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TOWARDS SAFE SPEEDS AND CREDIBLE SPEED LIMITS

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ABSTRACT

Speed is an inherent characteristic of mobility and a hazard to safety. Several approaches exist of how to manage speed. In the Netherlands, the emphasis has mainly been on harm minimisation during the last decades, due to the implementation of the Sustainable Safety vision. Speed management remains a core issue in this vision, by means of an integral approach of applying speed management measures. Setting a credible speed limit is one of the important issues here.

A few years ago, a number of Dutch regional authorities asked for assistance in developing a decision support system for speed management as a basis for their traffic safety policy. In their opinion, speed management is of growing importance to improving road safety even further. Particularly the low casualty numbers present decision makers at the regional and local level a difficult job when they have to decide where and when to take action. Furthermore, some decision makers have the general question where they have a speeding or credibility problem and what can be an effective solution for that location. These issues were merged into a set of algorithms on safe speeds and credible speed limits (SaCredSpeed) that could be used in a decision support instrument for all types of roads.

The SaCredSpeed algorithm uses input data of road design and image, and traffic characteristics of stretches of roads in order to calculate a safe speed and speed limit for that particular situation. This means that, depending on the legal traffic situation and further road design details, safe speed limits are defined. The safe speed is related to the real speed (V90 as a default) if this data is available. The SaCredSpeed algorithm can then check the credibility of the speed limit (current or ideal) and the enforcement situation (optional). Depending on the fit between the results of all these assessments, SaCredSpeed offers suggestions for adaptations. These can consist of a) speed limit adaptations, b) road design adaptations or c) additional adaptations in enforcement. These suggestions can also take into account the road network function, the condition of the adjacent roads, the traffic volume, and the priorities the decision maker wants to set.

The first draft of the SaCredSpeed algorithm was tested in a number of regions in the Netherlands. The results from the safe speeds and credible speed limit assessments are discussed, as well as the SaCredSpeed suggestions for improving the situation. The paper will conclude with suggestions for further steps to take.

INTRODUCTION

Within the field of road traffic transport and traffic safety, policy makers deal with the question what to do and where. Not only do they have the delicate task to balance the available resources over a number of interests, they also face the problem of growing unpredictability of the locations that need special attention from a safety point of view. This last issue becomes especially apparent in countries, regions or areas with low annual casualty numbers. The question then is: how to determine where to take which action?

It is common use to look for locations with high annual clusters in crashes, and to determine what measures are needed based on the most common crash causations on that particular location: the reactive black spot approach. It is very easy to get public support for this kind of safety policy, but it is only useable when a particular amount of crashes have occurred. Another way to cope with road safety hazards is by means of a proactive 'safe system' approach. The basis of proactive measures are general crash patterns and knowledge of factors that are known to affect risk or exposure. Particularly in countries with a high safety standard, there is better notion of the fact that exact crash locations are hard to predict because probability and coincidence of many factors play a large role in the causation of crashes. Elements that play a role in the cause or the severity of crashes are far better known, better to predict and better to influence than crashes themselves. These elements are also known as Safety Performance Indicators (SPI, e.g. 1). They are defined as "any measurement that is causally related to crashes or injuries, used in addition to a count of crashes or injuries, in order to indicate safety performance or understand the process that leads to accidents." (1, pg 5). The importance of a SPI depends on 1) the strength of its relationship with crash or injury occurrence, 2) the contribution to the crash and 3) the extent to which road safety measures or programs can influence the SPI. In road transport, the causal chain of action is generally presented as: structure and culture – safety measures and programs – safety performance indicators – crashes – (social costs) (2, 3).

One of the most important SPI's is speed: there is a strong link with the cause as well as with the severity of crashes (4). Even in most crashes that have been analyzed by the police as not being the result of inappropriate speed, speed plays a role as it is an inherent factor of transportation. In this sense, it is different from SPI's such as alcohol or seat-belt use for instance. A lot of crashes occur without any influence of alcohol; road crashes without the influence of speed are impossible, then it would not be a road crash.

There are several ways to influence speed: regulation by speed limits, enforcement and communication are effective, but so are the layout of the road and road environment. To what extent these factors are tuned to each other determines the quality of the road system (e.g. 5). The general view is that, for all these measures, there will be more commitment and more desired behavior if they are 'credible'. This gives an interesting point of departure for road safety policy in general and speed management in particular.

These facts, combined with the notion that it is increasingly difficult to define effective road safety measures, were the basis for a method to help road safety decision makers to set safe and credible speed limits. The development of this method was a direct response to the request of a number of Dutch regional authorities who asked for a decision support system with a specific focus on speeding problems. A decision support system was developed which incorporates algorithms that are based on scientific knowledge and more in particular the advanced Sustainable Safety vision about how to manage safe speeds and credible speed limits (e.g. 5, 6). These algorithms are called 'SaCredSpeed'. The principles within SaCredSpeed for safe speed limit setting are based on the harm minimization approach. However, no local crash data are used for this, but rather general safety principles that derive from crash tests and other research. Internationally, this is a unique approach for speed limit setting. Another unique value of SaCredSpeed is the inclusion of the credibility of speed limits as a means to get safer speeds.

The Dutch harm minimization approach is, until now, particularly elaborated in engineering measures. In the Netherlands, for instance, the following general Sustainable Safety rules exists: function, design and use of the road should be in harmony with each other. That is:

- Roads ideally have only one function: a flow function or an exchange function
- Where traffic mixes (exchange function), low speeds are required for safety reasons. To get low speeds, speed limits have to be supported by the design of the road and the layout of the environment;
- Where traffic flows, the design of the road has to support that high speeds can be managed safely. This is elaborated by means of access restrictions for slow and vulnerable road users and physical separation of driving directions of cars.

- Furthermore, the road design has to be recognizable and predictable for road users, and also forgiving to prevent that errors turn into severe crashes.

In the Netherlands, the emphasis on safe speed limits is most visible in the introduction of 30 km/h zones in urban access areas and 60 km/h zones on rural access roads. The large scale implementation of these zones was particularly promoted during the Start-up program of Sustainable Safety during the last decade (5). Their legitimacy is largely based on car-pedestrian crash-test results and the probability of fatal outcome (7). The 60 km/h speed limit on rural access roads was a political compromise between the 30 to 40 km/h that was recommended from a sustainable safety point of view, the original speed limit of 80 km/h and some other considerations, such as travel time. Deviations from this speed limit system are allowed when the road design or other issues provide reasons to do so.

These principles of safe speeds and credible speed limits are transformed into an algorithm (8, 9). This algorithm is freely available for all traffic specialists and consultancy, for instance to take as basis for a software tool, as was currently done in ViaStat by VIA consultancy. Currently, three pilot studies have been performed with SaCredSpeed. This article will present and discuss the results from these studies. Before doing so, the article first provides a description of the different steps in the algorithm together with their backgrounds.

2 ABOUT SACREDSPEED

SaCredSpeed is a set of algorithms that can be used for a speed management decision support instrument directed at safety of speeds and credibility of speed limits. As the algorithm covers all road types, it can be used by a wide variety of authorities dealing with road safety. Since SaCredSpeed uses an integral safety approach towards speed management measures, including road layout, legal issues, speed enforcement and communication, it can also be useful for consultations between different road safety stakeholders. The SaCredSpeed algorithms focus on the issues that are considered to be most relevant for safe speeds and credible speed limits without being too complex in the first stage. The content of the algorithms is based on as much scientific knowledge as available. This means that the SaCredSpeed algorithms can still be expanded by taking more details into account and adding new scientific knowledge when this comes available. As other speed related issues, such as traffic flow and environmental problems, are not included in SaCredSpeed, these topics may also be added later on.

The input that is required for the SaCredSpeed algorithms to work concerns all kinds of data about road construction, road layout (e.g. road width, vulnerable road user facilities, density of speed reducing measures etc.), the legal traffic situation (access restrictions), posted speed limit, police enforcement (effort and methods), and speed data if available (see 8 for more details (in Dutch)). Because each change in the aforementioned characteristics can be relevant for the safe speed, the measured driving speed or the credibility of the speed limit, data collection has to be done by 'dynamic segmentation'. This means that a road section is defined as a stretch of road which has one set of similar characteristics. Such a section may have no relationship with the existing national section division.

The next paragraph will discuss the content of the SaCredSpeed algorithms and what they can give as output.

2.1 The SaCredSpeed algorithms

The general algorithm of SaCredSpeed (*Figure 1*) consists of three separate assessments: safety of speeds and/or speed limits, credibility, and enforcement of speed limits. In each assessment, it is determined which countermeasures could lead to a better situation. The results of the assessments can be combined for a final advise.

Safe speed assessment (SSA) and comparison between speed and speed limit (VSLC)

First of all, the safe speed limit is assessed and compared to the actual speed limit. The safe speed assessment is based on the advanced Sustainable Safety requirements (5) for harmony between function, design, and use of a road. This means that SaCredSpeed assesses how well the access restriction, the road construction and speed limit are tuned according to the advanced insights of the Dutch safe system approach (see safety features in *Table 1*). The situation of pedestrians and/or cyclists mixing with motorized traffic is used as the basic situation and is considered to be safe at a maximum speed of 30 km/h of the motorized vehicle (7). Only when vulnerable road users are physically separated from the motorized traffic, higher speeds are safe. Speeds of 80 km/h and

more are only considered as safe for motorized traffic if a sufficient forgiving road side and separation of driving directions are present (10, 11). Because this safe speed limit system mainly considers crashes with a car, some additions were made based on other literature (see 9). This results in the following characteristics to be evaluated in relation to the speed limit:

- Physical separation of driving directions
- Moped/bicyclist facilities (separate paths)
- Pedestrian facilities
- Forgiving road sides
- Parking
- Access restrictions
- Width of the obstacle free zone (shoulder)
- Stopping sight distance of the road
- Density of junctions and access lanes

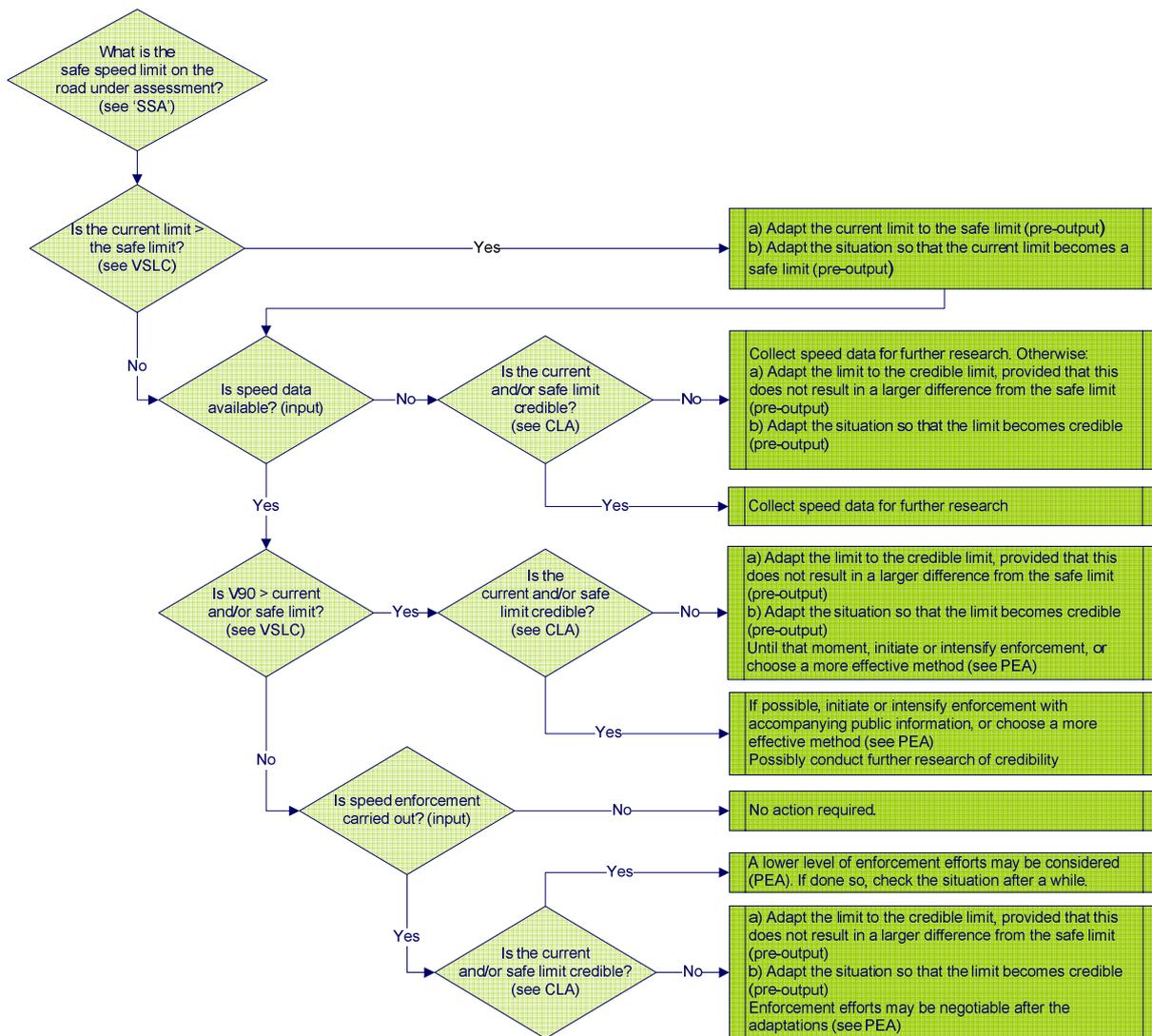


FIGURE 1 General algorithm of SaCredSpeed with SSA= safe speed assessment, VSLC = V90 speed, safe speed and speed limit comparison, CLA = credible limits assessment, PEA = police enforcement assessment

The next option, which is strongly recommended, is to assess the relationship between the operation speed (V90 as default) and the safe speed. Assessment of the operation speed gives extra insight into the problem that may exist. The V90 speed is taken as a default for two reasons:

- 1) it is linked to the definition of safe speed (10, 5),
- 2) 10% of violating drivers is generally perceived as acceptable by the Dutch police.

The choice to use V90 is adaptable, for instance to the common V85, or to the V95 for stricter outcomes.

If the speed limit and/or operation speed are higher than the safe speed limit or the current speed limit (optional), there is a problem with the safety of the system, even though no crashes may have occurred yet. The next step is to assess the credibility of the speed limit to see if this is part of the problem.

TABLE 1 Overview of the Characteristics Associated with Safety and Credibility per Speed Limit

Speed limit	Safety features	Credibility features
30 (40) km/h	Mixing of fast traffic and vulnerable road users or situation with pedestrian facilities and/or bicycle lanes; parking in parking spaces alongside the roadway.	<ul style="list-style-type: none"> – Road stretch of 50m – 50m < space between physical speed limiters < 150 m – densely built-up area (buildings at both sides of the road) – 4,5m < road width < 5,5 m – uneven road surfacing
50 km/h	Separation of vulnerable road users and fast traffic; moped on the roadway; parking on the roadway is allowed; stopping sight distance 47 m.	<ul style="list-style-type: none"> – Road stretch of 126m – Physical speed limiters on junctions – Moderate densely built-up area – 5,9m < road width < 7,2m; 2,5m < lane width < 3,0m – even or uneven surfacing
60 km/h	Road without vulnerable road users; obstacle-free zone > 2.5 m or forgiving roadside; parking on the roadway not allowed; stopping sight distance 64 m.	<ul style="list-style-type: none"> – Road stretch of 177m – Physical speed limiters on road sections and junctions – densely or sparsely rural area with some buildings – 4,5m < road width < 5,5m – even or uneven road surfacing
70 km/h	No access for mopeds and bicycles; no physical separation of driving directions; obstacle-free zone > 4.5 m or forgiving roadside; (semi-)hard shoulder; parking on the roadway not allowed; stopping sight distance 82 m.	<ul style="list-style-type: none"> – Road stretch of 236m – raised junctions – sparsely built-up area (for roads in urban area's) or densely rural area – 7,2m < road width < 8,8m; 2,9m < lane width < 3,6m – even road surfacing
80 km/h	No access for slow traffic; physical separation of driving directions; obstacle-free zone > 6 m or forgiving roadside; (semi-)hard shoulder; parking on the roadway not allowed; stopping sight distance 105 m.	<ul style="list-style-type: none"> – Road stretch of 303m – raised junctions; – densely or sparsely rural area – 6,8m < road width < 8,3m; 2,5m < lane width < 3,0m – even road surfacing
100 km/h	No access for slow traffic; physical separation of driving directions; no lateral conflicts; obstacle-free zone > 10 m or forgiving roadside; hard shoulder; parking on the roadway not allowed; stopping sight distance 170 m.	<ul style="list-style-type: none"> – Road stretch of 463m – no physical speed limiters – sparsely rural area – 18,0m < road width < 22,0m; 2,9m < lane width < 3,6m – even road surfacing
120 km/h	No access for slow traffic; physical separation of driving directions; no lateral conflicts; obstacle-free zone > 13 m or forgiving roadside; hard shoulder; parking on the roadway not allowed; stopping sight distance 260 m.	<ul style="list-style-type: none"> – Road stretch of 657m – no physical speed limiters – sparsely rural area – 21,6m < road width < 26,4m; 3,2m < lane width < 3,9m – even road surfacing

Credibility assessment (CLA)

When operation speed is higher than the posted and/or safe speed limit, the speed limit may not be credible. A credible speed limit is defined as the speed that most road users consider to be reasonable given a particular road layout. Drivers tend to better comply with speed limits when they are more credible (12, 13). A number of objective road layout factors have been found to influence speed behavior and credibility. Based on existing studies (see 9 for an overview), five characteristics are used now in SaCredSpeed to assess credibility either acting as an accelerator or a decelerator (14):

- Road width
- Density of the road environment elements (e.g. buildings or trees versus open space)
- Length of straight road stretches
- Quality of the road surface

- Density of physical speed reducing measures (e.g. speed humps)

Per speed limit, each of these characteristics has an ideal value (see the credibility features in *Table 1*). If a characteristic deviates from the ideal for that speed limit, it is coded as either an accelerator or a decelerator, depending on whether the value of the characteristic is above or below the ideal value. The ideal values are mainly based on current knowledge and common advises from several road design guidelines (see 9 for an overview).

Subsequently, the overall effect is determined by adding up all influences per road section, giving an equal weight to each characteristic. If all features have an ideal value or if there is an equal amount of accelerators and decelerators on a particular road section in relation to the speed limit, this limit can be considered as 'credible'. If the accelerators outnumber the decelerators (or v.v.) on a particular road section, it is likely that people tend to drive faster (c.q. slower).

Because driving speed can also be influenced by other external factors, such as police enforcement, the next optional step is to assess the availability and type of police enforcement on the road. If speeds do not exceed the speed limit although it is assessed as uncredible, this may be due to police enforcement. As it is better for long lasting compliance to speed limits and public support in general, and because enforcement sources are limited, this may give more reason to adapt the credibility of the speed limit. Furthermore, the need for additional enforcement can be assessed for reasons of safety.

Police enforcement assessment (PEA)

The police enforcement assessment is particularly useful when speed data is available. In general, this assessment is based on the rule that generic prevention is preferred rather than specific prevention because generic prevention affects a larger number of road users than the specific prevention (15, 16). This means that enforcement methods in combination with additional road user information are promoted that result in high (subjective) probability of getting caught (see 9 for more details).

Final diagnosis

When decision makers want more help than the separate SaCredSpeed assessments just discussed, a final diagnosis can be made in which the possible countermeasures of the SaCredSpeed assessments are combined. That is, the characteristics (i.e. road design, speed limit or traffic situation) that are not tuned to the safe speed are compared to the characteristics that determine the credibility and the need for (additional) enforcement. The final countermeasures suggested can roughly be divided into the following categories:

1. Adaptation of the posted speed limit to make it safe(r) and/or (more) credible;
2. Adaptation of the road design and its surroundings to increase safety and/or credibility of the current speed limit;
3. Adaptation of the enforcement method and/or efforts and accompanying public information campaigns. Increasing the level of police enforcement must particularly be seen as a temporary solution to a speeding problem, bridging the period between the identification of the problem and the more structural infrastructural solutions.

When combining the assessments, solutions have to be tuned to each other. For instance, if on a 50 km/h road the safe speed is determined to be 30 km/h but the speed limit is determined as credible, the following solutions may be possible:

- the road layout may be adapted in such a way that 50 km/h becomes a safe speed limit without deteriorating the credibility (e.g. by physically separating vulnerable road users from the motorised traffic).
- the road layout may be downgraded so that 30 km/h becomes a credible speed limit, without deteriorating safety (for instance by placing physical speed limiters or applying a road diet).

Which of these solutions and the more detailed suggestions for improvement (i.e. which road design elements might be changed) are suggested, depends on a number of other factors. These are:

- The level of ambition of the decision maker: will he aim for a V90 and a design that is safe according to Sustainable Safety? Or is he satisfied with a speed and design that are in accordance with the current speed limit and guidelines? Independent of this ambition, SaCredSpeed always will be distinct about the ideal situation to aim for.
- The function of the road in the road network: if one of the scarce main roads of an area is under assessment, it is more likely to adapt the situation to be in harmony with the current road network function, rather than to downgrade the road because its design is not safe enough.

- The inconsistencies and discontinuities in relation to the adjacent roads in the network. This can be taken into account by the direction of the solution and the measures that can be taken. However, if inconsistencies and discontinuities are inevitable, the situation must be improved as soon as possible.
 - Cost-effectiveness of the various countermeasure that offer a solution: the costs of implementing the measure(s) compared to the monetarised general amount of saved road deaths and severely injured.
- The decision maker is also supported in the prioritizing process by ranking the relative seriousness of the problems of the road(s) under assessment in combination with their traffic volumes. This should be done because a large mobility on a risky road will result in a relatively large number of victims than a risky road with nearly no traffic.

2.2 Towards SaCredSpeed in practice

As (safety) policy in the Netherlands has been devolved to regional and local authorities as much as possible, these authorities face the question how to deal with issues, particularly when no path has been directed by the national government. Within this political context, the provinces of Fryslân and Flevoland took the initiative to start the development of a transparent instrument to support decision makers in setting safe speeds and credible speed limits. Several other parties joined: the provinces of Zeeland and the city-region of Parkstad, the national government (DVS), consultancy (VIA) and road safety research (SWOV). The different parties had the following role and responsibility in the process:

- SWOV developed the SaCredSpeed algorithms and commented on the practical elaboration of these algorithms for use in a decision support instrument. They also initiated further research based on the results and data that were gathered later on.
- The regions Fryslân, Flevoland, Parkstad and Zeeland acted as commissioner and user group or close link to the user group. They also initiated cooperation of road safety professionals in their own region. Finally, they acted as data supplier and data owner.
- Consultant VIA had the role of secretary, data gatherer, software developer and information disperser to user groups. They also executed pilots.
- National Water and Transport department (RWS/DVS) supported the project, also as one of the potential user groups

The start of the process consisted of the development of the SaCredSpeed algorithm and defining the type of data that would be needed for the assessments (8, 9). The consultant started to gather the data from those roads that were of interest for three of the participating region. The algorithms were elaborated to implement them into GIS-software and they were applied to the data of the pilot-regions. These regions will act upon the outcomes in the near future. The data and results of the studies are used now to do further research on the topic of credibility.

3 STUDIES WITH SACREDSPEED

The practical applicability of SaCredSpeed has now been tested in three regions of the Netherlands: Fryslân, Parkstad and Zeeland. The results will be discussed altogether.

3.1 Method

Objectives

All pilot-regions were particularly interested in addressing the issue of safe speeds with an assessment of locations where safety and credibility of speed limits needs attention.

Data and data gathering

The provinces of Fryslân and Zeeland focussed on their provincial road network (mainly 80 and 100 km/h roads), the city-region of Parkstad applied SaCredSpeed on its whole network (mainly 50 and 80 km/h roads). *Table 2* shows details of the three assessed networks. From these networks, the data was gathered as described in §2, since this was not generally available. Dynamic segmentation data gathering was done by driving with a photo-equipped car along the road, making photographs each few meters, and noting changes in road layout compared to the previous section.

Speed data was mainly available from fixed road surface loop detectors (provincial networks) or temporary speed tubes (some local roads). From these classed speed data, the mean V90 was used, over one year for the fixed loops and over one week for the temporary tubes. The assumption was made that this speed measurements were representative for the whole road section on which the loop detector was located. Speed data were only

available for a very small amount of the pilot-networks. Police enforcement data were even more hardly available and will therefore not be included.

TABLE 2 General Characteristics of the Pilot-networks

Characteristic	Fryslan	Zeeland	Parkstad
Total size of the road network	530 km	333 km	435 km
30 km/h roads	1%	0%	8%
50 km/h roads	6%	3%	68%
60 km/h roads	5%	3%	2%
70 km/h roads	5%	2%	2%
80 km/h roads	65%	68%	15%
100 km/h roads	18%	24%	4%
120 km/h roads	0%	1%	0%

Data analysis

Data were analysed by using the length of each segmentation. SaCredSpeed outcomes were compared to each other in percentages of the length per road type and/or per region.

3.2 Results

Safety of speed limit and speed

Of the analysed roads, mainly the rural roads (60, 80 100 and 120 km/h roads) had a too high speed limit to be safe according to the SaCredSpeed algorithm (see *Table 3*). Because the networks of Fryslân and Zeeland consisted mainly of rural roads, they had the highest amount of unsafe roads of the pilot regions. The 80 km/h roads of Parkstad, however, scored much better (3% versus 93 and 96% of unsafe roads).

TABLE 3 Safety Characteristics per Road Type

Characteristic	Amount of unsafe speed limits per region			Safety details: amount of unsafe roads (over all regions, per road type)										Most common safe speed limit	
	Fryslan	Zeeland	Parkstad	Physical separation of driving directions	Forgiving roadside	Obstacle-free zone	Stopping sight distance	Access restriction	Moped/ bicyclist facilities	Pedestrian facilities	Junctions and access lanes	Parking	Safe speed limit	% with this safe speed limit	
General	87%	89%	12%												
30 km/h roads	0%	0%	0%										30 km/h	90%	
50 km/h roads	34%	2%	8%						84%	26%	49%	5%	30 km/h	64%	
60 km/h roads	61%	46%	48%			77%			40%	88%	62%	0%	70 and 30 km/h	42 and 41%	
70 km/h roads	31%	9%	48%		89%	82%	54%	95%	26%		9%		80 km/h	38%	
80 km/h roads	96%	93%	3%	93%	91%	95%	38%	78%	9%		11%		70 km/h	77%	
100 km/h roads	97%	100%	100%	83%	90%	95%	22%	52%					70 km/h	77%	
120 km/h roads	-	85%	-	0%	48%	80%	42%	0%					80 km/h	85%	

Safety problems on the rural roads were particularly due to an insufficient obstacle free zone and on the higher speed limit roads also problems with forgiving road sides and physical separation of driving directions. Fewer rural roads also suffered from lack of safe access restrictions and an insufficient stopping sight distance. On the urban roads, the most prominent problem was the lack of separate two-wheeler facilities.

Most road types, except for most 30 and large parts of 60 and 70 km/h roads, had a safe speed limit that was lower than the actual speed limit (see *Table 3*). The majority of roads of which speed measurements were available turned out to have a higher V90 than would be safe. This was also the case for the roads that had a lower speed limit than would be safe.

Credibility of the speed limit

Approximately half of the pilot network had a credible speed limit, particularly due to the 50 and 80 km/h roads. Too high speed limits to be credible were most common on 100 and 120 km/h roads, mainly due to relative narrow road width (see *Table 4*). Too low speeds limits were particularly found on 30 and 60 km/h roads. Main reasons for this were physical speed reducing measures in combination with straight roads stretches and even road surfaces.

TABLE 4 Credibility Characteristics per Road Type

Amount of credible speed limit per region				Credibility characteristics: amount of uncredible roads (over all regions per road type)					Most common credible speed limit (all roads)	
Characteristic	Friesland	Zeeland	Parkstad	Road width	Straight road stretches	Density of the environment	Physical speed reducing measures	Road surface	Credible speed limit	% with this credible speed limit
Too low a speed limit to be credible	10%	6%	17%							
30 km/h roads	56%	100%	85%	13%	10%	2%	62%	87%	50 km/h	78%
50 km/h roads	21%	43%	9%	37%	15%	11%	0%	0%	50 km/h	65%
60 km/h roads	85%	86%	91%	19%	46%	14%	89%	0%	80 km/h	81%
70 km/h roads	68%	55%	35%	19%	35%				80 km/h	54%
80 km/h roads	2%	2%	1%	46%	57%				80 km/h	73%
100 km/h roads	0%	0%	0%	10%	71%				80 km/h	91%
120 km/h roads	-	0%	-	82%					80 km/h	100%
Too high a speed limit to be credible	40%	41%	25%							
30 km/h roads	0%	0%	0%	3%	26%					
50 km/h roads	33%	37%	22%	12%	21%		28%	3%		
60 km/h roads	14%	11%	1%	4%	13%		0%	2%		
70 km/h roads	31%	34%	65%	37%	14%	12%	11%			
80 km/h roads	26%	22%	36%	42%	12%	66%	6%			
100 km/h roads	100%	99%	100%	86%	4%	32%	2%			
120 km/h roads	-	100%	-	18%						

Most common credible speed limits according to SaCredSpeed were 50 km/h for the 30 and 50km/h roads and 80 km/h for all other roads. On the roads where speed data was available, most roads had a higher V90 than the current speed limit. V90 was always higher than the speed limit on roads with a lower speed limit than credible.

Combined assessments and priorities

The largest part of the assessed road network (68% on average), turned out to have a lower safe speed limit than credible limit. One exception were the 120 km/h roads (Zeeland), where 85% had a similar safe and credible speed limit of 80 km/h. In general, 25% of the road network had similar safe and credible speed.

To help the road authority, 8 priority-steps were defined, which consisted of different assessment combinations of the safe speed, the credible speed limit and the posted speed limit. The first four priorities consisted of combinations of safety and credibility problems, the following two were particularly on safety problems, and the last two mainly on credibility. In the assessed networks, an average amount of 4% was indicated as 'first priority'. Main reason for this quite low percentage was the fact that speed data was only available for a few locations.

4 CONCLUSIONS AND DISCUSSION

This paper has presented the initial version of a decision support method to help decision makers towards safe speeds and credible speed limits (SaCredSpeed) and the first results of three pilot study that were performed with SaCredSpeed. The SaCredSpeed algorithm uses data about the road design and road image, traffic characteristics and behavioral data (if available) to assess the safety and credibility of a road traffic situation. The algorithm makes use of scientific knowledge as much as possible. It offers the opportunity to make this knowledge more practically available to decision makers. Due to its transparency, the decision support system is easier to understand and to apply this. In an international context of speed management approaches, SaCredSpeed is quite unique in the sense that it takes harm minimization as a starting point for setting safe speed limits, rather than economic optimization or other points of view. Speed limit credibility is also explicitly taken into account in the SaCredSpeed algorithm, in order to stimulate decision maker's awareness of this issue and as a way of coming to safe(r) speeds in a more natural driver-friendly way.

The results of the three pilot studies showed that a majority of roads currently have a speed limit that is higher than the limit that has to be considered as safe. This is not very surprising, as the current definition of safe speeds is quite new and much stricter for many road types than is common use and advised in guidelines. It however can

give road authorities an idea or impulse where to consider further action from a proactive and preventive point of view, certainly with the background of decreasing crash data. The results of the pilot study showed that particularly on rural roads, the safety quality is poor, mainly due to insufficient obstacle-free zones, and lack of forgiving road sides and physical separation of driving directions. On urban roads, safety quality was better, but roads with speed limits over 30 km/h often failed to have separate two-wheeler facilities. Main reasons for rural roads to be relatively more often 'unsafe' than urban roads according to SaCredSpeed, may be that rural roads need to conform to more safety requirements in order to handle high speeds safely than is the case on urban roads, where speeds are much lower. Cost-effectiveness of measures to improve these situations will of course play an important role, particularly when roads have low traffic volumes.

Regarding the credibility of speed limits, the study showed that the SaCredSpeed assessment made a distinction between roads with the result that about half of the roads were classified as 'credible'. Roads with too high a speed limit where particularly the 30 and 60 km/h roads, due to lack of physical speed reducing measures, straight road stretches and even road surfaces. These road types are in the Netherlands also known as respectively urban and rural 'access roads', and were implemented on a large scale in the last decade due to the Startup-programme of Sustainable Safety. This impulse was an improvement towards safer road design, but the choice for large-scale implementation also led to more low-cost realizations (e.g. 5), with uncredible speed limits as a result.

Surprisingly, too high speed limits were found to be quite common, particularly on high-speed roads due to narrow road width. For locations where speed data were available, V90 turned out to be most often higher than the speed limit, but always in those cases that were assessed as having too low a speed limit. The participating road authorities indicated the credibility assessment did not always give credible results itself. They felt that not only the density of environmental elements is relevant for credibility of speed limits, but also some more types of elements. These notes and the match with the speed data revealed that the credibility assessment needs some improvement or fine-tuning, which may be found in the following three directions:

- Adaptation of the cut-off points of the credibility-relevant characteristics as either being neutral, an accelerator or a decelerator per speed limit.
- Characteristics that will be found to dominate credibility scores, should get more weight than others.
- Adding new relevant characteristics to the credibility assessment.

SWOV has the intention to investigate these issues further and improve the SaCredSpeed algorithm with the resulting knowledge.

It was hardly possible in this pilot study to come to conclusions regarding the safety level of the driving speeds nor regarding the potential improvements of increasing the enforcement level because data on actual driving speeds and information about the current speed enforcement activities were largely missing. Still, it was possible to identify those road sections that would need changes in road design. The experience, however, is that speed data is needed to come to better results.

When combining safety and credibility characteristics, some conflicting issues appear: wide roads and obstacle-free road shoulders are, for instance, good for safety because crash objects are more distant to the road users. However, an open road image, distant to many obstacles will provoke the tendency to speed, which is, under similar conditions, related to a higher crash risk. In this sense, the design elements that are required to provide a sufficient level of safety given a particular speed limit, may not always be in line with the requirements for credibility of that speed limit. This is just one example indicating that it is possible that a certain road characteristic has a positive effect on safety and a negative effect on credibility, or the other way round. It is important to bear in mind that, whenever there is a conflict in effect of a certain road characteristic with respect to safety and credibility, the interest of safety should master over the interest of credibility. First priority is to develop safe speeds and speed limits. Credible speed limits are an important way to contribute to speed limits compliance and therewith safer travel speeds.

Research on speed limit credibility is still very limited. Credibility may be partly determined by general parameters consistent over different countries, but it may be also partly developed by learning, and thus depending on specific national and cultural road design characteristics. Other issues that need further research are 1) the relative contribution of road characteristics in combination with each other to safety in general and credibility of the speed limit in particular and 2) the safety and credibility potential of dynamic speed limits and the way this can be communicated to the road user and influence his driving behavior. Dynamic speed limits and

more fine-tuning of credibility assessments will be interesting topics for further research in the near future, which will be used to improve the SaCredSpeed method even further.

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