Nu komen de foto's met de vragen.
Succes!

→

*20 questions like this, but each time with a different photo:*

Met welke snelheid (in km/u) zou u hier rijden?

10 15 20 25 30 35 40 45 50 55 60 65 70

Welke snelheidslimiet denkt u dat hier geldt?

- 15 km/u
- 30 km/u
- 50 km/u
- 60 km/u

→

Ten slotte worden er een aantal vragen gesteld over uw gebruik van vervoermiddelen. **Let op:** Vul deze vragen niet in voor uw huidige situatie i.v.m. de Corona maatregelen, maar voor uw situatie tijdens normale omstandigheden.

---

Hoe vaak maakt u gebruik van de auto voor onderstaande activiteiten?

| | 4 of meer dagen per week | 1-3 dagen per week | 1-3 dagen per maand | 6-11 dagen per jaar | 1-5 dagen per jaar | Nooit |
|---|---|---|---|---|---|---|
| Naar het werk gaan (woon-werkverkeer) | ○ | ○ | ○ | ○ | ○ | ○ |
| Zakelijk reis in de werksfeer (reizen voor het werk) | ○ | ○ | ○ | ○ | ○ | ○ |
| School/studie | ○ | ○ | ○ | ○ | ○ | ○ |
| Doen van dagelijkse boodschappen | ○ | ○ | ○ | ○ | ○ | ○ |
| Winkelen | ○ | ○ | ○ | ○ | ○ | ○ |
| Bij iemand op bezoek gaan | ○ | ○ | ○ | ○ | ○ | ○ |

→

Hoe vaak maakt u gebruik van onderstaande overige vervoermiddelen naast de auto?

| | 4 of meer dagen per week | 1-3 dagen per week | 1-3 dagen per maand | 6-11 dagen per jaar | 1-5 dagen per jaar | Nooit |
|---|---|---|---|---|---|---|
| Trein | ○ | ○ | ○ | ○ | ○ | ○ |
| Bus/tram/metro | ○ | ○ | ○ | ○ | ○ | ○ |
| Motor/bromfiets/snorfiets | ○ | ○ | ○ | ○ | ○ | ○ |
| Fiets/e-bike | ○ | ○ | ○ | ○ | ○ | ○ |
| Lopen | ○ | ○ | ○ | ○ | ○ | ○ |

→

Hoe belangrijk zijn de onderstaande aspecten voor u om voor een bepaald vervoermiddel te kiezen? Ik wil ...

| | Zeer onbelangrijk | Onbelangrijk | Neutraal | Belangrijk | Zeer belangrijk |
|---|---|---|---|---|---|
| ... op een gezonde manier reizen | ○ | ○ | ○ | ○ | ○ |
| ... zo min mogelijk reiskosten kwijt zijn | ○ | ○ | ○ | ○ | ○ |
| ... op een comfortabele manier reizen | ○ | ○ | ○ | ○ | ○ |
| ... zo min mogelijk reistijd kwijt zijn | ○ | ○ | ○ | ○ | ○ |
| ... milieuvriendelijk bezig zijn | ○ | ○ | ○ | ○ | ○ |

→

Als dank voor het invullen van de enquête worden vijf VVV Cadeaukaarten ter waarde van € 25,- verloot. Vul uw e-mailadres in als u mee wilt doen aan de verloting. Het e-mailadres wordt uitsluitend gebruikt voor het verrichten van de loting en communicatie met de winnaars.


---

Wilt u kans maken op het winnen van een VVV Cadeaukaart?

- ◯ Ja, mijn e-mailadres is: __________
- ◯ Nee

→

Mogelijk wordt er een (kort) vervolgonderzoek gedaan waarbij er wordt gevraagd welke weg- en omgevingskenmerken u heeft gebruikt om te komen tot uw ingevulde snelheden. Vul uw e-mailadres in als u bereid bent hier aan deel te nemen. Het e-mailadres wordt uitsluitend gebruikt voor de selectie van respondenten en eventuele communicatie hierover.

---

Bent u bereid deel te nemen aan een mogelijk vervolgonderzoek?

- ◯ Ja, mijn e-mailadres is: ________
- ◯ Nee

---

Indien u verder nog opmerkingen over de enquête heeft, dan kunt u die hier kwijt:

→

Dit is het einde van de vragenlijst, hartelijk dank voor uw deelname!

Met uw antwoorden heeft u bijgedragen aan het in kaart brengen van de invloed van diverse weg- en omgevingskenmerken op de snelheid. Doel van het onderzoek is om de inrichting van wegen binnen de bebouwde kom te verbeteren ten gunste van de verkeersveiligheid.

Voor eventuele vragen en/of opmerkingen kunt u contact opnemen met Joran van Kessel (jvkessel@goudappel.nl).

U kunt dit venster nu sluiten.

# Appendix B: Overview characteristics

The table below shows all the characteristics (and corresponding categories) that were initially collected from all roads. The characteristics in italics relate specifically to the photo of the road. These characteristics could only be assessed based on the photographs.

| Characteristic | Description | Categories |
|---|---|---|
| **Road characteristics** | | |
| Road width | The continuous (paved) section of a road intended for use by vehicles. | Width rounded in half meters |
| Lane width | The width between the bicycle (suggestion) lanes, or equal to the road width if there is no marking or visual distinction on the road surface. | Width rounded in half meters |
| Pavement | Kind of pavement for cars | -grey asphalt<br>-red asphalt<br>-large clinkers<br>-small clinkers<br>-otherwise |
| *Shape* | The shape of the road (as visible in the photo) | -straight<br>-curved |
| Marking | Marking on the road. | -no<br>-middle<br>-bicycle lanes |
| Driving direction separation | How lanes of opposite directions are separated from each other. | -no separation<br>-small separation (e.g. clinker strip)<br>-physical separation |
| *Speed de-accelerators* | Speed decelerators (as visible in the photo) | -no<br>-speed bump<br>-narrowing<br>-plateau<br>-otherwise |
| *Junction* | Junction visible in proximity | -no<br>-yes |
| *Pedestrians/cyclists crossing* | Pedestrians/cyclists crossing visible nearby | -no<br>-yes |
| Location cyclists | Location of cyclists | -roadway<br>-bicycle (suggestion) lane<br>-separated bike path |
| Location of pedestrians | Location of pedestrians | -roadway<br>-footpath both sides<br>-footpath one side |
| **Dynamic characteristics** | | |
| *Vehicles* | Presence of other vehicles | -no<br>-own direction<br>-other direction<br>-both directions |
| *Cyclists* | Presence of other cyclists | -no<br>-own direction<br>-other direction<br>-both directions |
| *Pedestrians* | Presence of other pedestrians | -no<br>-own direction<br>-other direction<br>-both directions |
| *Other traffic* | Presence of other traffic (based on the answers to the previous three questions) | -no<br>-yes |

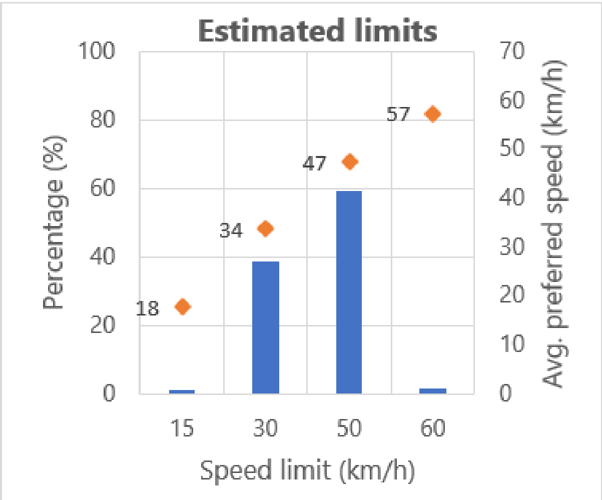
| Road environment characteristics | | |
|---|---|---|
| Lampposts | Lampposts beside the road | -no<br>-yes |
| *Parked cars* | Presence of parked cars beside the road | -no<br>-left and right side<br>-left side<br>-right side |
| Location parked cars | Parking type of cars | -not applicable<br>-on the road<br>-parallel<br>-perpendicular |
| Trees | Presence of trees beside the road | -no<br>-left and right side<br>-left side<br>-right side |
| Distance to trees | Distance to trees from the side of the road | -not applicable<br>-within 1 meter<br>-more than 1 meter |
| Tree density | Visibility of trees based on species, size and quantity | -not applicable<br>-small<br>-large |
| Hedges | Presence of hedges beside the road | -no<br>-left and right side<br>-left side<br>-right side |
| Distance to hedges | Distance to hedges from the side of the road | -not applicable<br>-within 1 meter<br>-more than 1 meter |
| Buildings | Presence of buildings beside the road | -no<br>-left and right side<br>-left side<br>-right side |
| Building density | Distance between buildings | -not applicable<br>-contiguous<br>-interruptions<br>-freestanding |
| Distance to buildings | Distance to buildings from the middle of the road | Distance in meter |
| Building height | The average height of buildings beside the road | -not applicable<br>-1/2 layers<br>-3 layers or more |
| Type of environment | The main function in the environment | -shopping<br>-living<br>-otherwise |
| *Clarity of the situation* | Clarity of the situation based on objects present and visibility to all sides | -clear<br>-average<br>-complex |

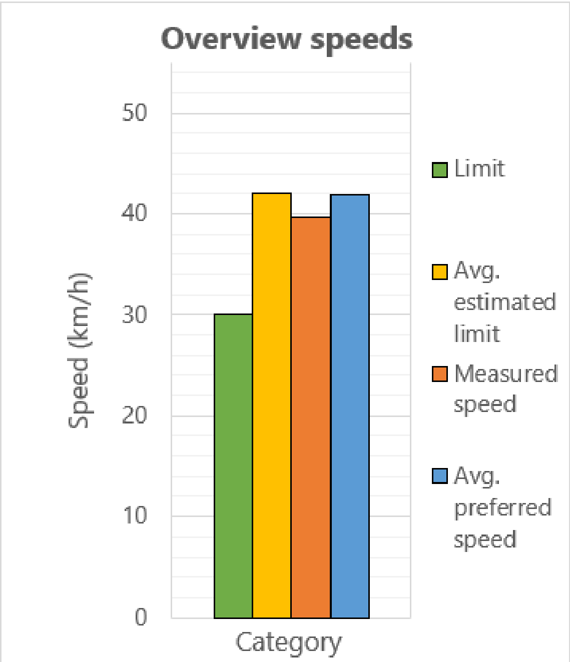
# Appendix C: Overview speeds per road

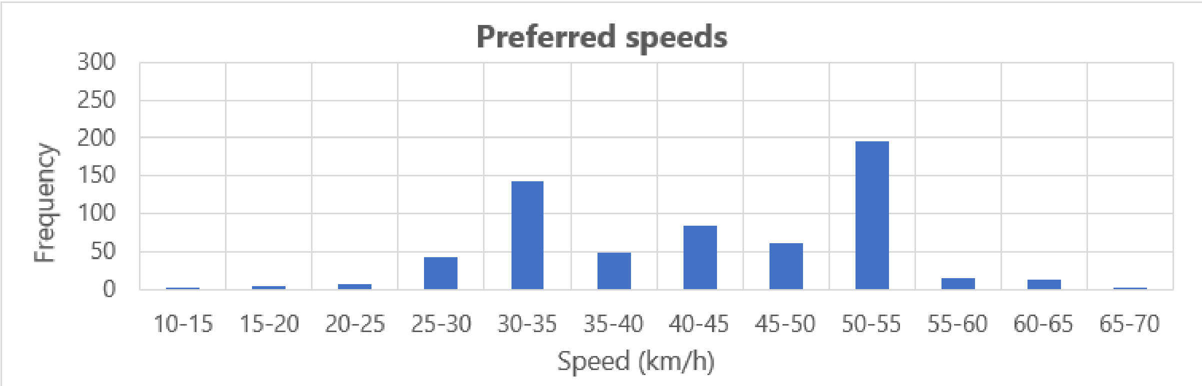
On the pages below an overview is provided of the given answers per road and the photos of the roads are shown. Three graphs are shown for each road:

- Estimated limits: per limit, the percentage of respondents that chose this option is displayed. Besides, using the orange dots, the average preferred speed of the respondents who chose the limit in question is shown.
- Overview speeds: the speed limit, the average estimated limit by the respondents, the measured (HERE) speed and the average preferred speed given by the respondents.
- Preferred speeds: for each class, the frequency is presented to show the distribution of the chosen preferred speeds.

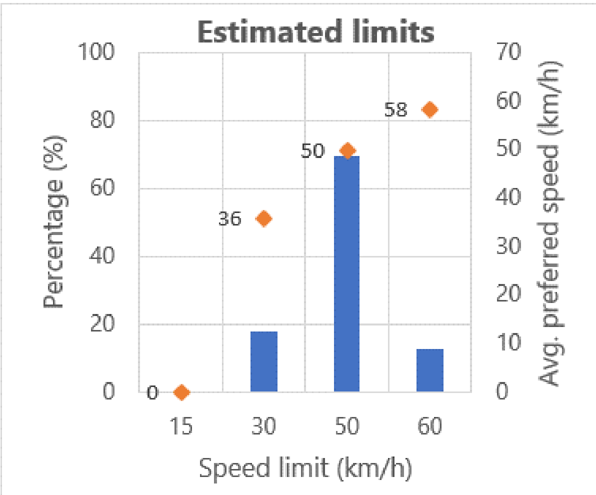
**Number:** 1
**Street:** Maliesingel
**Place:** Utrecht

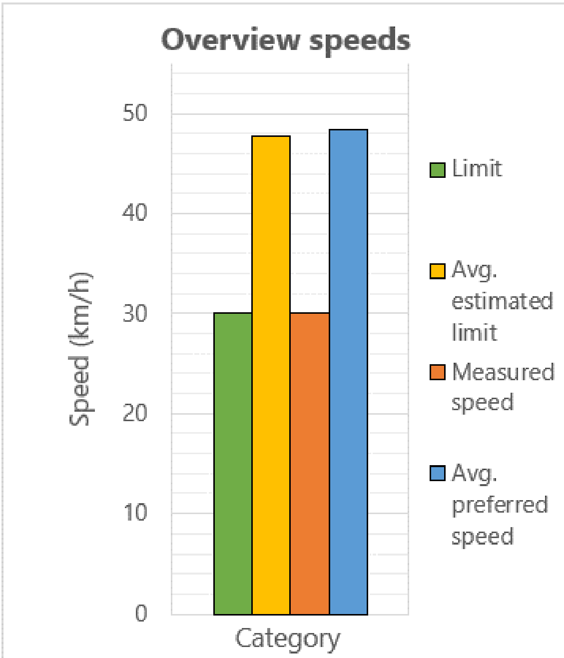


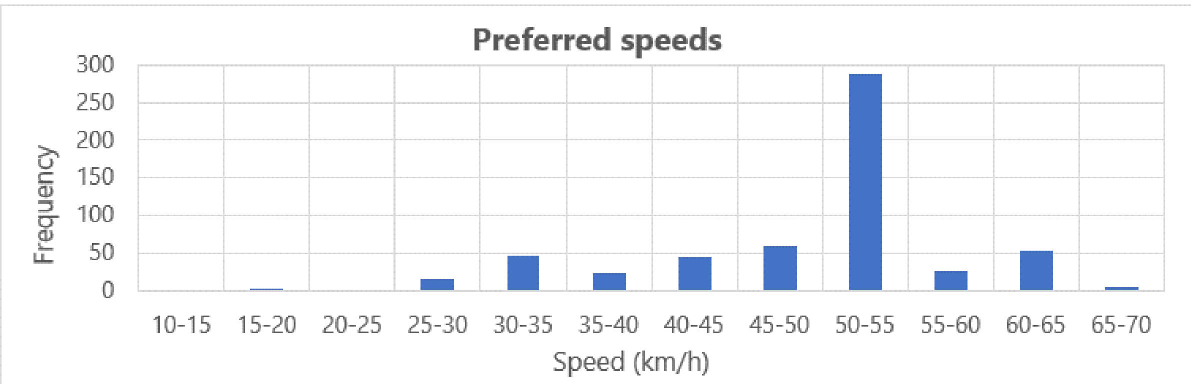



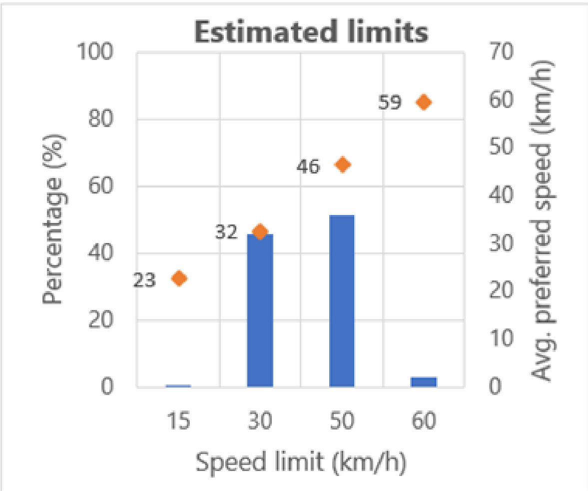
**Number:** 2
**Street:** Bornberg
**Place:** Amersfoort

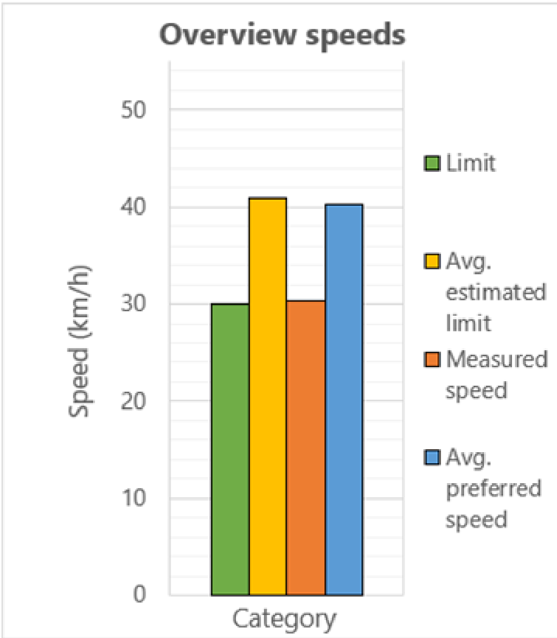


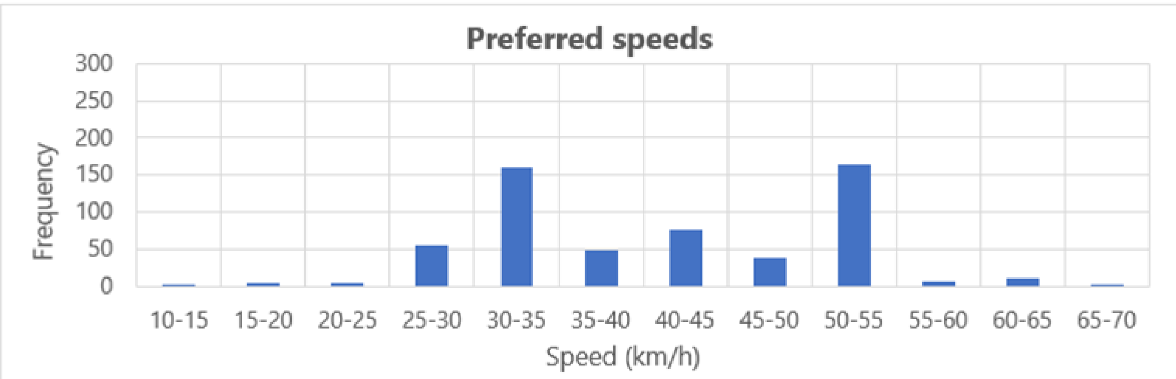



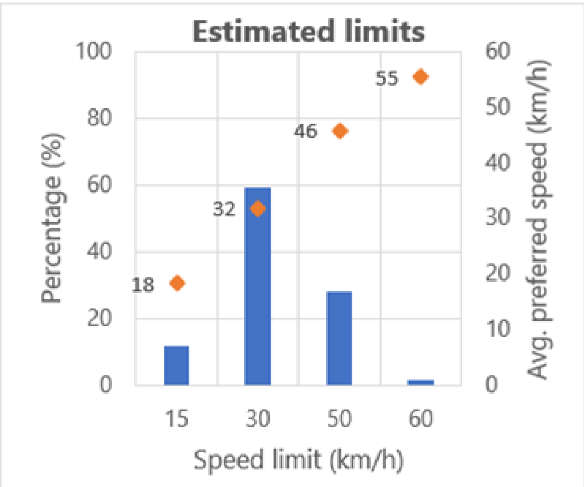
**Number:** 3
**Street:** Vrouwenpolder
**Place:** Amersfoort

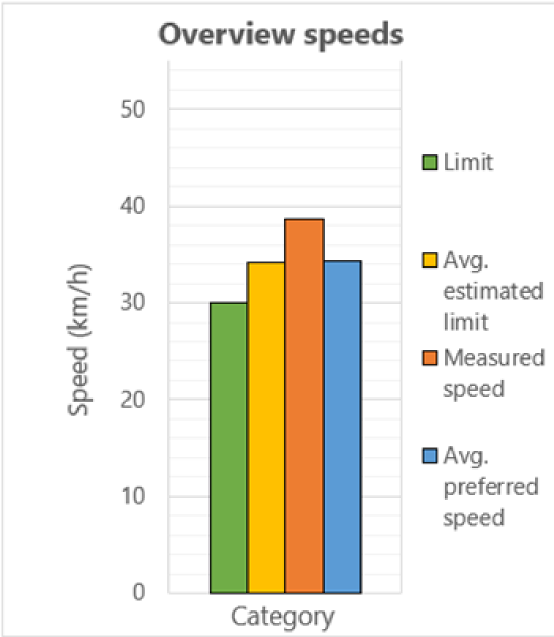


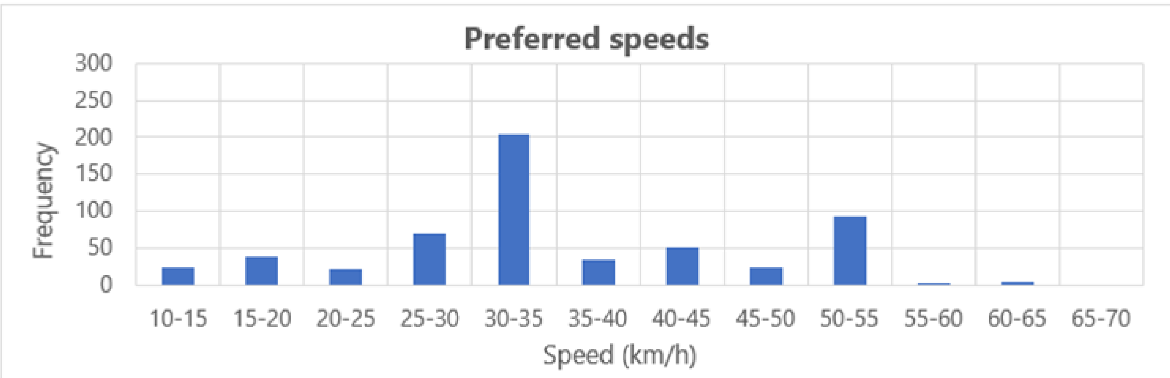



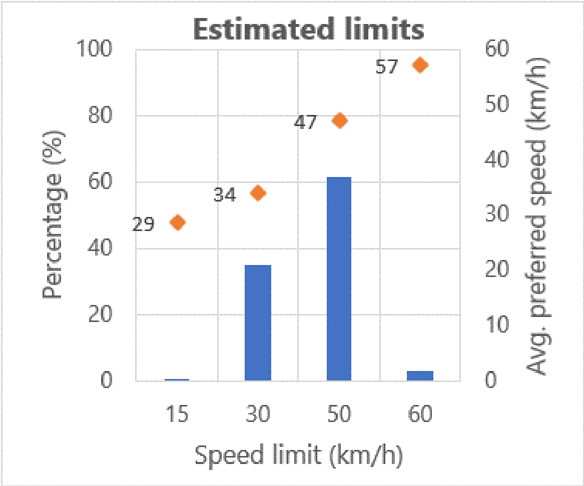
**Number:** 4
**Street:** Laauwikstraat
**Place:** Nijmegen

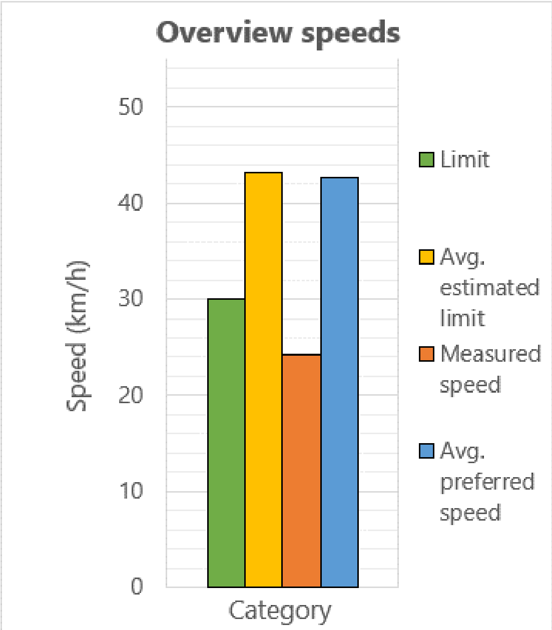


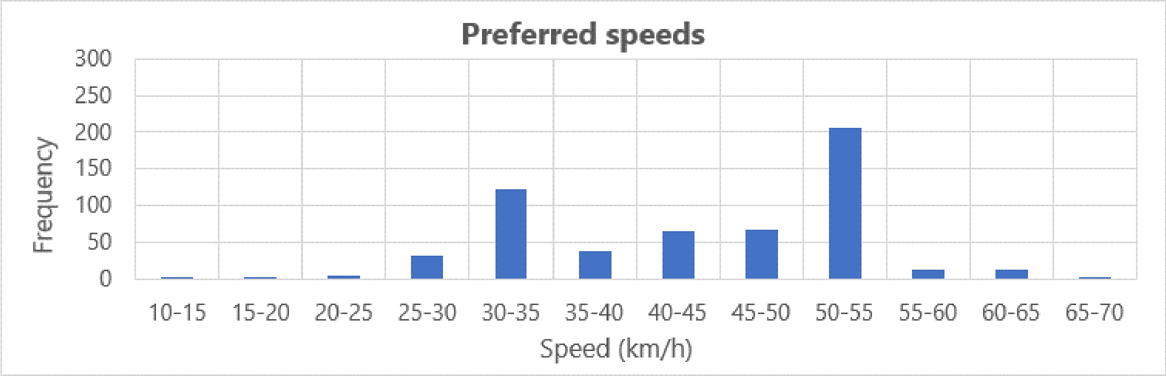



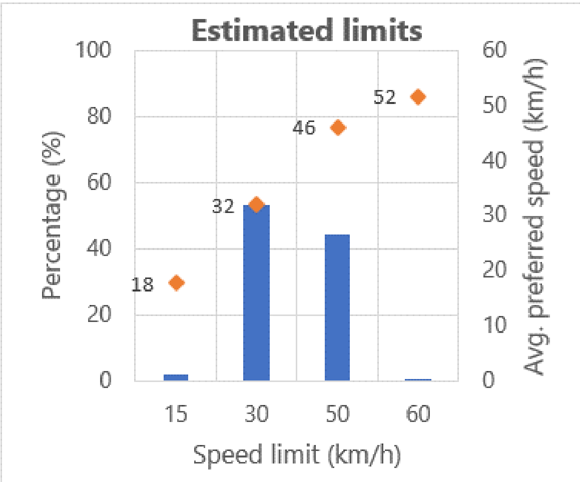
**Number:** 5
**Street:** Martinetsingel
**Place:** Zutphen

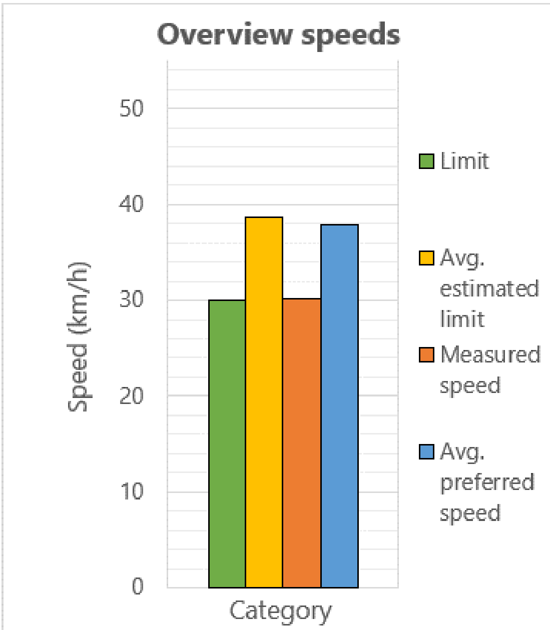


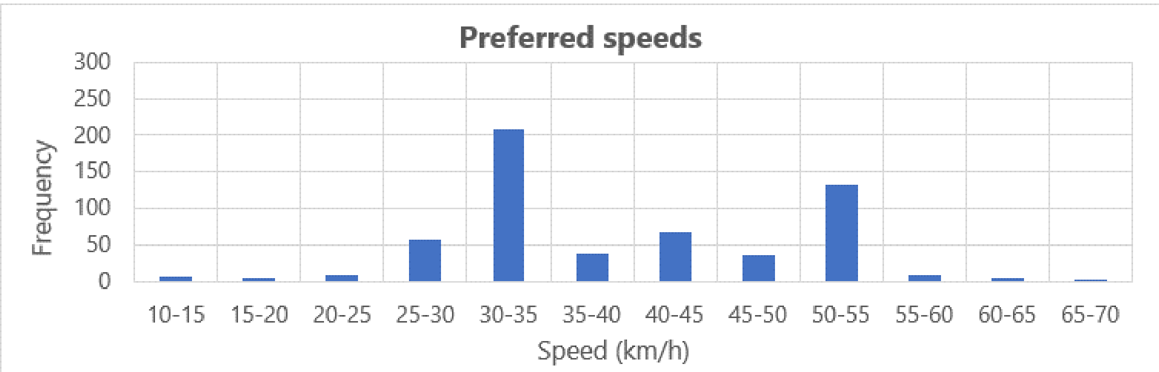



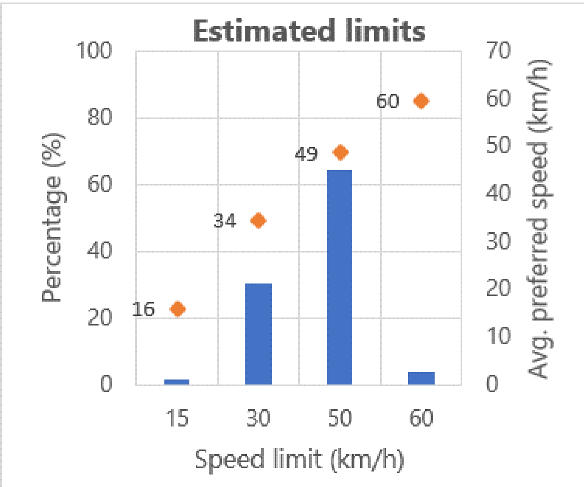
**Number:** 6
**Street:** Albertus van Leeusenweg
**Place:** Deventer

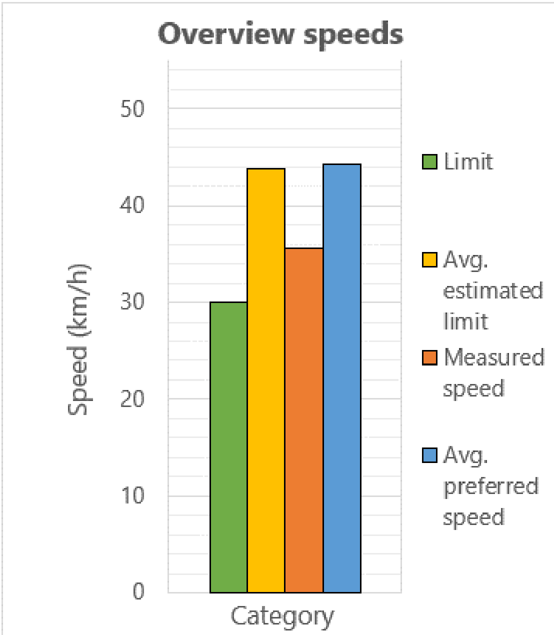


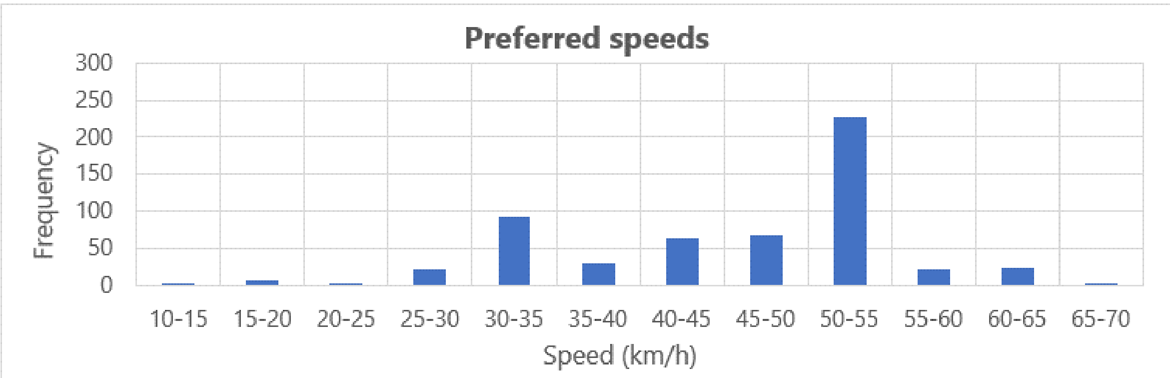



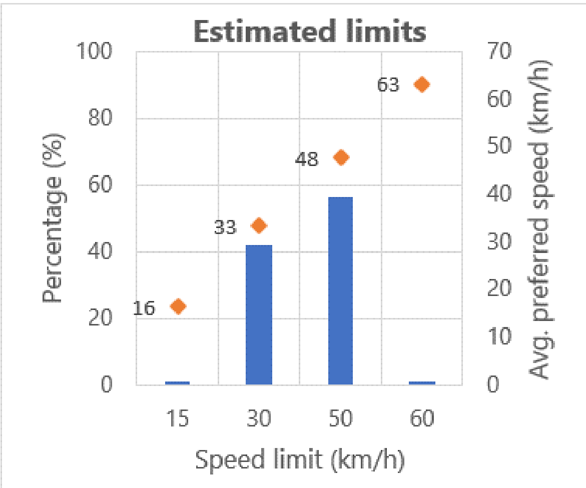
**Number:** 7
**Street:** Oldenzaalsestraat
**Place:** Denekamp

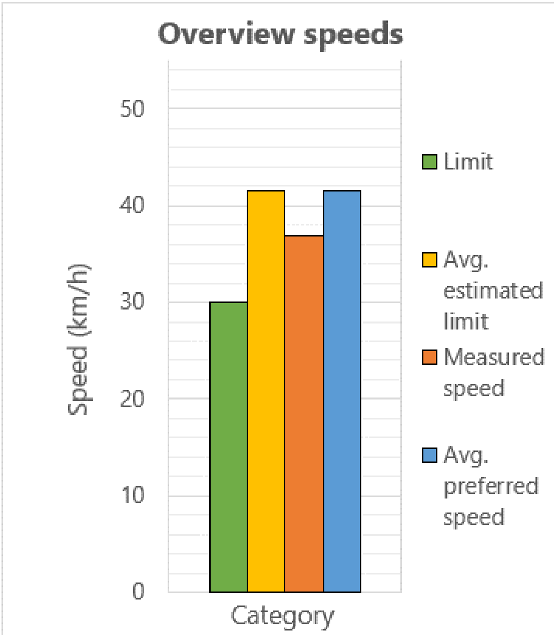


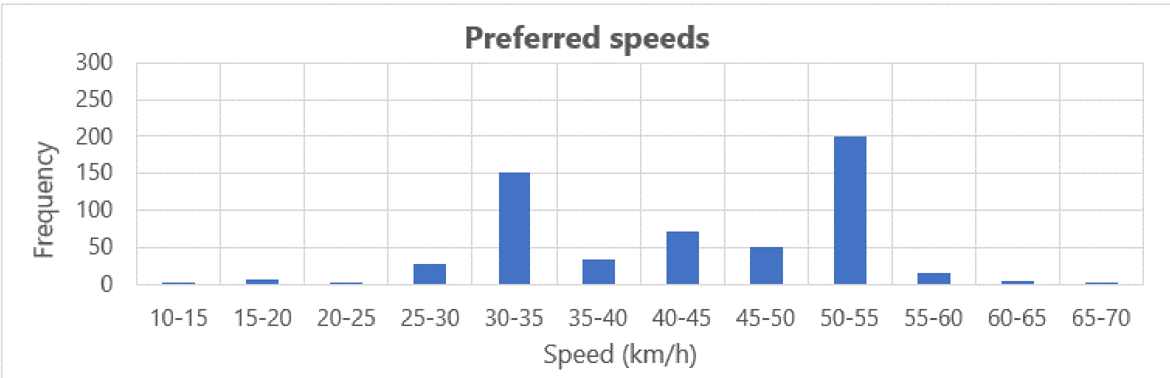



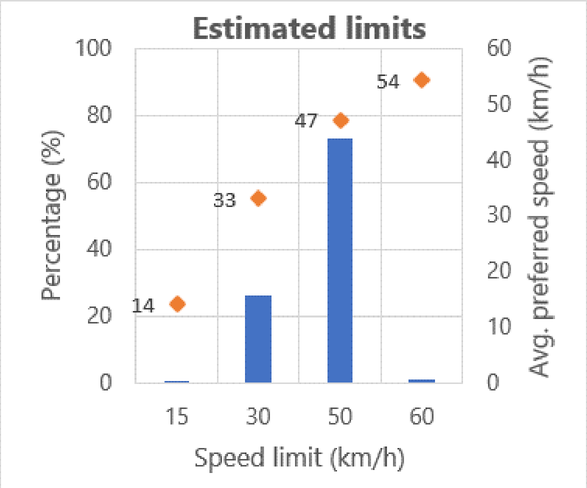

**Number:** 8
**Street:** Hoofdstraat
**Place:** Voorthuizen

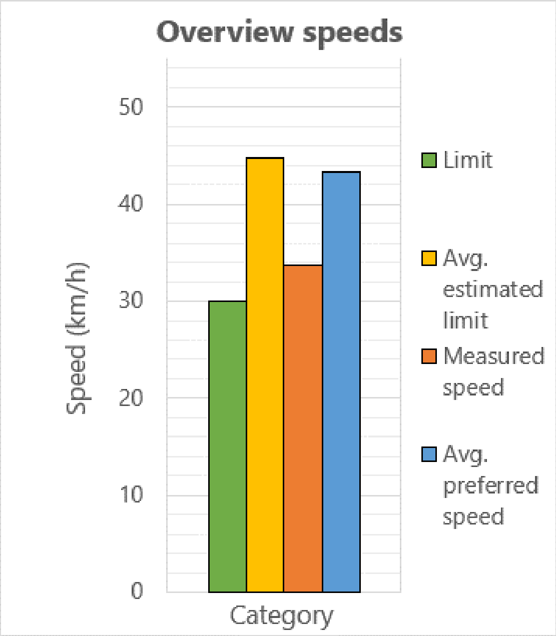


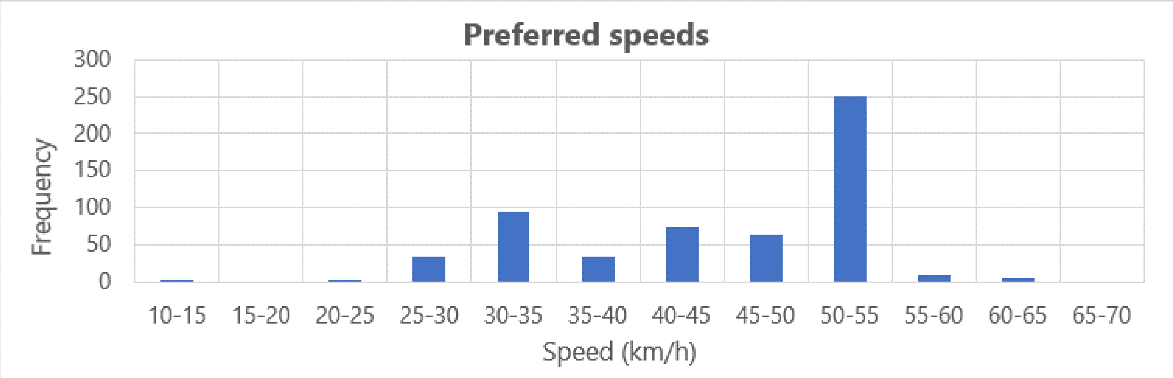



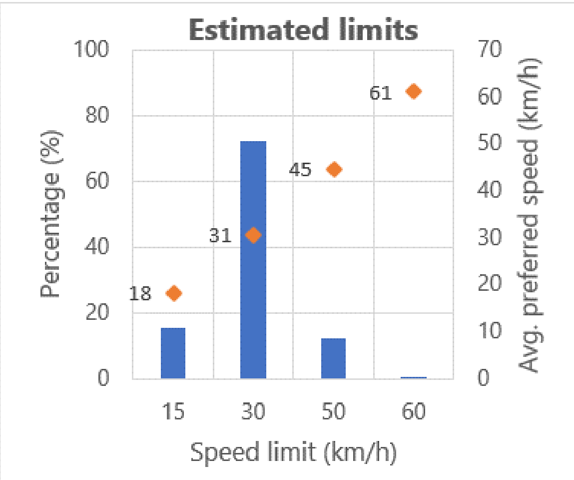
**Number:** 9
**Street:** KNSM-laan
**Place:** Amsterdam

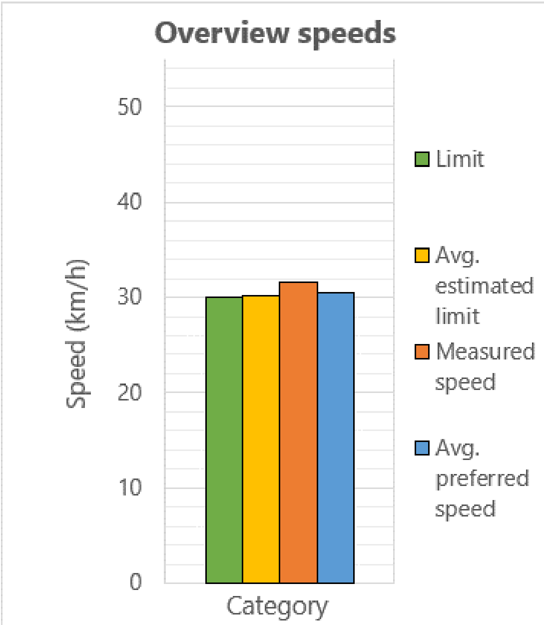


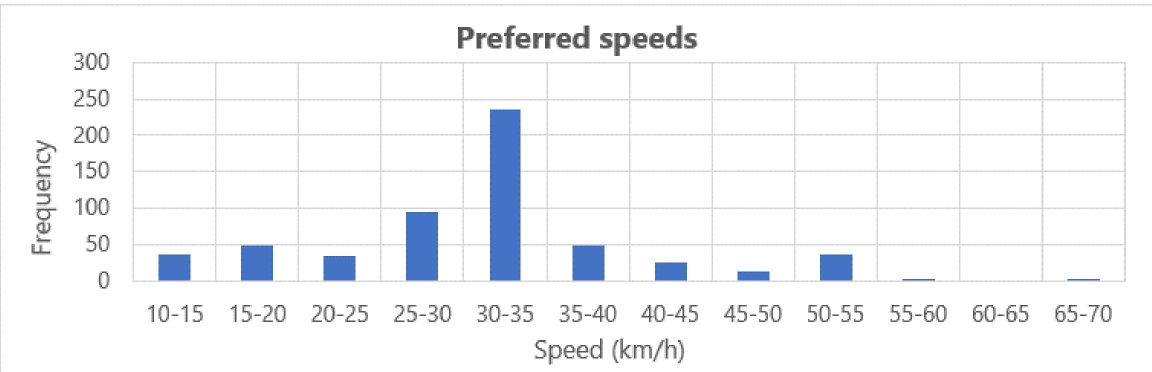



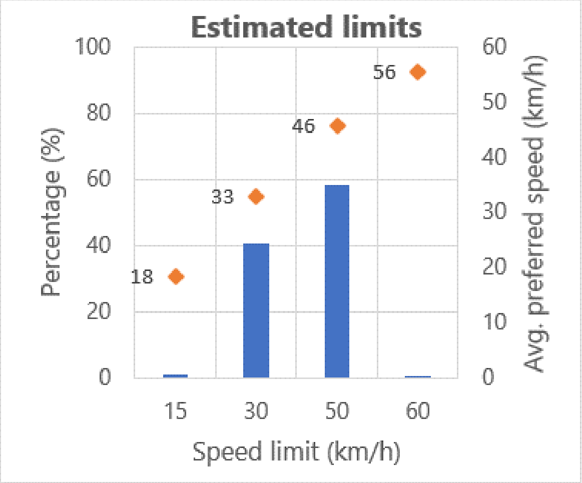
**Number:** 10
**Street:** Dorpsstraat
**Place:** Castricum

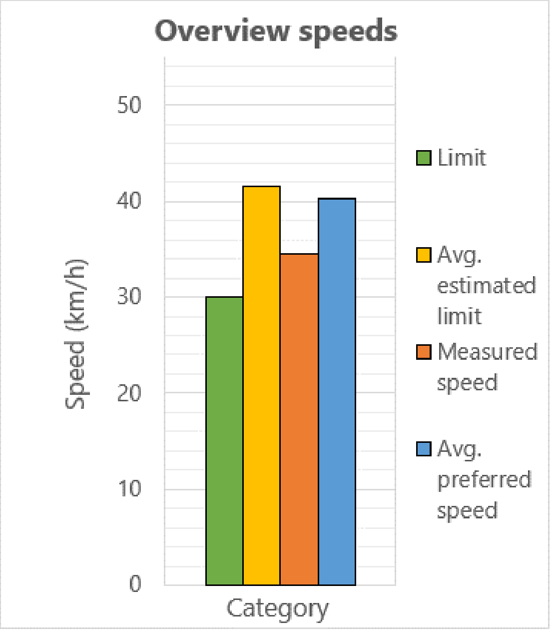


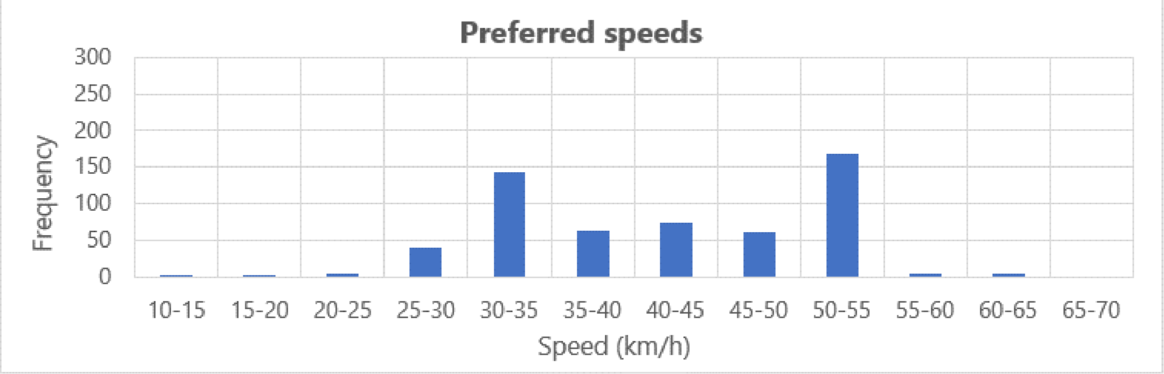



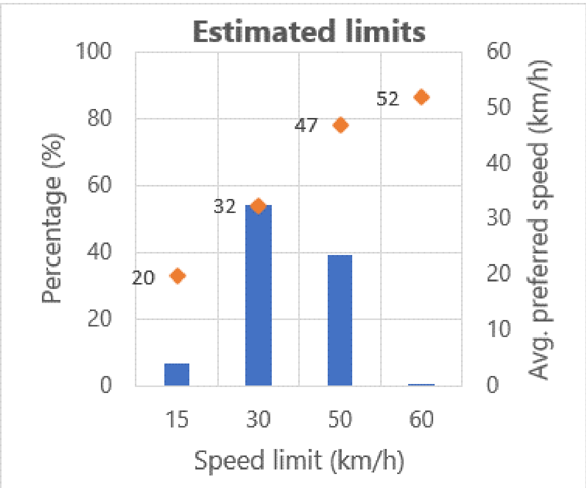
**Number:** 11
**Street:** Westerstraat
**Place:** Enkhuizen

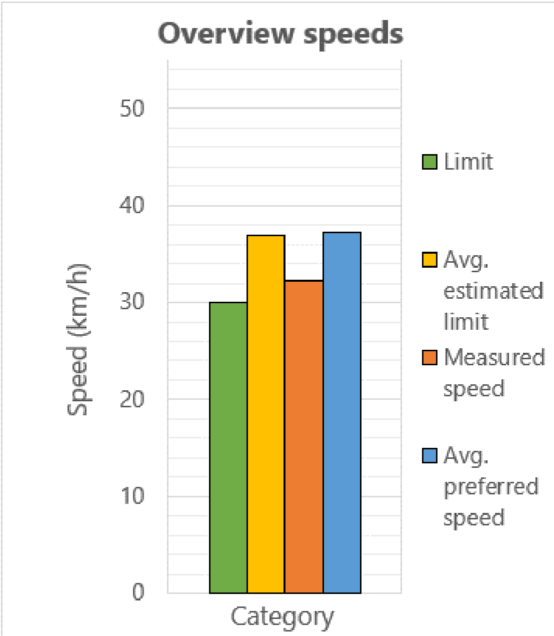


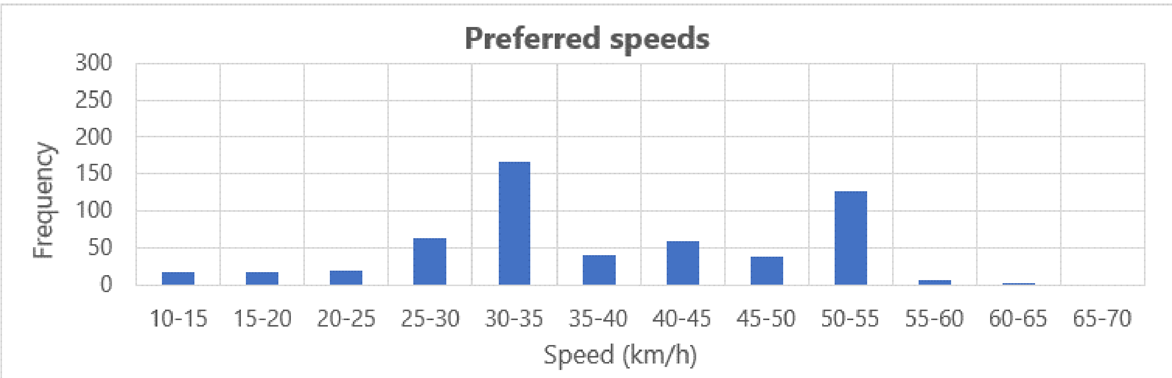



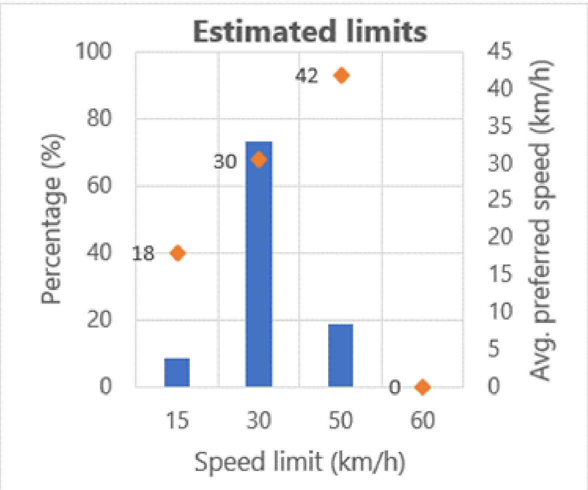
**Number:** 12
**Street:** Van Heutszsingel
**Place:** Coevorden



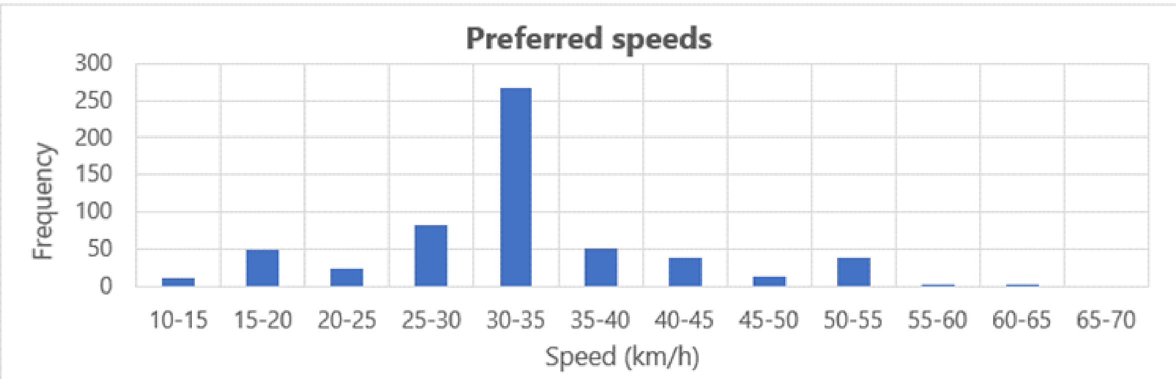



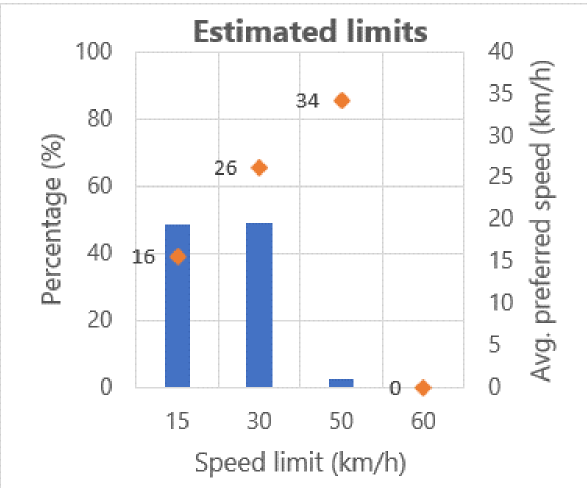
**Number:** 13
**Street:** Stationsstraat
**Place:** Assen

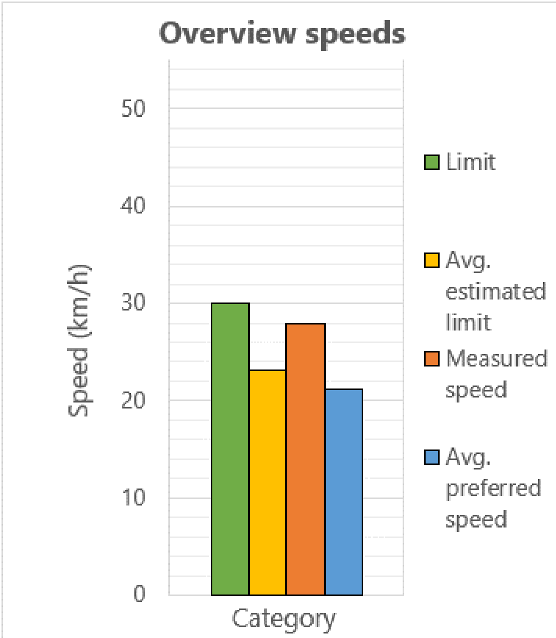


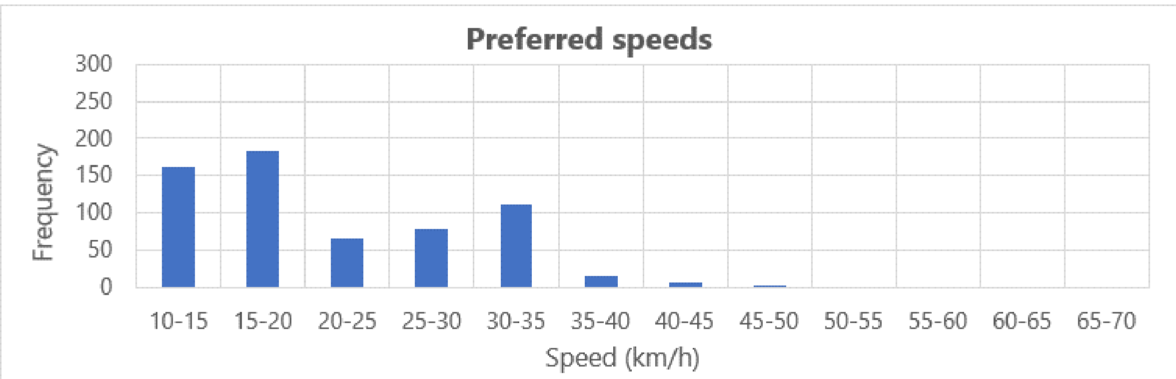




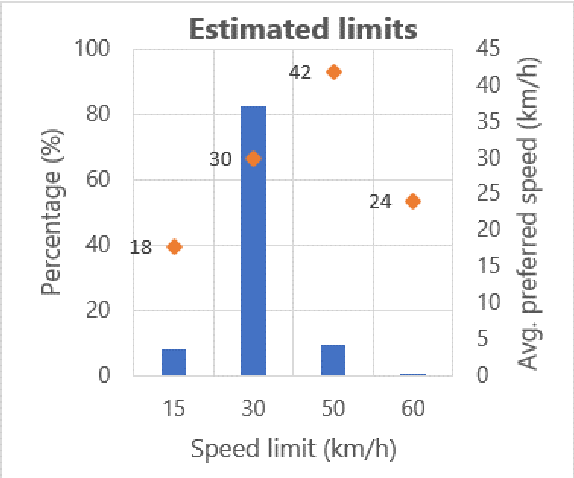
**Number:** 14
**Street:** Buorren
**Place:** Akkrum

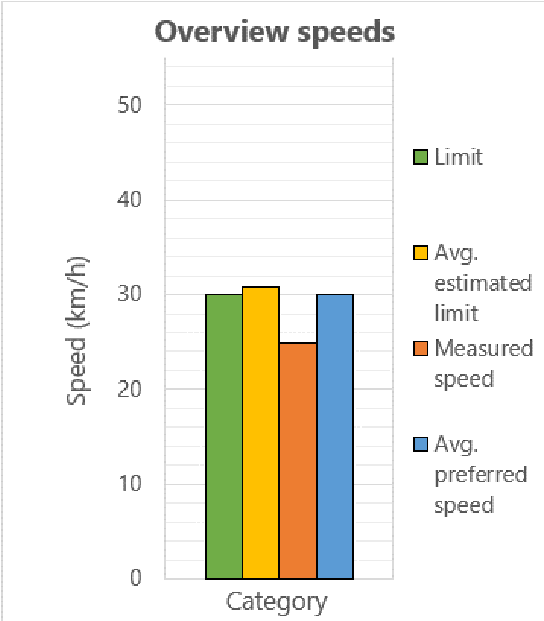


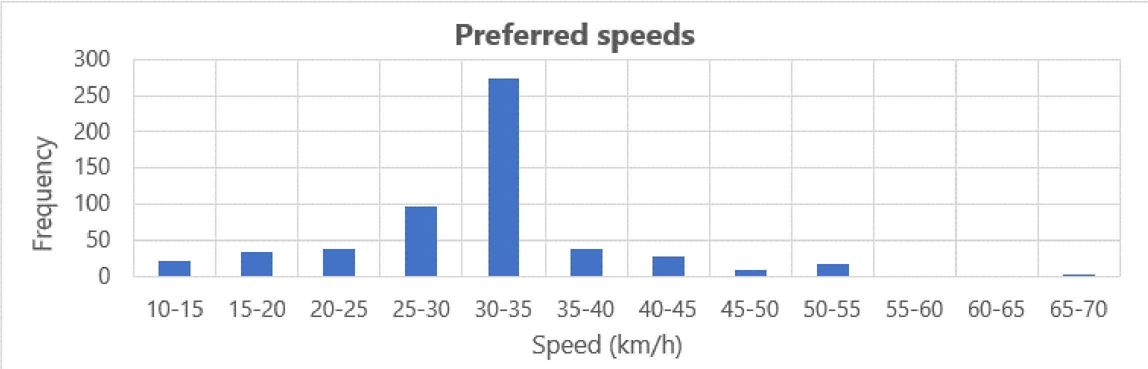



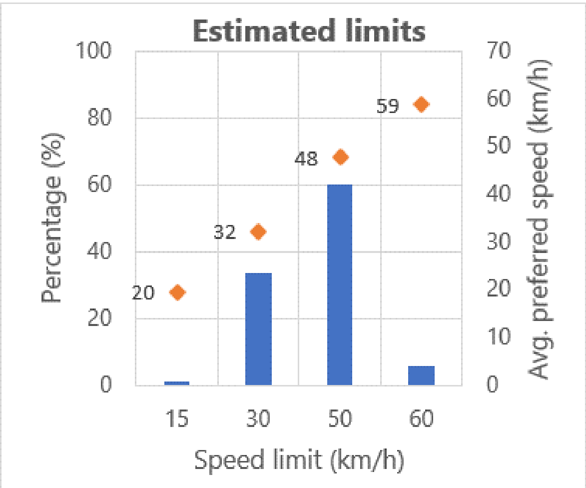

**Number:** 15
**Street:** Kruisweg
**Place:** Hoofddorp

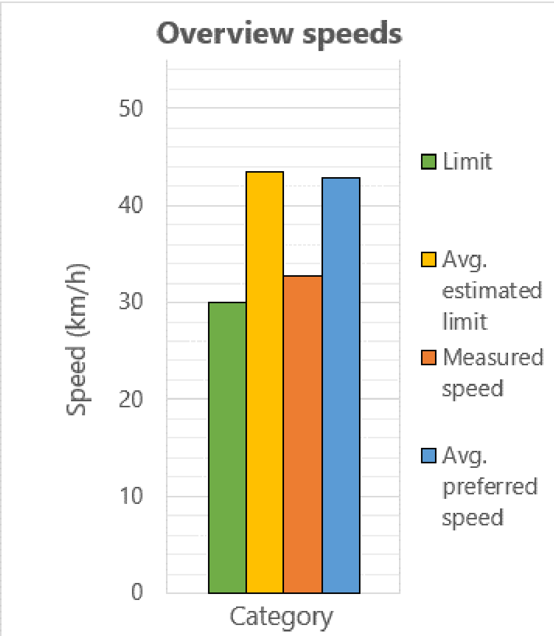


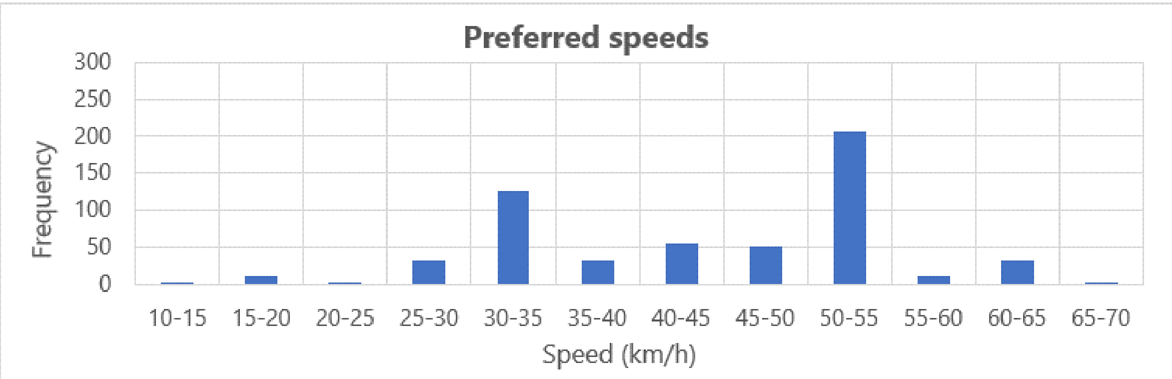



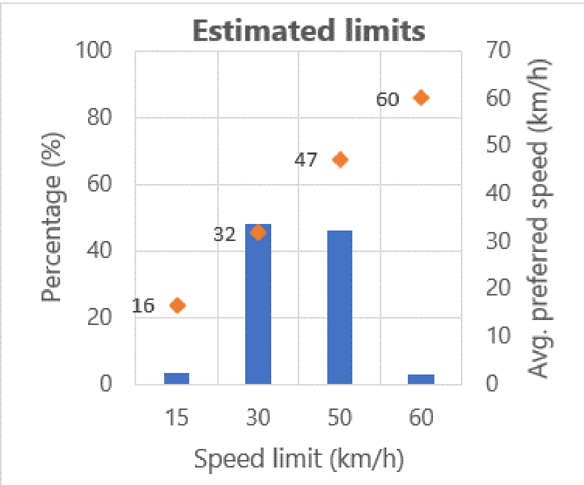
**Number:** 16
**Street:** Noordhoeklaan
**Place:** Goes

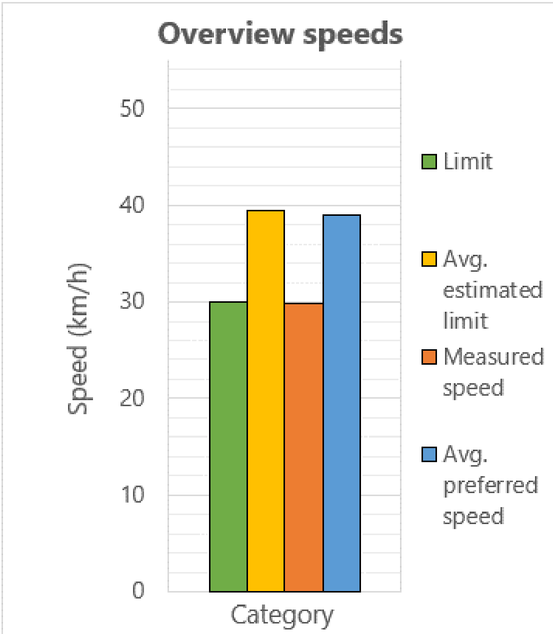


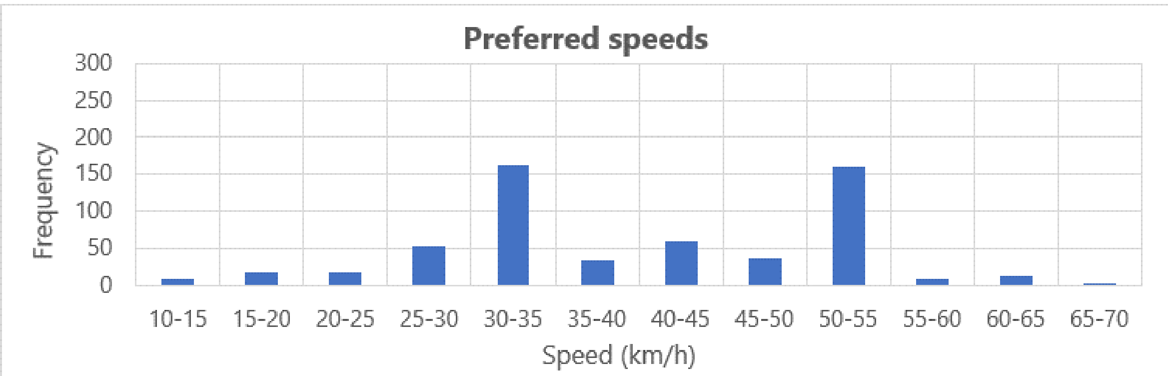



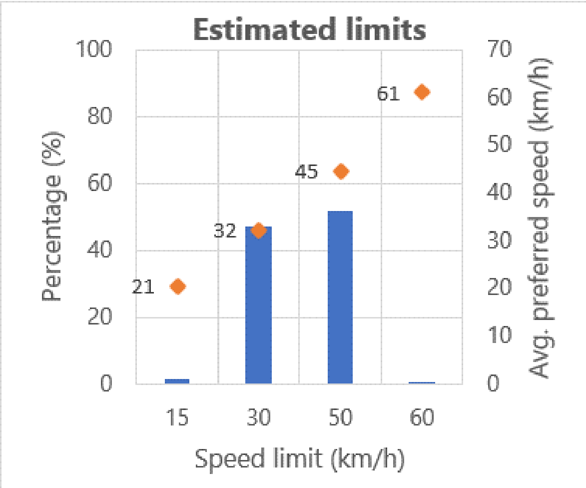
**Number:** 17
**Street:** Boulevard de Ruyter
**Place:** Vlissingen

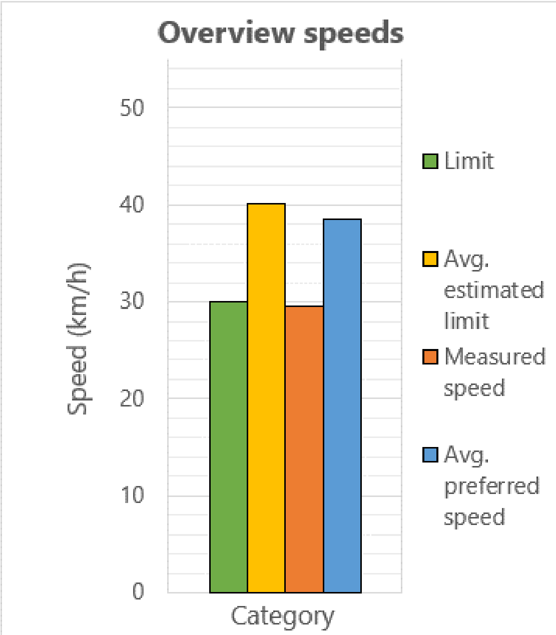


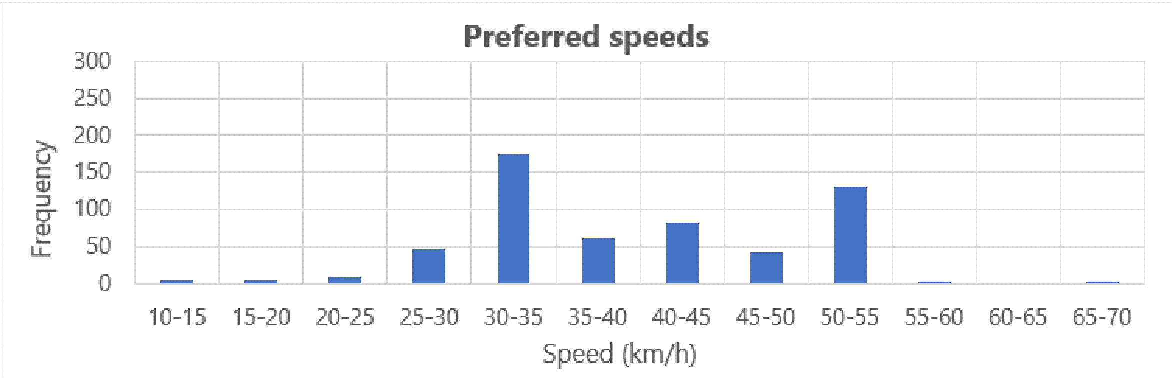



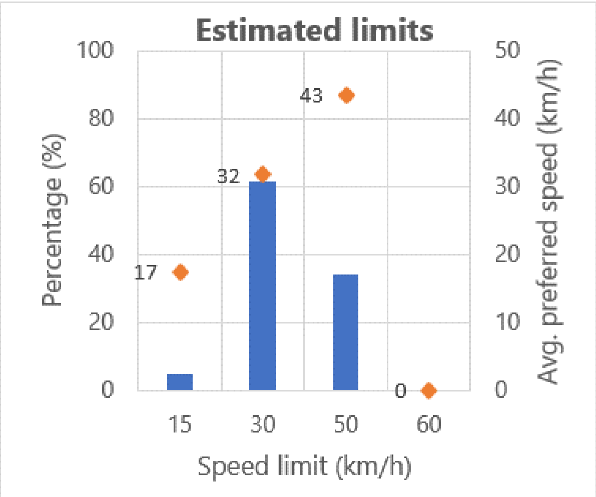
**Number:** 18
**Street:** Stationsstraat
**Place:** Bergen op Zoom

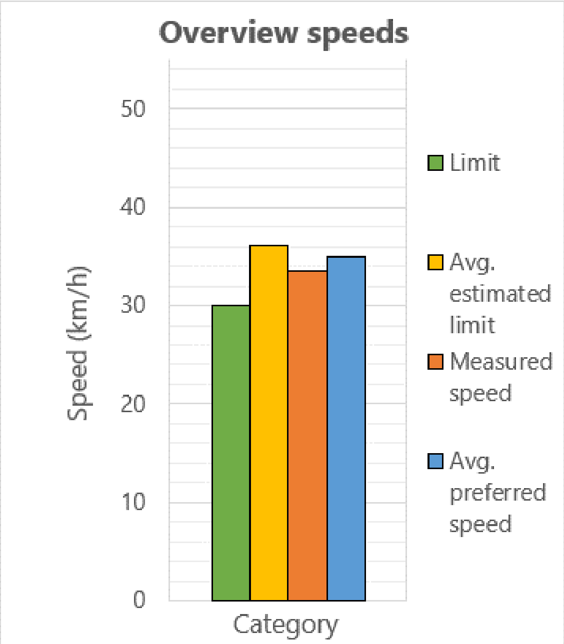


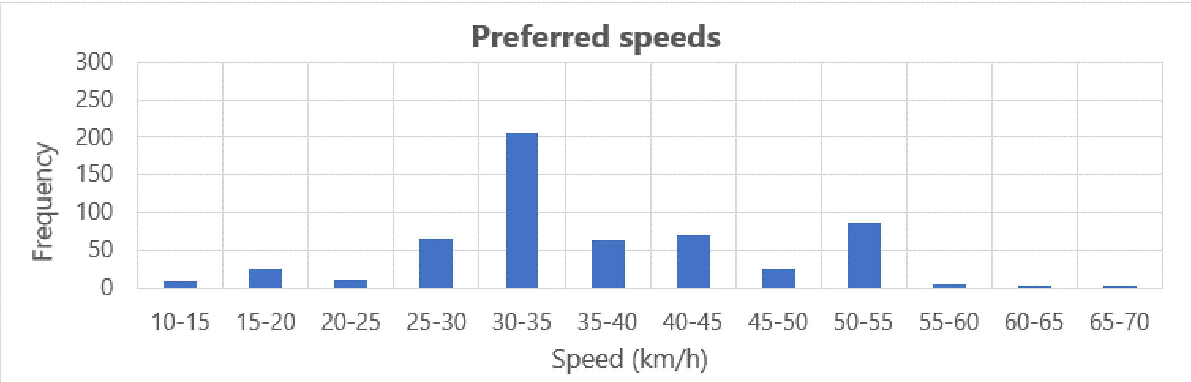



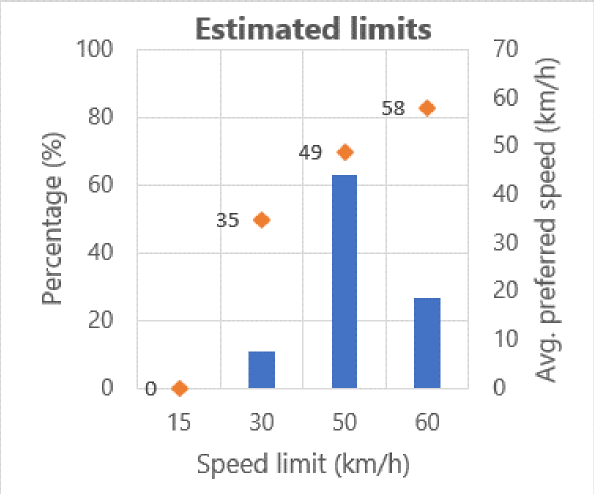

**Number:** 19
**Street:** Sint Annaplein
**Place:** Baarle Nassau

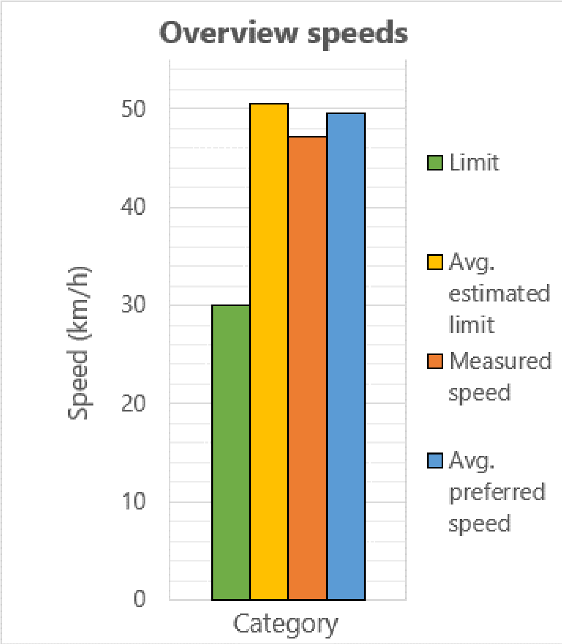


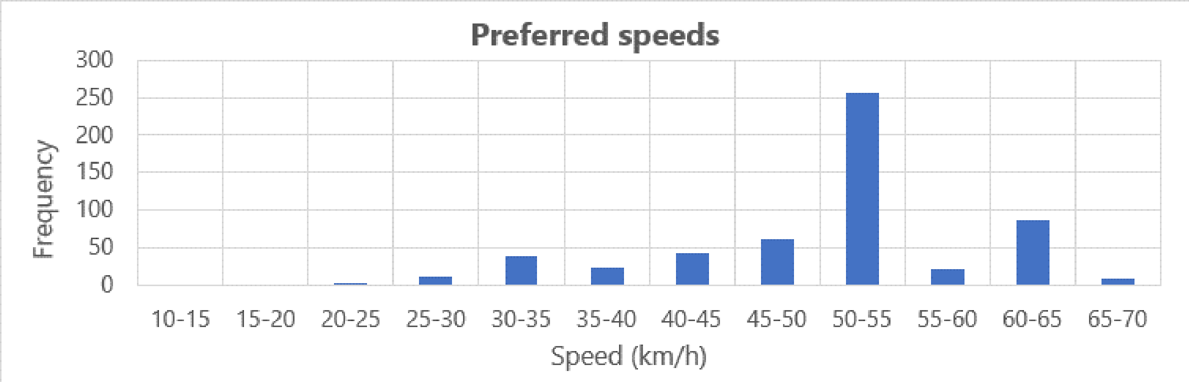



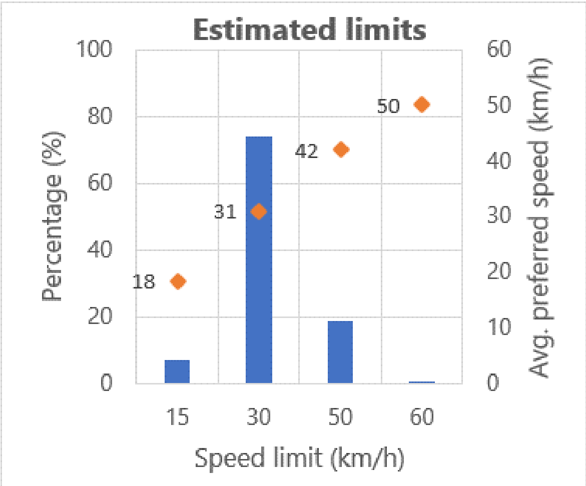
**Number:** 20
**Street:** Sint Gerlach
**Place:** Valkenburg

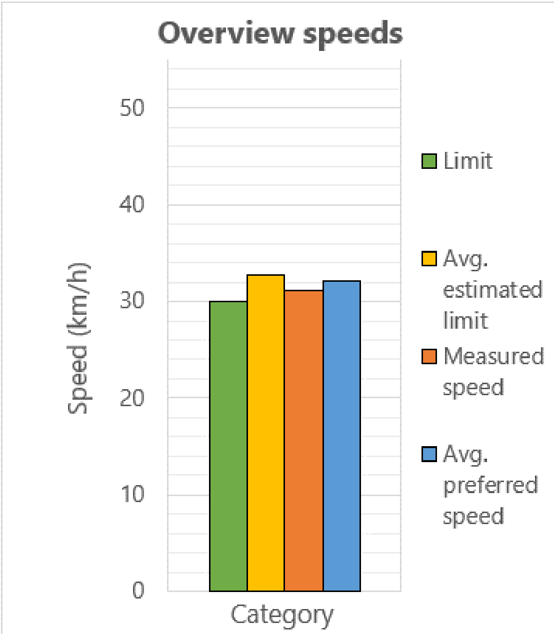


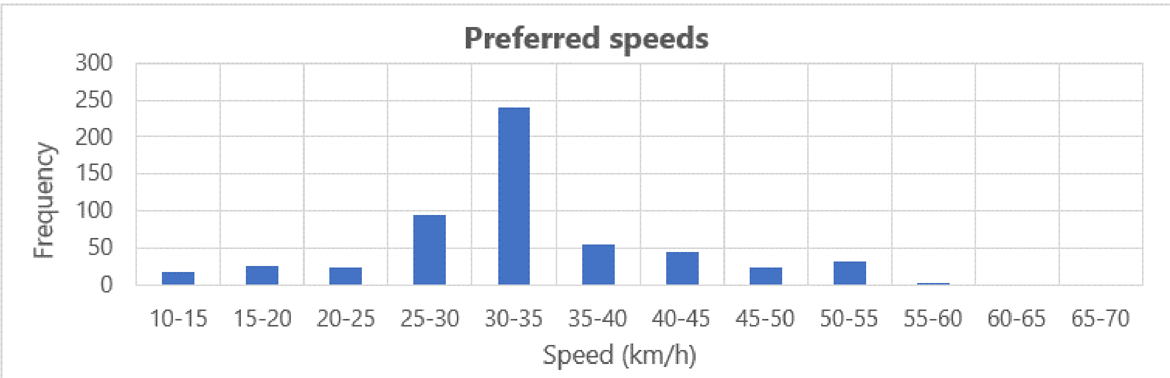



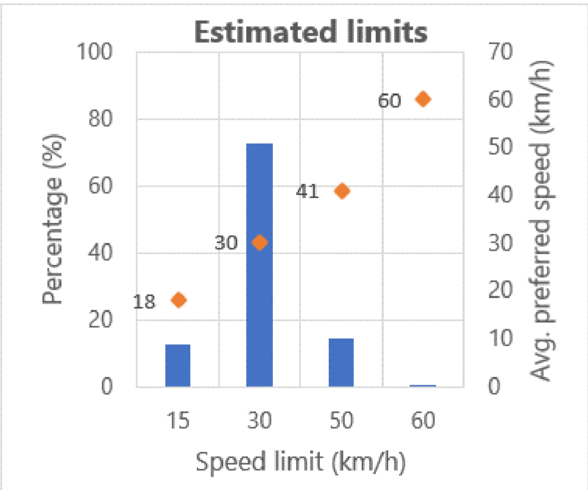
**Number:** 21
**Street:** Dennenweg
**Place:** Enschede

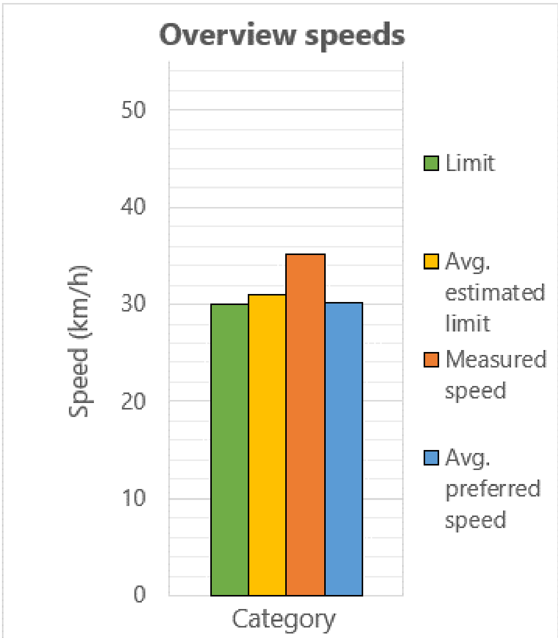


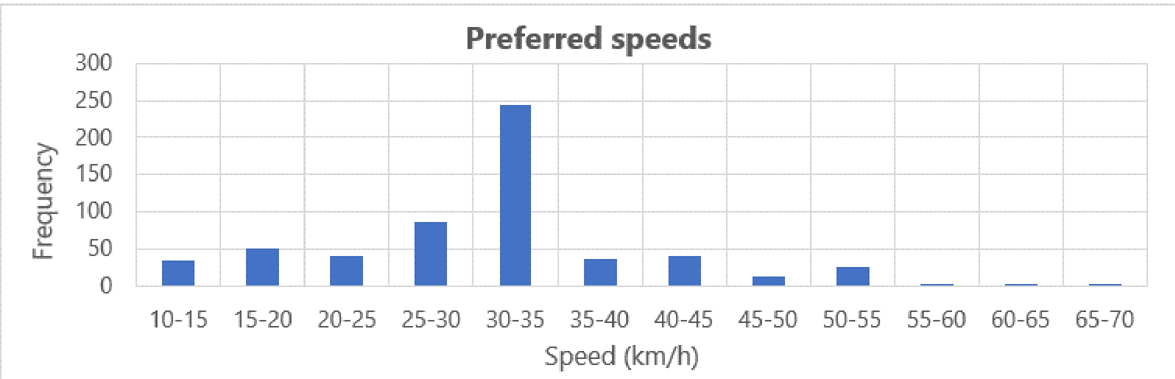



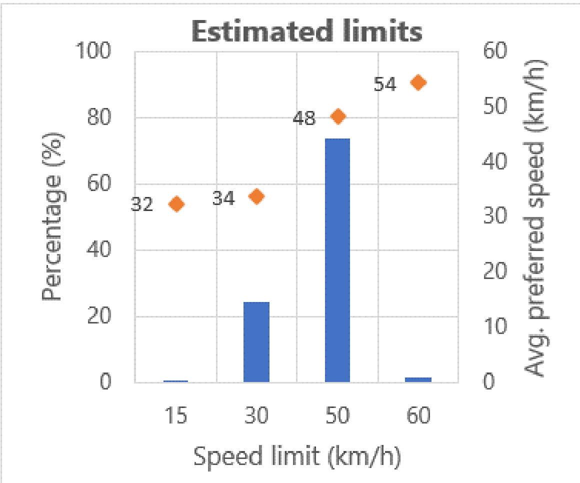

**Number:** 22
**Street:** Nieuwe Haagdijk
**Place:** Breda

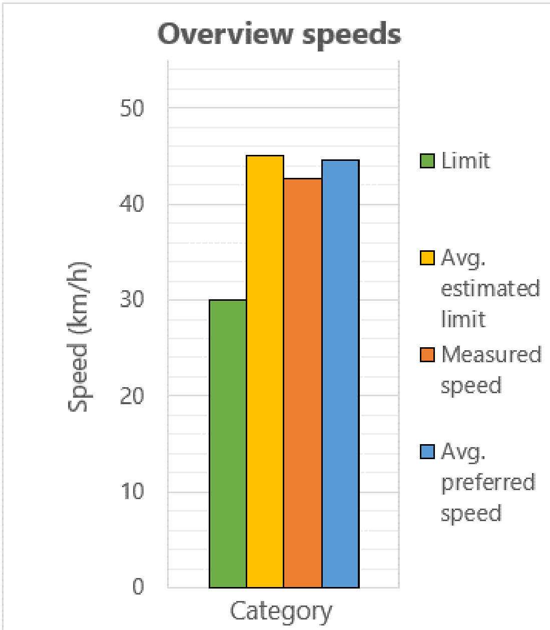


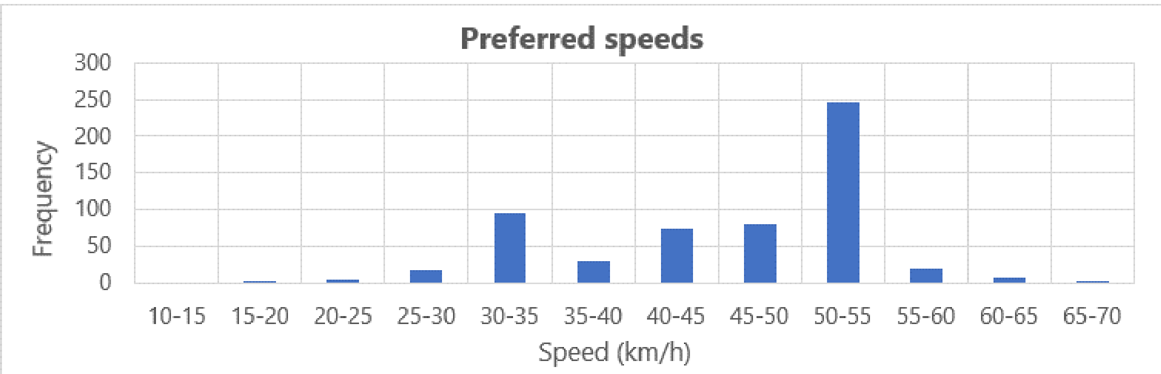



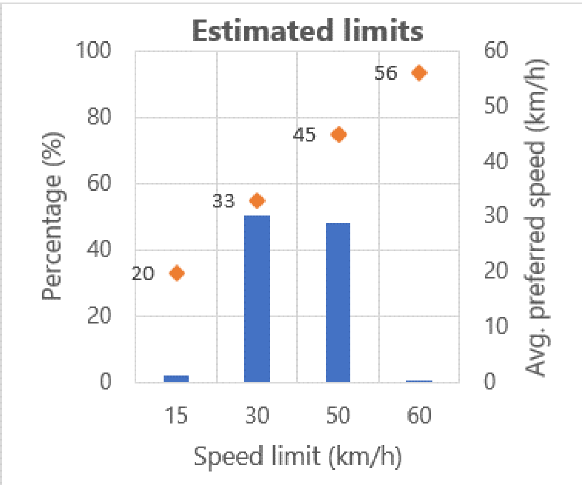
**Number:** 23
**Street:** Sint Bonifaciuslaan
**Place:** Eindhoven

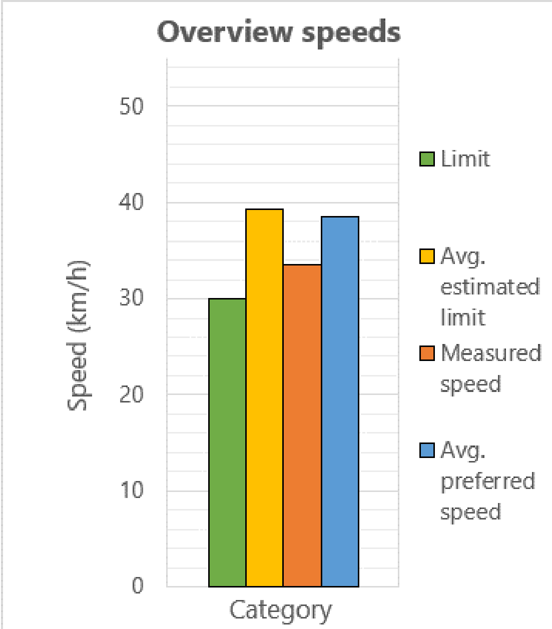


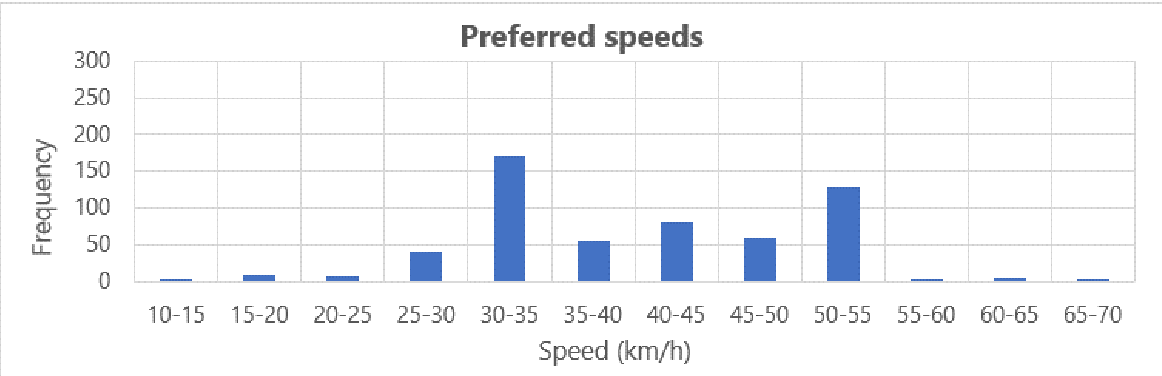



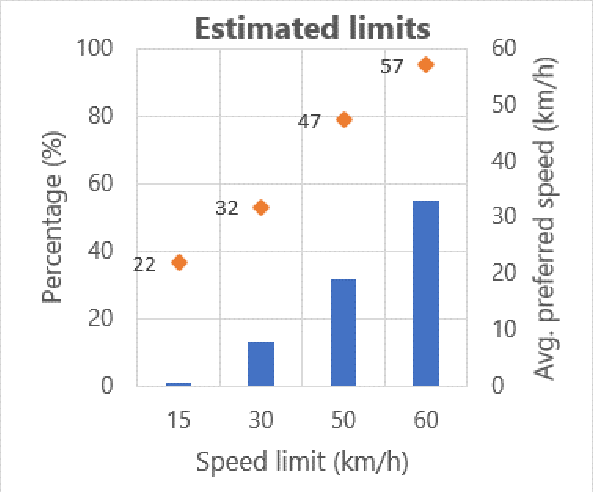
**Number:** 24
**Street:** Julianastraat
**Place:** Purmerend

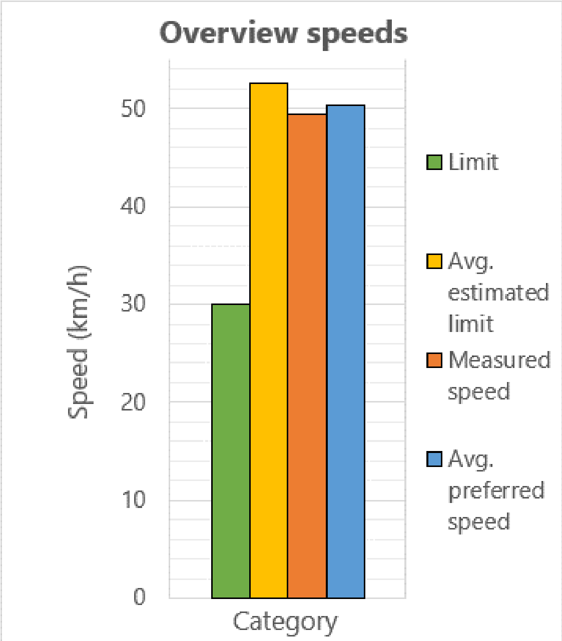


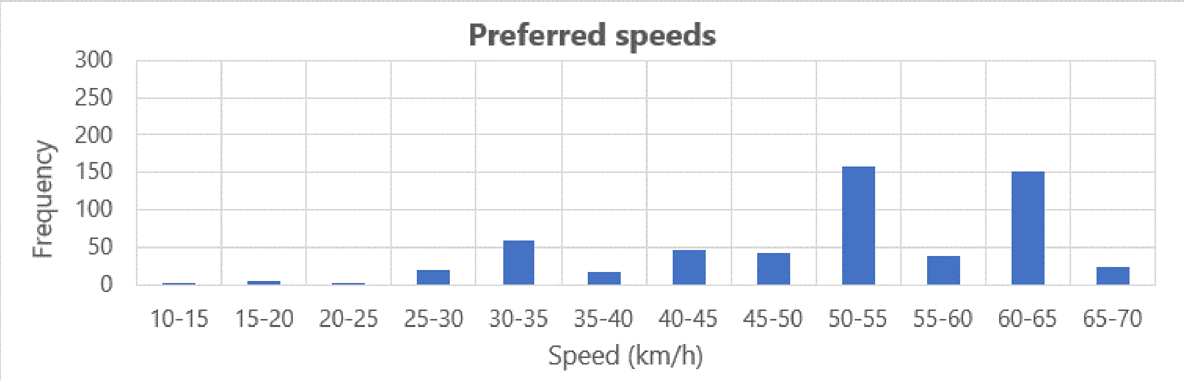



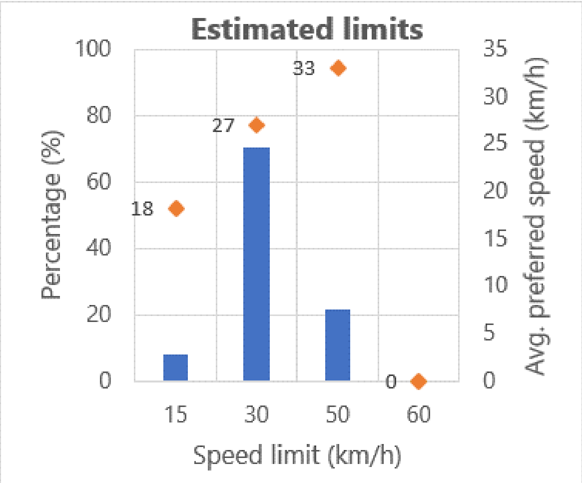
**Number:** 25
**Street:** Westerweg
**Place:** Purmerend

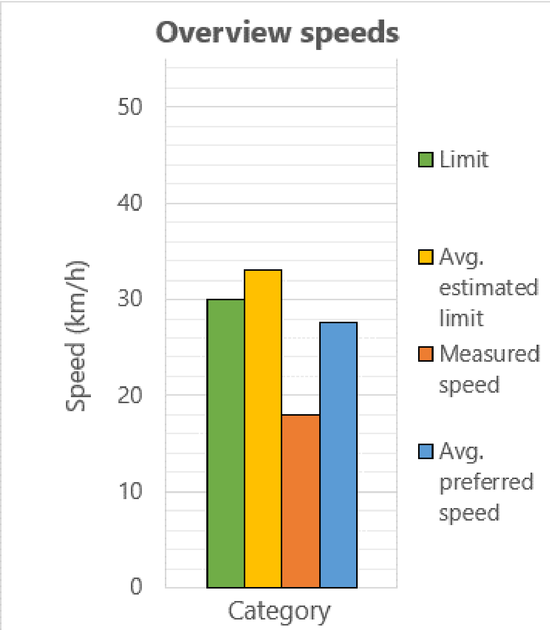


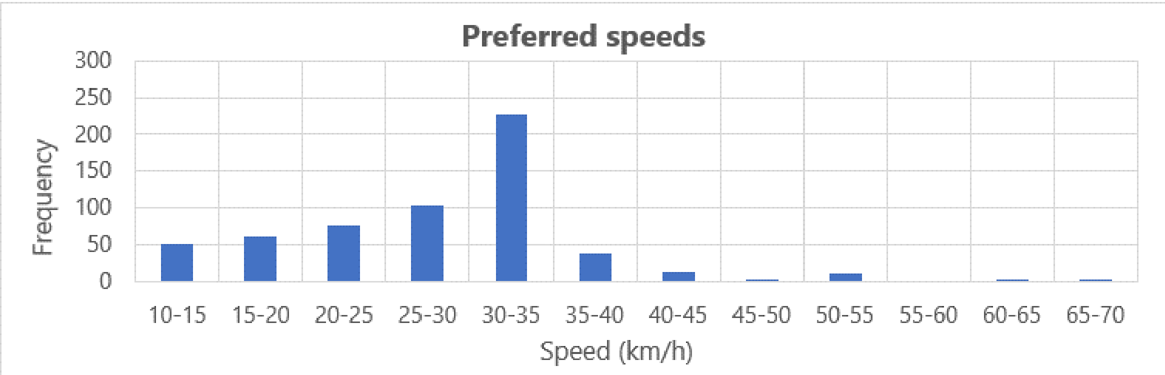



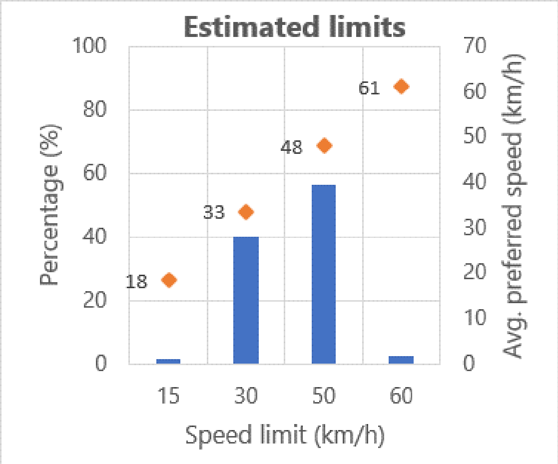
**Number:** 26
**Street:** Rousseaustraat
**Place:** Apeldoorn

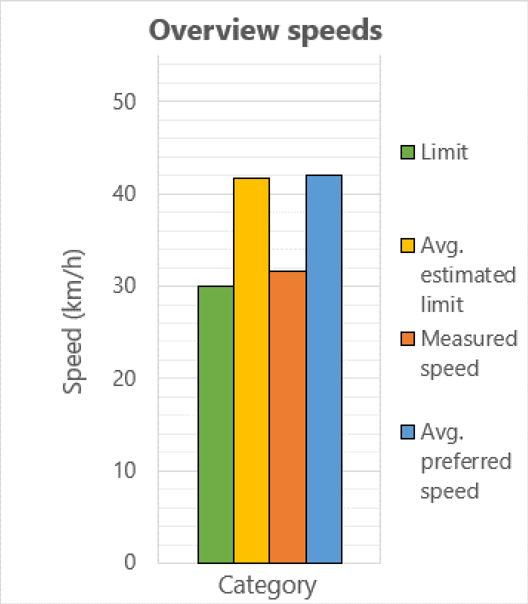


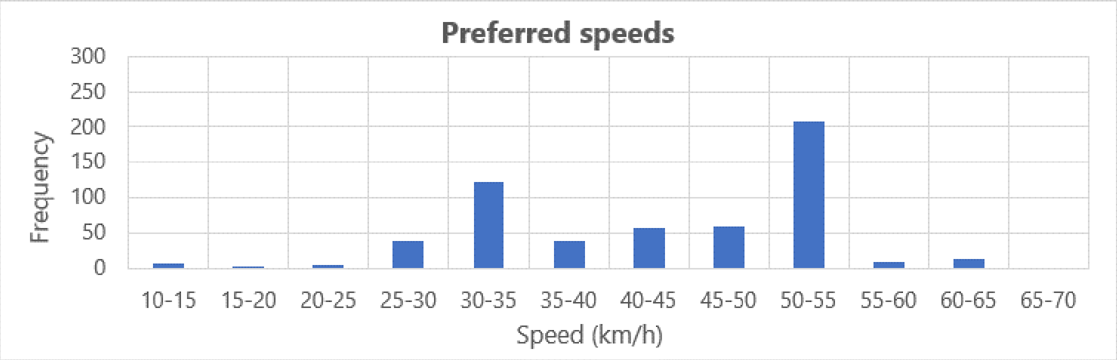



**Number:** 27
**Street:** Tollewei
**Place:** Heeg



Road 28

Road 29

Road 30

Road 31

Road 32

Road 33

Road 34

Road 35

# Appendix D: Overview preferred speeds per road

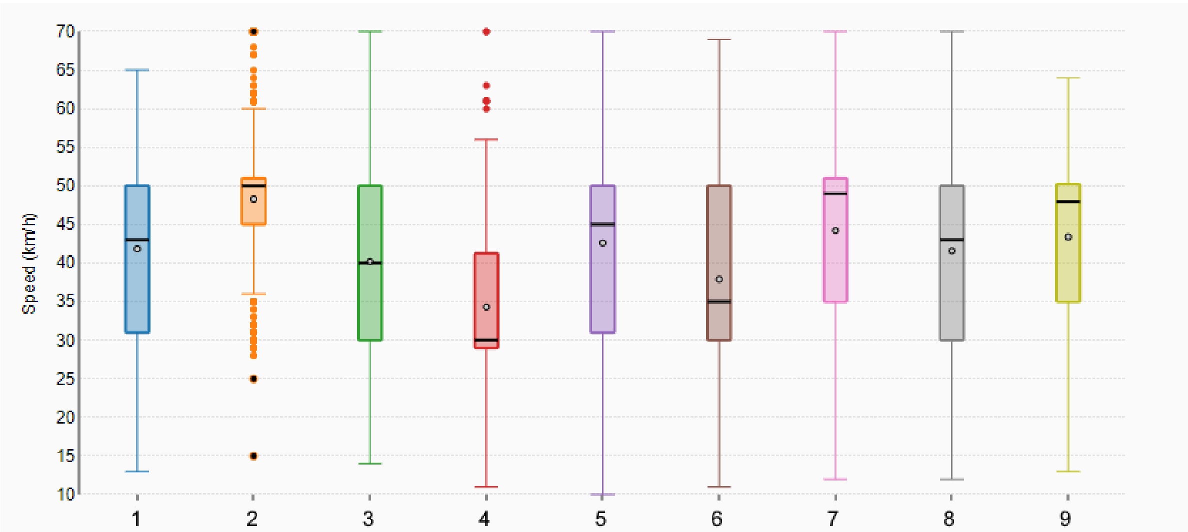
The tables and graphs below give more insight into the distribution of the preferred speeds as given by the respondents for each road. The table contains the following columns:

- Road: Number of the road (corresponds to the numbering used in Appendix C).
- N: Number of respondents who entered a preferred speed for the road in question. Because random selections of roads were shown to respondents and some of the answers were not used, small differences between roads are visible.
- Min: the lowest preferred speed filled in.
- Q1 (First quartile/25th percentile): the median of the lower half of the dataset, 25% of all speeds are below this value.
- Median (Q2 / 50th percentile): the middle value of the dataset.
- Q3 (Third quartile, 75th percentile): the median of the upper half of the dataset, 75% of all speeds are below this value.
- Max: the highest preferred speed filled in.
- Mean: the average preferred speed.
- SD (standard deviation): measure of the amount of variation.

The boxplots below the tables graphically show the distribution. The median is indicated with a black line and the average with a dot. The bottom of the coloured bar indicates Q1, the top is Q3. From both points, a distance of 1.5 times the interquartile range (IQR = Q3 – Q1) is measured out and a whisker is drawn at the largest/lowest observed speed that falls within this distance. All other observed speeds are plotted as outliers (the dark points indicate speeds with a deviation of more than three times the IQR).

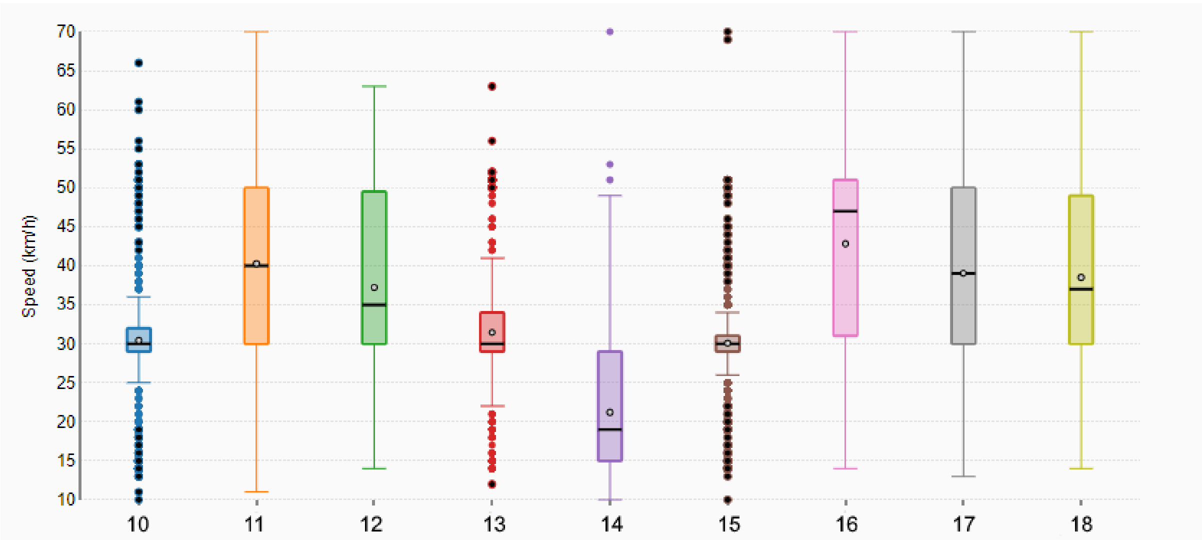
## Road 1-9

| Road | N | Min | $Q_1$ | Median | $Q_3$ | Max | Mean | SD |
|---|---|---|---|---|---|---|---|---|
| 1 | 648 | 13 | 31 | 43 | 50 | 65 | 41.8426 | 9.7529 |
| 2 | 656 | 15 | 45 | 50 | 51 | 70 | 48.3018 | 8.7474 |
| 3 | 663 | 14 | 30 | 40 | 50 | 70 | 40.2112 | 10.1021 |
| 4 | 644 | 11 | 29 | 30 | 41.25 | 70 | 34.3012 | 10.9472 |
| 5 | 656 | 10 | 31 | 45 | 50 | 70 | 42.6159 | 9.7564 |
| 6 | 666 | 11 | 30 | 35 | 50 | 69 | 37.9009 | 9.8526 |
| 7 | 656 | 12 | 35 | 49 | 51 | 70 | 44.2149 | 10.1178 |
| 8 | 662 | 12 | 30 | 43 | 50 | 70 | 41.5876 | 9.9498 |
| 9 | 652 | 13 | 35 | 48 | 50.25 | 64 | 43.3819 | 8.9724 |



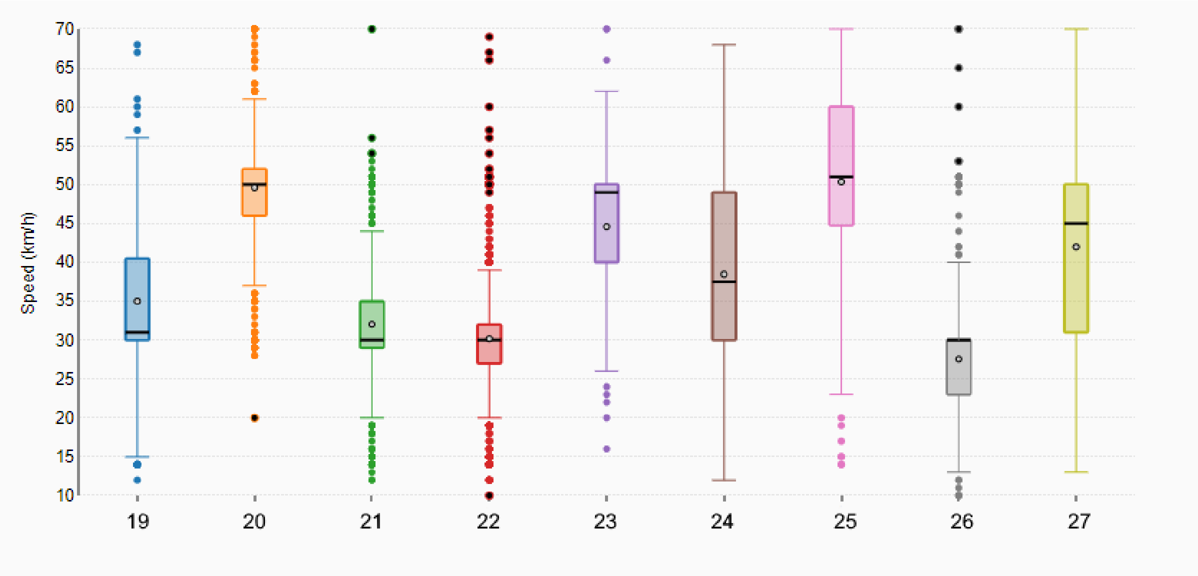
### Road 10-18

| Road | N | Min | $Q_1$ | Median | $Q_3$ | Max | Mean | SD |
|---|---|---|---|---|---|---|---|---|
| 10 | 656 | 10 | 29 | 30 | 32 | 66 | 30.4299 | 9.0117 |
| 11 | 662 | 11 | 30 | 40 | 50 | 70 | 40.2598 | 9.4631 |
| 12 | 643 | 14 | 30 | 35 | 49.5 | 63 | 37.2193 | 10.6934 |
| 13 | 659 | 12 | 29 | 30 | 34 | 63 | 31.4522 | 8.3164 |
| 14 | 656 | 10 | 15 | 19 | 29 | 70 | 21.218 | 7.9073 |
| 15 | 643 | 10 | 29 | 30 | 31 | 70 | 30.0793 | 7.534 |
| 16 | 648 | 14 | 31 | 47 | 51 | 70 | 42.8318 | 10.7189 |
| 17 | 660 | 13 | 30 | 39 | 50 | 70 | 39.0364 | 11.3634 |
| 18 | 649 | 14 | 30 | 37 | 49 | 70 | 38.4977 | 9.4472 |



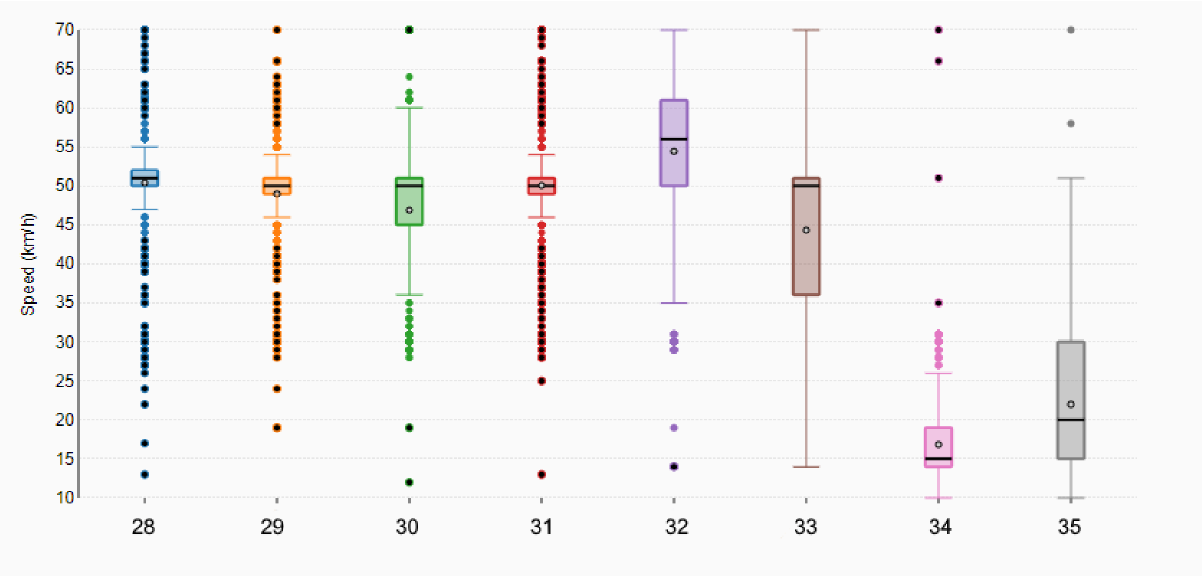
## Road 19-27

| Road | N | Min | $Q_1$ | Median | $Q_3$ | Max | Mean | SD |
|---|---|---|---|---|---|---|---|---|
| 19 | 659 | 12 | 30 | 31 | 40.5 | 68 | 35 | 9.529 |
| 20 | 652 | 20 | 46 | 50 | 52 | 70 | 49.6166 | 9.0989 |
| 21 | 640 | 12 | 29 | 30 | 35 | 70 | 32.0281 | 8.3027 |
| 22 | 648 | 10 | 27 | 30 | 32 | 69 | 30.1775 | 8.9766 |
| 23 | 666 | 16 | 40 | 49 | 50 | 70 | 44.5841 | 8.72 |
| 24 | 656 | 12 | 30 | 37.5 | 49 | 68 | 38.4588 | 9.4178 |
| 25 | 668 | 14 | 44.75 | 51 | 60 | 70 | 50.3473 | 11.612 |
| 26 | 652 | 10 | 23 | 30 | 30 | 70 | 27.5613 | 8.0328 |
| 27 | 652 | 13 | 31 | 45 | 50 | 70 | 41.9801 | 10.1999 |



Road 28-35

| Road | N | Min | $Q_1$ | Median | $Q_3$ | Max | Mean | SD |
|---|---|---|---|---|---|---|---|---|
| 28 | 652 | 13 | 50 | 51 | 52 | 70 | 50.4049 | 7.7405 |
| 29 | 648 | 19 | 49 | 50 | 51 | 70 | 48.9753 | 6.8325 |
| 30 | 651 | 12 | 45 | 50 | 51 | 70 | 46.8971 | 8.0775 |
| 31 | 657 | 13 | 49 | 50 | 51 | 70 | 50.0563 | 8.0493 |
| 32 | 647 | 14 | 50 | 56 | 61 | 70 | 54.4436 | 9.6235 |
| 33 | 647 | 14 | 36 | 50 | 51 | 70 | 44.3354 | 9.3171 |
| 34 | 651 | 10 | 14 | 15 | 19 | 70 | 16.8402 | 6.0746 |
| 35 | 675 | 10 | 15 | 20 | 30 | 70 | 22.003 | 8.2134 |

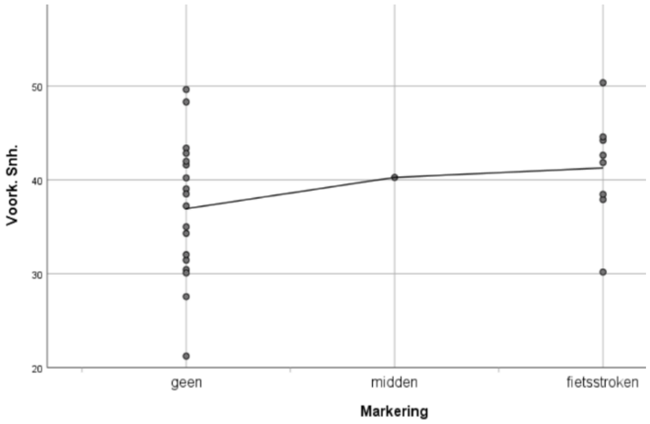


# Appendix E: Results per characteristic

The overview below shows the distribution of the roads over categories of characteristics and speed. In the table, it is indicated with a plus sign in brackets if several categories have been merged into one category in the data analysis.

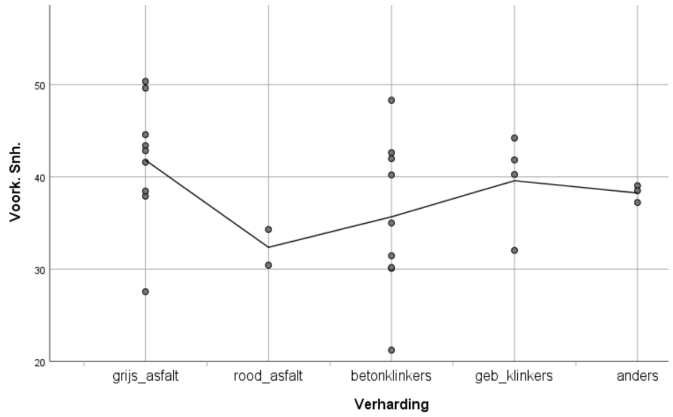
## Road marking

| | Speed | N |
|---|---|---|
| No road marking (1) | 36.9 | 18 |
| Road marking (2+3) | 41.2 | 9 |
| **Sig.:** 0.142 | **Total:** | 27 |



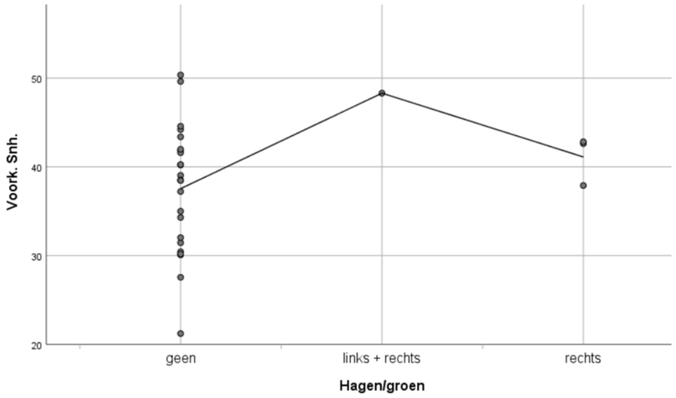

## Pavement

| | Speed | N |
|---|---|---|
| Grey asphalt (1) | 41.8 | 9 |
| Clinkers (3+4) | 36.9 | 13 |
| **Sig.:** 0.133 | **Total:** | 22 |



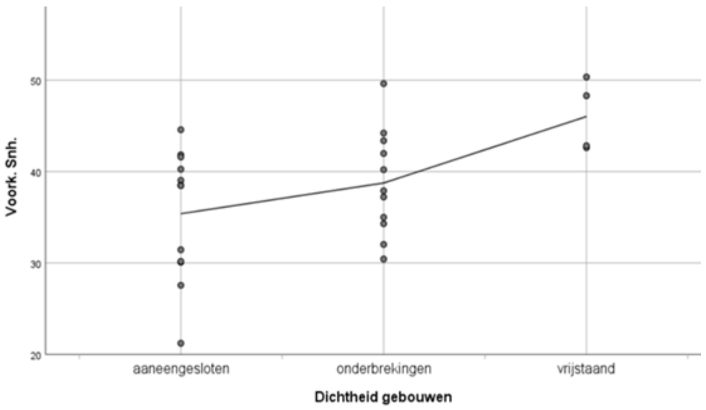

## Hedges

| | Speed | N |
|---|---|---|
| No (1) | 37.5 | 23 |
| Yes (2+3) | 42.9 | 4 |
| **Sig.:** 0.161 | **Total:** | 27 |



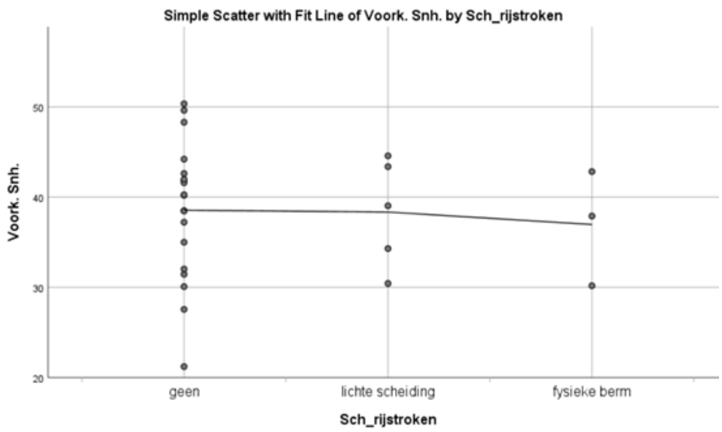

## Building density

| | Speed | N |
|---|---|---|
| Large (1) | 35.4 | 12 |
| Small (2+3) | 40.7 | 15 |
| **Sig.:** 0.014 | **Total:** | 27 |



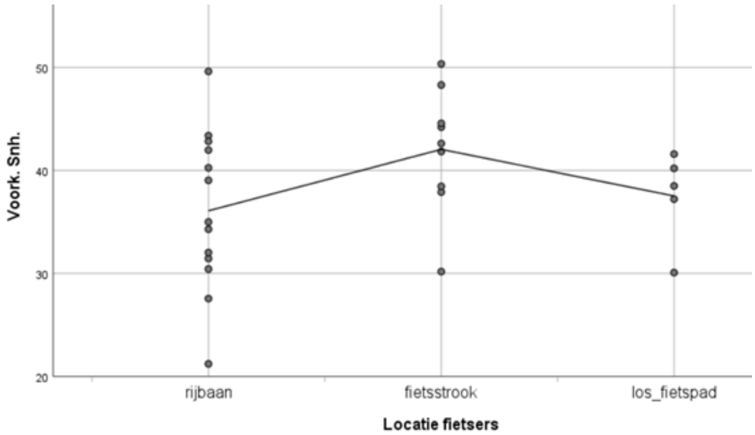
## Lane separation

| | Speed | N |
|---|---|---|
| No (1) | 38.6 | 19 |
| Yes (2+3) | 37.8 | 8 |
| **Sig.:** 0.812 | **Total:** | 27 |



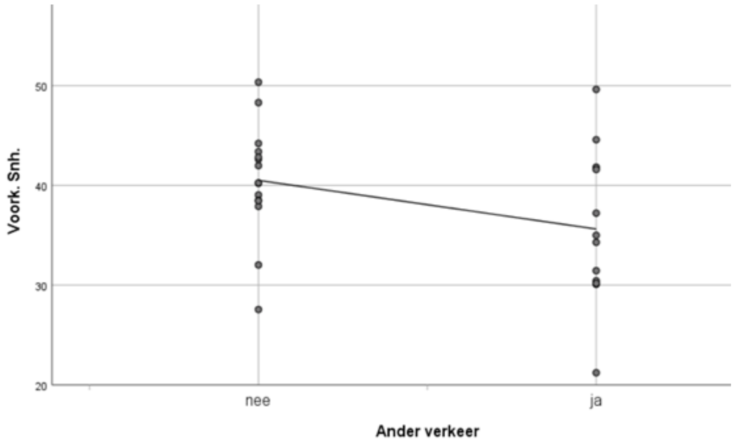

## Location cyclists

| | Speed | N |
|---|---|---|
| Road/separated path (1+3) | 36.5 | 18 |
| Cycling lane (2) | 42.0 | 9 |
| **Sig.:** 0.049 | **Total:** | 27 |



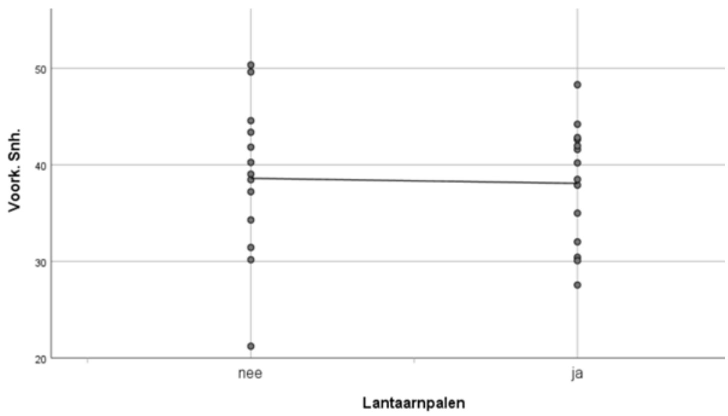

## Other traffic

| | Speed | N |
|---|---|---|
| No (1) | 40.5 | 15 |
| Yes (2) | 35.6 | 12 |
| **Sig.:** 0.071 | **Total:** | 27 |



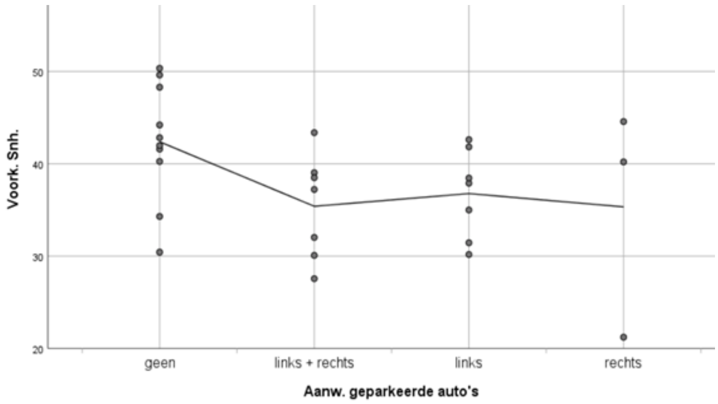

## Lamp posts

| | Speed | N |
|---|---|---|
| No (1) | 38.6 | 13 |
| Yes (2) | 38.1 | 14 |
| **Sig.:** 0.852 | **Total:** | 27 |



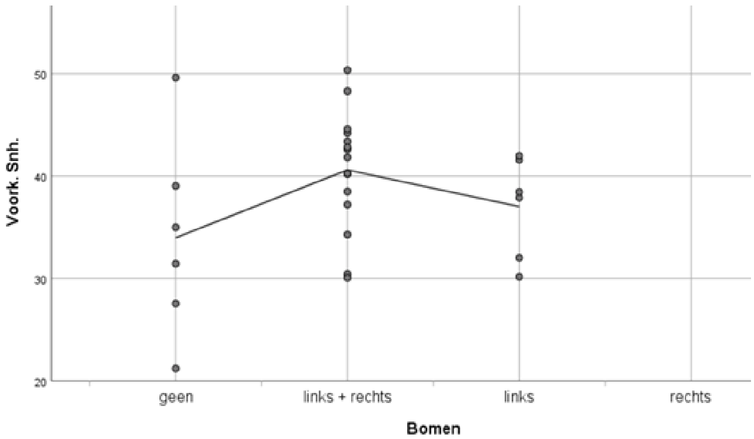
## Parked cars

| | Speed | N |
|---|---|---|
| No (1) | 42.4 | 10 |
| Yes (2+3+4) | 36.0 | 17 |
| **Sig.:** 0.018 | **Total:** | 27 |



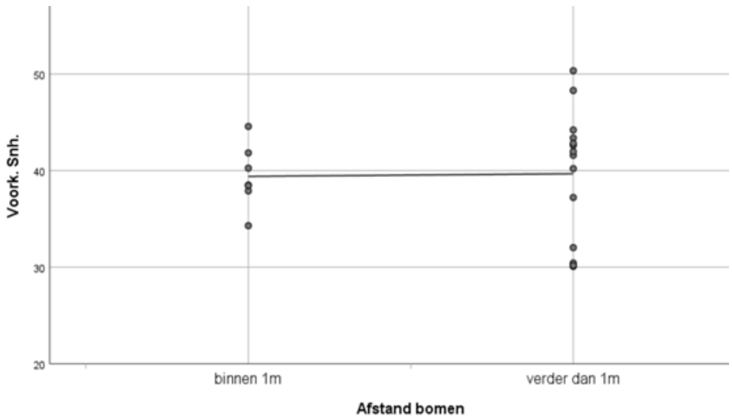

## Trees

| | Speed | N |
|---|---|---|
| No (1) | 34.0 | 6 |
| Yes (2+3) | 39.6 | 21 |
| **Sig.:** 0.084 | **Total:** | 27 |



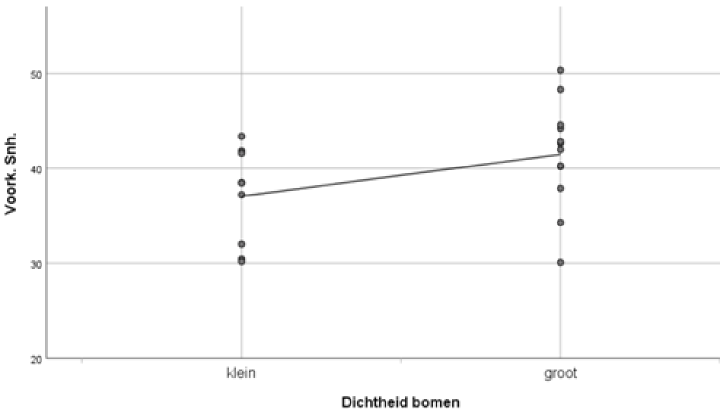

## Distance to trees

| | Speed | N |
|---|---|---|
| Within 1 meter (1) | 39.4 | 7 |
| > 1 meter (2) | 39.7 | 14 |
| **Sig.:** 0.904 | **Total:** | 21 |



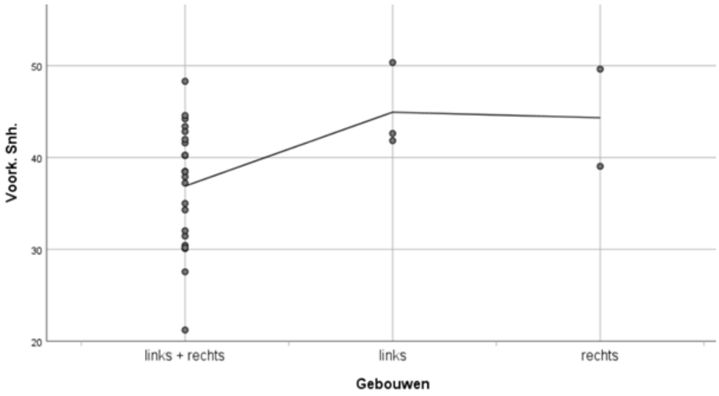

## Tree density

| | Speed | N |
|---|---|---|
| Small (1) | 37.1 | 9 |
| Large (2) | 41.5 | 12 |
| **Sig.:** 0.079 | **Total:** | 21 |



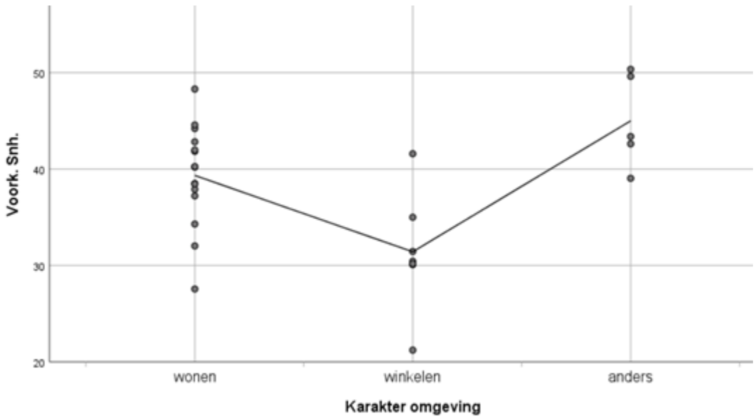
## Buildings

| | Speed | N |
|---|---|---|
| Two sides (1) | 36.9 | 22 |
| One side (2+3) | 44.7 | 5 |
| **Sig.:** 0.021 | **Total:** | 27 |



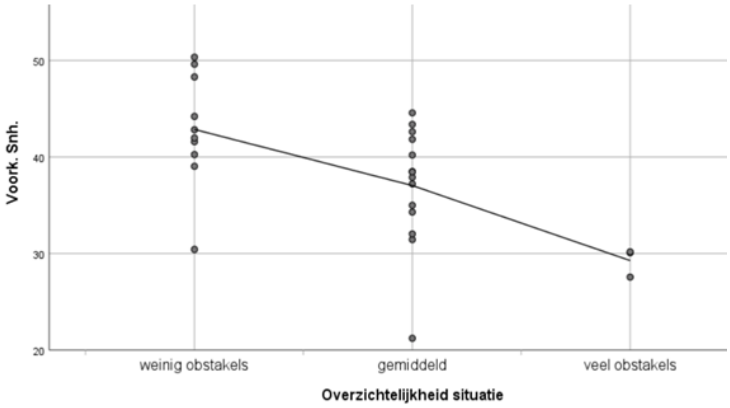

## Main function environment

| | Speed | N |
|---|---|---|
| Otherwise (1+3) | 40.8 | 20 |
| Shopping (2) | 31.4 | 7 |
| **Sig.:** 0.001 | **Total:** | 27 |




## Clarity of the situation

| | Speed | N |
|---|---|---|
| Clear (1) | 42.9 | 10 |
| Average/complex (2+3) | 35.7 | 17 |
| **Sig.:** 0.007 | **Total:** | 27 |




## Speed de-accelerators

| | Speed | N |
|---|---|---|
| No (1) | 39.2 | 24 |
| Yes (2) | 31.2 | 3 |
| **Sig.:** 0.058 | **Total:** | 27 |