VUFO GmbH

Verkehrsunfallforschung an der TU Dresden GmbH

TECHNISCHE UNIVERSITÄT DRESDEN

ein Unternehmen der TUDAG

Qualitative assessment of Intelligent Speed Adaptation (ISA) systems

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Datum: 2018.10.22 18:43:03 +02'00'

Dresden, 22 October 2018

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I. Abbreviations

Symbol	Description
ACEA	European Automobile Manufacturers' Association
ADAC	Allgemeiner Deutscher Automobil-Club e.V.
AEB	Autonomous Emergency Braking
AEB-PCD	Autonomous emergency braking for pedestrians and cyclists
BASt	Federal Highway Research Institute of Germany
BCR	Benefit-cost ratio
CEN	European Committee for Standardization
DESTATIS	Federal Statistical Office in Germany
ECU	Electronic Control Unit
ERSO	European Road Safety Observatory
ESC	Electronic Stability Control
ETSC	European Transport Safety Council
ETSI	European Telecommunications Standards Institute
EU	European Union
Euro NCAP	European New Car Assessment Programme
Euro RAP	European Road Assessment Programme
FAT	Research Association of Automotive Technology of Germany
FIA	Féderation Internationale de l'Automobile
GIDAS	German In-Depth Accident Study
GPS	Global Positioning System
GSR	General Safety Regulation
IRTAD	International Traffic Safety Data and Analysis Group
ISA	Intelligent Speed Adaptation
ISO	International Organization for Standardization
ITS	Intelligent Transport Systems
ITF	International Transport Forum
LDM	Local Dynamic Maps
LKA	Lane Keeping Assistance
M1 vehicles	Vehicles used for carriage of passengers, comprising not more than eight seats in addition to the driver's
NHTSA	National Highway Traffic Safety Administration
OECD	Organisation for Economic Co-operation and Development
OEM	Original Equipment Manufacturer
PROSPER	Project for Research On Speed adaptation Policies on European Roads
RAIDS	Road Accident In-Depth Studies (UK)
SWOV	Institute for Road Safety Research (Netherlands)
TRL	TRL Limited (UK)
UNECE	United Nations Economic Commission for Europe
VUFO	Traffic Accident Research Institute at University of Technology Dresden

II. Structure

III. Executive Summary

The EU Regulations General Safety Regulation (EC) No 661/2009 (GSR) and Pedestrian Protection Regulation (EC) No 78/2009 shall be upgraded by state-of-the-art vehicle safety measures to protect drivers, passengers, pedestrians and cyclists in road accidents. The Commission proposed 19 measures with the potential to save many lives and mitigate injuries on EU roads. One of these proposed measures was the mandatory fitting of Intelligent Speed Adaptation (ISA). FIA Region I requested a desk study to be conducted by the VUFO reviewing the impact of such systems through a qualitative assessment. This, by looking into the ISA definition, benefit cost data from the Commission's impact assessment, technical constraints, root cause and correlation with accident statistics, infrastructure issues, accuracy and acceptance. The study considered the latest literature, safety statistics and any available information from relevant data sources (e.g. from the EU Commission, Euro NCAP) to produce scientific evidence.

In a first step, the question should be answered, how many accidents, related to speeding, are occurring on the roads within the EU. Statistics and detailed information regarding vehicle speed as a cause/contributing factor of accidents were not available at the entire EU level. If statistics were available, the accessible information was mostly general and not necessarily linked to accident statistics. Nevertheless the available accident data showed a proportion of 3% related to excessive vehicle speed as root cause average in Europe.

The major findings were that

- 50% of the investigated accidents occurred inside urban areas
- 42% took place during twilight or night
- 52% occurred on damp, wet or other slippery roads
- in 56% of the accidents speed limiting traffic signs were available
- 44% of the speeds were limited by location. This means that the driver could not rely on a speed limit sign but had to derive from the vehicle's location (urban, extra-urban, motorway etc.) what country-specific speed limits are applicable.

Looking at the benefit-cost ratios (BCR) derived by TRL [1] for ISA for six EU member states, several questions were raised concerning benefit/ cost calculation input data validity (old and insufficiently comprehensive).The costs were based on the premise that by 2010 all new vehicles would come with a satellite navigation system as standard [2]. Looking into the equipment rate for new cars in Germany in 2017 [3], only 60% of the new vehicles were equipped with a navigation system. Furthermore, the BCR calculation of [2] assumed that speed limit data incorporated into digital road maps would be available on a pan-European basis by 2010, which is not the case in 2018. Another question arose why no societal costs were included in the TRL analysis. In this context, societal costs meant costs for map data creation, provision, and maintenance including updates of urban areas, speed zone variations, construction sites etc. Since the projected benefit rates assumed and based on an EU-wide 100% retrofit within ten years, the question arose if a complete retrofit is technically possible. No evidence was found that this service was offered to consumers on a large scale in the EU market.

The prediction of the system related safety benefits in the TRL study ranged from a minimum saving of 24 fatalities (low estimate-high confidence) up to 249 fatalities (upper estimate – high+medium+low confidence) saved over a five-year period in the EU (Table 11) [4]. ISA trials showed a positive effect of ISA on driving speeds with an average speed reduction of 2 to 7 kph [5].

User acceptance is essential for the success and effectiveness of ISA. Factors influencing the acceptance have been presented. The system with the least intrusive effects on driving behaviour had a higher acceptance than a more intruding and controlling ISA.

Traffic sign recognition for ISA systems is highly depending on the availability of standardized speed limit signs, which is not a given in Europe.

The error rate of the systems concerning traffic sign recognition owing to either false or no detection of the speed limit was found to be dependent on the sensing part of the system, with cameras, GPS or both. Looking into different studies the average ISA detection error rate was about 10% under dry, ”normal” conditions, whereas under exceptional conditions like rain or during night the average error rate was assumed to be about 15-25%. A test of ADAC in 2018 showed an error rate of about 10% in traffic sign recognition [6]. The tested cars were all equipped with camera and GPS. In Euro NCAP testing, a full score at rating is only possible for a combined method of camera and map. The evaluated ratings of the years 2017 and 2018 show that 2 of the 16 tested cars, fitted with an ISA system have implemented both technologies as source of the speed limit information. However, the Commission proposal allows camera and/or map-based ISA, which means that the GSR requirements would be complied with if at a minimum either system would be fitted or combined.

Beside traffic sign recognition the required speed information for ISA can be gained from digital road maps and the vehicle position detected by GPS. A highly frequent update of the map would be needed to ensure ISA detection robustness. The main issues are the absence of an online update possibility and GPS inaccuracy (retrieval of wrong road segments with wrong speed limit). Since 2009 there are efforts of the European Union to standardize geographic road network data with the help of ETSI and CEN.

1. Introduction

Inapt or excessive speed is identified by some institutions and investigations as the main factor in the occurrence of accidents. As early as 1998, the Transportation Research Board found [7] that excessive speed was an influencing factor in around 30% of fatal accidents.

According to a study by the European Road Safety Observatory (ERSO) of the EU Commission [8], 40-60% of drivers in the EU exceed the speed limit. 10-20% even exceed the limit by more than 10 kph.

The reduction of average speeds on the roads is expected to reduce the number of accidents. According to [1] the reduction of the average speed by 1 kph causes a reduction of 3% in the number of accidents. Whereby TRL [1] here referred to a calculation basis of Finch et. al. **from the year 1984**.

Intelligent speed adaptation in newly registered vehicles may address this problem under a set of conditions and assumptions. The aim is to avoid the exceedance of permitted speeds, to reduce average driving speeds and thus to avoid accidents, injuries and fatalities in Europe.

The present study will carry out a qualitative assessment of intelligent speed assistance systems (ISA) on the basis of literature analyses, statistics, and GIDAS evaluations.

The basis for the study are:

- Existing evidence from literature references
- GIDAS statistics analyses providing German accident statistics
- Analysis of other available statistical data

The topics to be highlighted are:

- Number/proportion of road accidents caused by inappropriate speed
- Safety effect of intelligent speed assistance systems
- Acceptance of such systems
- Necessary infrastructural prerequisites for the efficient introduction of ISA systems.

2. Definitions in field of speed and “Intelligent Speed Adaptation (ISA)”

2.1. Inadequate speed – excessive speed

Within this study the term “speed” is used to express “vehicle speed”. The speed is not related to wind speed, engine speed or other meanings.

Speeding, excessive speed or inadequate/inappropriate speed as a term is used by many institutions, statistics and data sources. It is essential for this analysis to define the wording which is used in relation to speed:

Excessive speed

Driving on roads with exceeding the official speed limit (including all posted speed limits like fixed, dynamic and variable speed limits).

Inadequate speed

Driving with a speed, which is not adopted to road and weather conditions. This velocity is not necessarily higher than the posted speed limit.

2.2. ISA systems

The abbreviation “ISA” is widely used in the area of advanced driver assistance systems. Different definitions of the abbreviation can be found in the literature, which need to be clarified and clearly specified in this study.

One definition of ISA was found in the TRL report [9]:

“Intelligent Speed Adaptation (ISA) describes a range of technologies which are designed to aid drivers in observing the appropriate speed for the road environment.”

With this wording, ISA systems could refer as well to fixed speed limits (e.g. by traffic signs) as to situational speed limits due to environmental factors (e.g. dry, wet, slippery, fog).

Another definition of the abbreviation (but with very similar meaning) is used by the testing consortium Euro NCAP [10]:

Table 1: Abbreviations of speed assist functions within Euro NCAP [10]

Abbreviation	**Explanation**	**Description**
SLIF	Speed Limit Information Function	System function with which the vehicle knows and communicates the speed limit at the location and circumstance
SLF	Speed Limitation Function	System which allows the driver to set a vehicle speed, to which he wishes the speed of his car to be limited and above which he wishes to be warned
ISA	Intelligent Speed Assist Function	SLF combined with SLIF, where the adjustable speed is set by the SLIF with or without driver confirmation

This study uses the ISA system approach in a sense which is also set out in the European Commission proposal [11]:

“intelligent speed assistance' means a system to aid the driver in observing the appropriate speed for the road environment by providing haptic feedback through the accelerator pedal with speed limit information obtained through observation of road signs and signals, based on infrastructure signals or electronic map data, or both, made available in-vehicle”

The analysis of the data and literature is focused on the situation with fixed official speed limits (traffic sign or location based).

2.2.1. Specifications of ISA systems

There are several ways to obtain the ISA functionality and objectives. In every case it is essential to get an information with regard to the speed limit. TRL defined the way of getting this information in different ways over time.

In 2015, TRL stated [1]:

“The speed limit information is either received from ***transponders*** in speed limit signs (a ‘beacon system’), ***or*** from a ***digital road map***, which requires reliable positioning information from GPS.”

Another report related to speed assistance in 2017 [9] defined:

“Systems could be ***based on maps*** of speed limits with GPS positioning of the vehicle ***or*** ***traffic sign recognition***. The system therefore requires accurate speed information maps **and/or** adequate road signs.”

The commitment within this study is the adoption of the definition from TRL [9] 2017 report, due to the fact that vehicle-to-X communication systems (‘beacon systems’) are neither available on the roads nor mentioned in any EU Commission paper.

ISA systems could have several specifications. It is a fact, that several names of these specifications could be found. This section will clarify the used names and meanings of ISA systems.

Table 2: Specifications of ISA systems in literature

Institution	Name	Specification/ description
EU Comm.	**Open ISA**	Warns the driver (visibly and/or audibly) that the speed limit is being exceeded. The driver him/herself decides whether or not to slow down. This is an informative or advisory system
EU Comm.	**Half-open ISA**	Increases the pressure on the accelerator pedal or provides haptic feedback (vibrations to the foot) when the speed limit is exceeded (the 'active accelerator'). Maintaining the same speed is possible, but less comfortable because of the counter pressure
EU Comm.	**Closed ISA**	Limits the speed automatically if the speed limit is exceeded. It is possible to make this system **mandatory or apply it on a voluntary basis**. In the latter case, drivers may choose to switch the system on or off
TRL	**Advisory ISA (=Open ISA)**	Warns the driver (visibly and/or audibly) that the speed limit is being exceeded. The driver him/herself decides whether or not to slow down. This is an informative or advisory system
TRL	**Voluntary ISA**	The driver chooses whether the system can restrict their vehicle speed and/or the speed it is restricted to.
TRL	**Mandatory ISA**	The driver’s speed selection is physically limited by the ISA system

Remark: The name voluntary or mandatory ISA should not be mixed up with the voluntary or mandatory introduction of such systems in new cars (approval process).

3. **Analysis of speeding accidents – facts and figures**

3.1. Analysis of official road accident statistics

3.1.1. IRTAD database

3.1.1.1. Outline [12]

The International Transport Forum (ITF) as a part of the OECD is an intergovernmental organisation with 59 member countries.

Since 2008 this forum runs the IRTAD database, which aggregates international key figures about road crashes. With this data it was possible to get a general overview about the road safety situation in Europe and the World. Basis of these statistics were official numbers, e.g. road accident numbers recorded by the police of the attending countries.

3.1.1.2. Results and summary

A very important result is that only a few countries provide detailed information regarding speed as a cause/contributing factor of accidents. There are several regions in which no data is available. If statistics are available, the accessible information is mostly general and not necessarily linked to accident statistics. As one example is given the rate of exceeded speeding in one country, but no evidence if this speed lead to accidents at all.

Causation of accidents with injured people is influenced by excessive speed (above speed limit) as a contributing factor. The numbers show a proportion of 3% as average in Europe. The values are spread from less than 1% (Italy, Germany, Hungary) to 10% (Czech Republic).

These numbers seem to give a tendency of the occurrence of speed as an accident causing factor within the countries. The issue with these percentages is the methodology of the recording process.

All national accident databases are based on police reports. The policemen are usually not reconstructing accidents and thus, are not able to state the exact initial speed value of the vehicles. ***From a scientific point of view the available accident statistics from IRTAD or comparable statistical portals <u>cannot be used</u> for in-depth studies***.

3.2. Analysis of GIDAS data

3.2.1. Outline

GIDAS is a collaborative project of the Federal Highway Research Institute (BASt) of Germany and The Research Association of Automotive Technology (FAT) of Germany (Figure 3-1). It started in 1999 including data of research areas Dresden and Hannover. In these areas about 2,000 accidents per year are investigated and recorded to the GIDAS database. Each case is encoded with about 3,400 variables. Following the documentation, each accident is reconstructed by an experienced engineer.

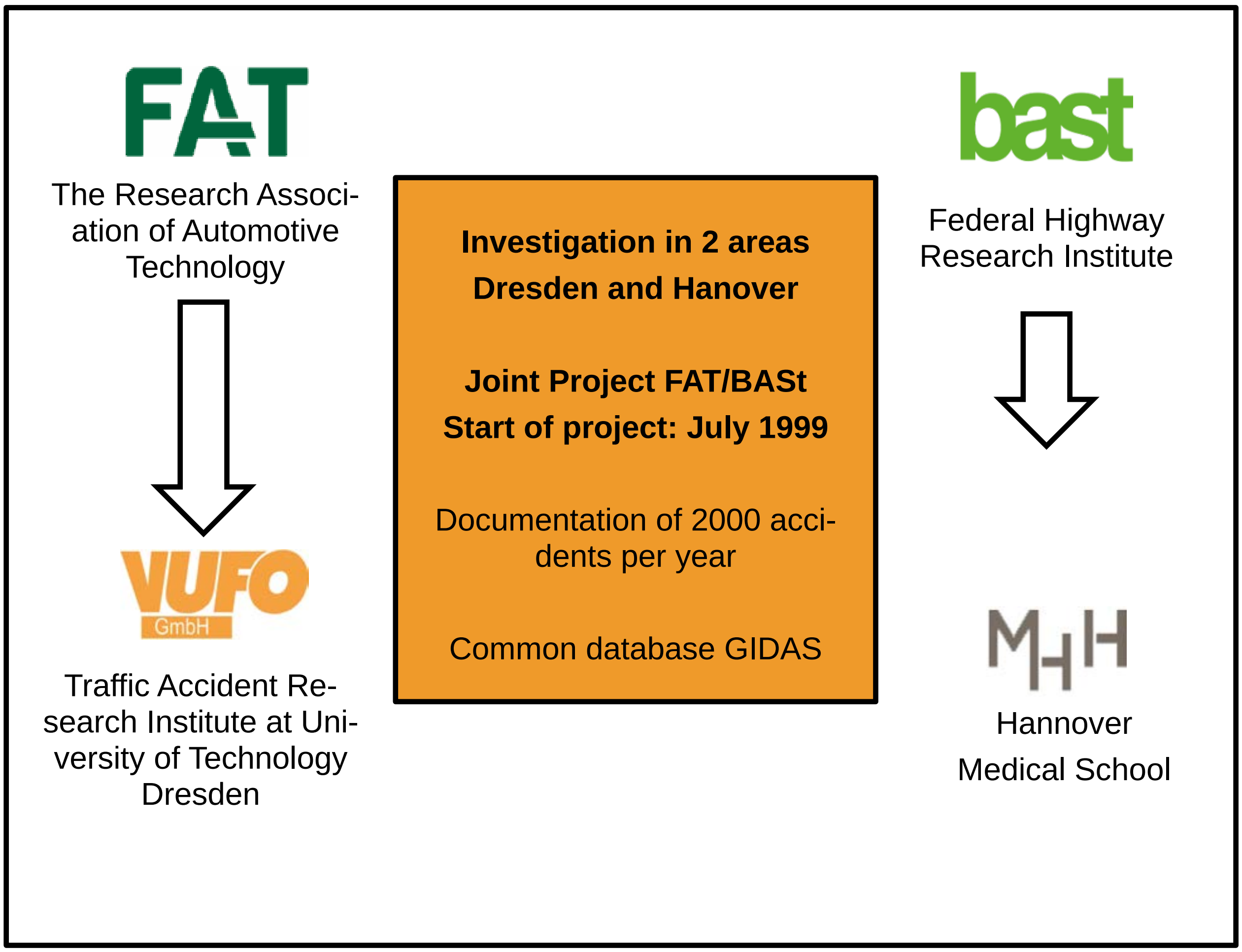


Figure 3-1: Structure of the GIDAS project

The use of the GIDAS database enables representative statements for the German traffic accident scenario. This is due to a high number of recorded accidents, the fact that the two research areas (Hannover and Dresden) topographically represent the German average and the investigation follows a statistical sampling plan. For further details see www.GIDAS.org [13].

3.2.2. GIDAS data sample

This study is performed with accidents that occurred in the years 2011 until 2016. The cases are completely documented and reconstructed. Thus, the evaluations were based on 10,742 road accidents with 20,827 involved parties.

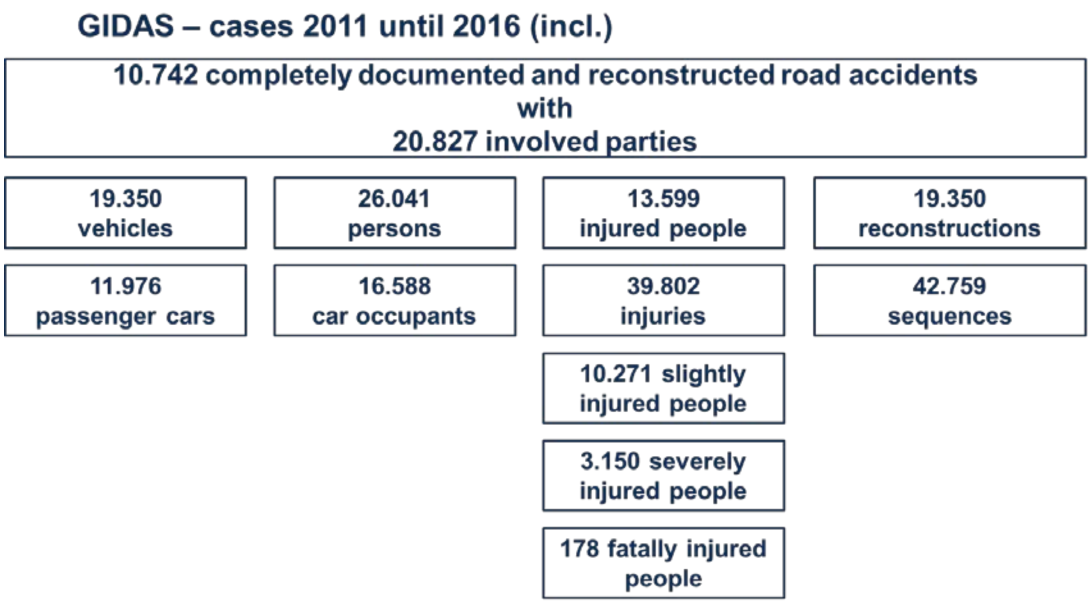


Figure 3-2: Data sample of the study [13]

3.2.3. Weighting and validation process

After the identification of the basic dataset it is essential to prove and weight the cases. With this process it is possible to get a subsample of the official road accident statistics in Germany.

The first step is the examination if the recorded cases meet the criteria to be counted in the official road accident statistics. Some cases will be excluded in this step (e.g. suicides, accidents on non-public roads). The next step is the weighting of the cases to reach the proportions within the dataset as they are registered in the official road accidents statistics.

The following results within this report are based on weighted data within the GIDAS database.

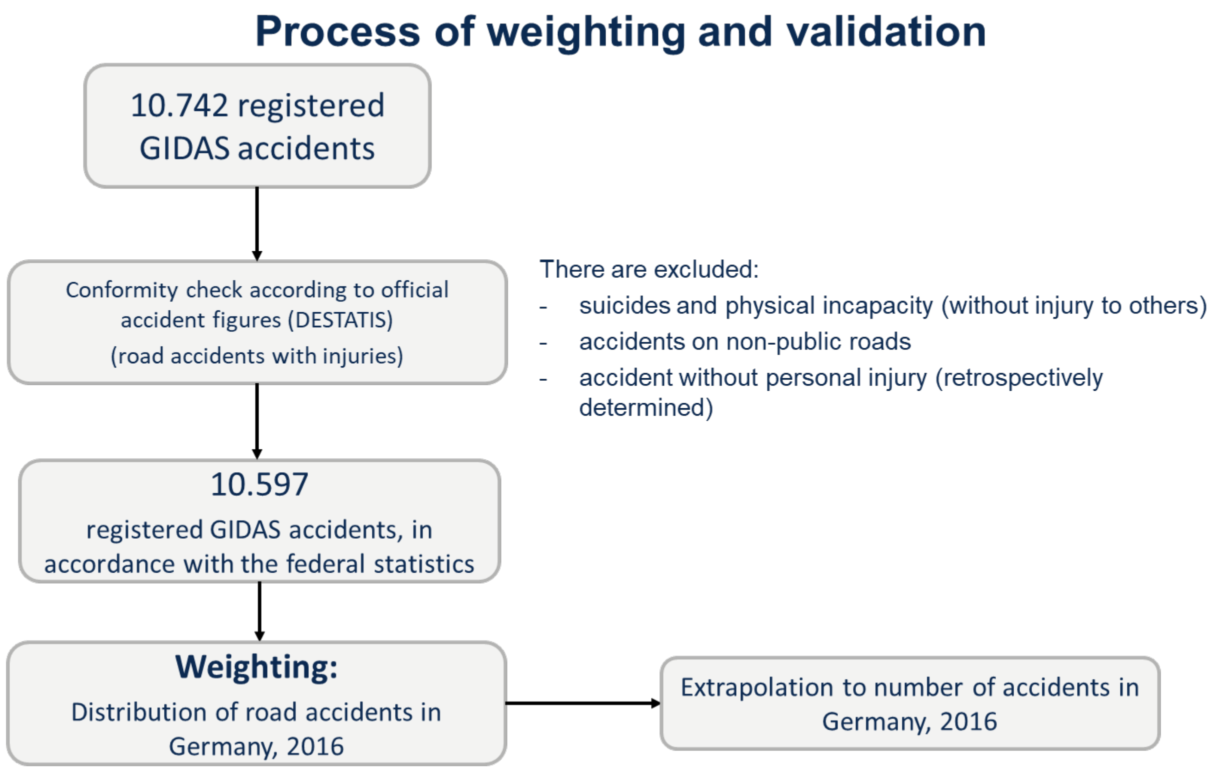


Figure 3-3: Process of weighting and proving within the study [13]

3.2.4. Results

3.2.4.1. Causing factors

The evaluation of the data shows the proportion of accidents in which excessive speed is a contributing factor. Main accident causers and non-causers could be travelling on the roads with excessive speed. This leads to an influence of the accident causation and/or accident severity.

The first analysis shall give an overview to the amount of accidents, which are influenced by excessive or inadequate speed. 100% represented all accidents with personal damage, severe or fatal injuries or fatal injuries. In Figure 3-4 and Figure 3-5 can be found, that in cases with fatal injuries, the proportion of accidents influenced (caused) by excessive speed is higher than in all cases with personal damage.

In the group of accidents with personal damage 8.2% of the cases were caused by excessive speed. In nearly every fifth accident (19.1%) with fatal injuries, excessive speed was a causing factor.

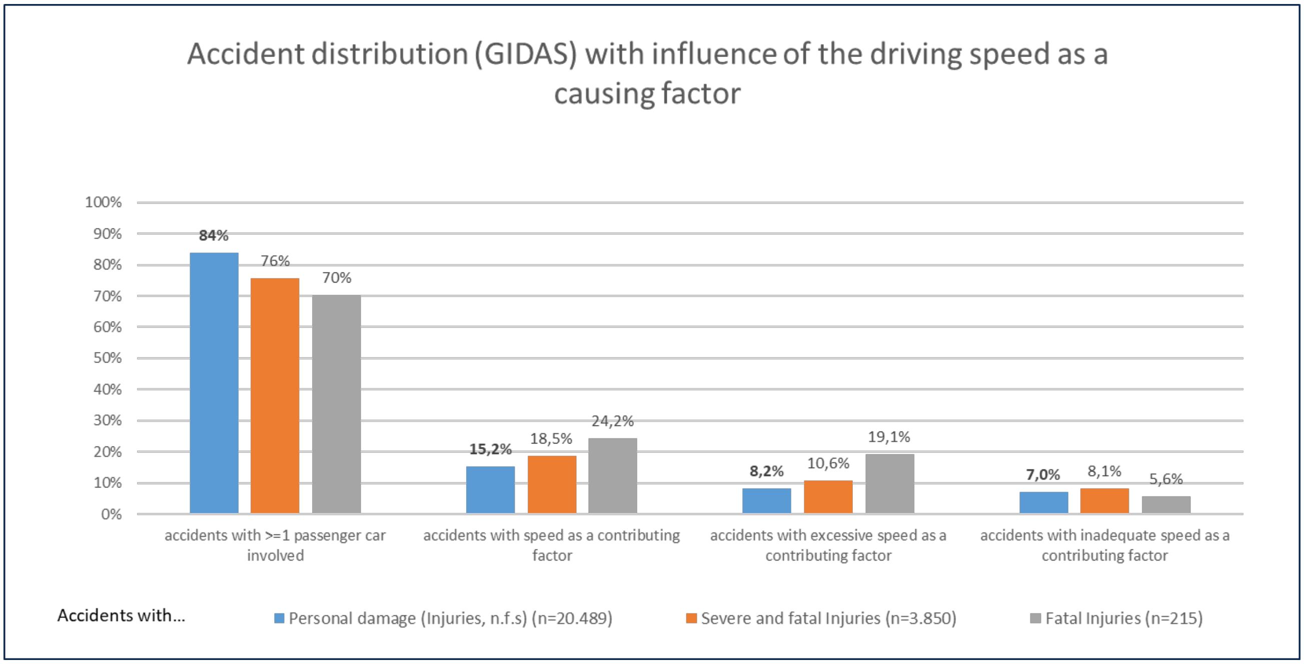


Figure 3-4: Accident distribution with influence of the driving speed as <u>contributing factor</u> [13]

In the next step, the relative frequency of excessive speed as the **<u>main accident causing factor</u>** is investigated.

In the group of accidents with injuries 1.9% were mainly caused by excessive speed. In 7.0% of accidents with fatal injuries, excessive speed was the main causing factor.

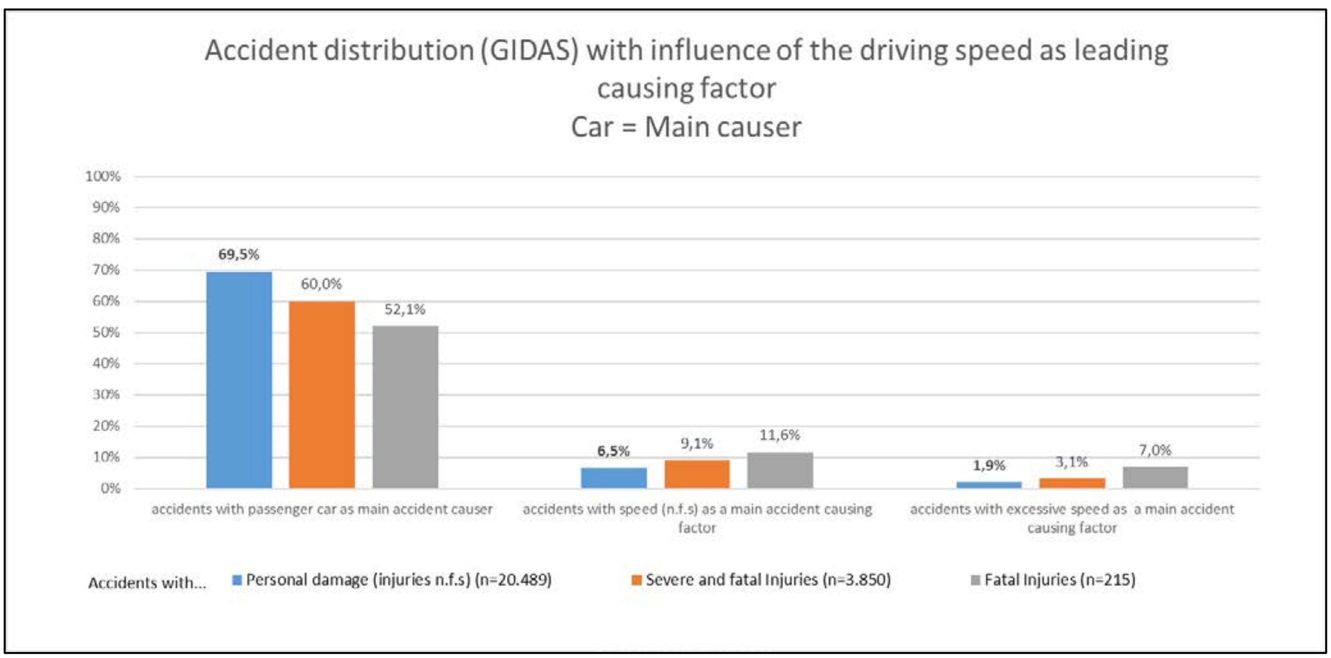


Figure 3-5: Accidents distribution with influence of the driving speed as <u>leading causing factor</u> [13]

3.2.4.2. Involved car drivers

The car drivers who caused an accident due to inadequate or excessive speed were compared to all car drivers (numbers in brackets) within GIDAS.

There are some differences in the gender distribution. It was found that 66% of the drivers were male (64%) and 36% female (34%).

The proportion of the age groups are given in Table 3. The GIDAS accident data show a tendency, that young drivers are more likely the main causers in speed accidents (n.f.s).

Table 3: Age groups of the accident causers (car driver) in GIDAS [13]

Car=main causer n= 13.935 (304 unknown)		Car=main causer Main accident causing factor= speed n.f.s. n= 1.329 (7 unknown)	
Age group	**rel. frequency**	**Age group**	**rel. frequency**
<18	0%	<18	0%
18-24	16%	18-24	24%
25-34	20%	25-34	26%
35-64	48%	35-64	40%
65+	16%	65+	10%

Nevertheless the groups with an age of 35 years and older represent 50% of the accident causers.

Remark: It is important to know, that the number of years in the age-classes in Table 3 are not equal. The 7 years of age (18-24 years) lead to 24% of the involved parties, where 30 years (35-64 years) lead to 40%. This shows, that the relative proportion of involvement is tending towards the younger drivers.

3.2.4.3. Accident locations and environmental conditions

For the next analyses, accidents of car drivers as main causers are compared to the ones that were caused by excessive speed.

Every second accident with excessive speed as main causing factor <u>occurred in urban areas</u>. Rural roads make up 40% and 10% of the cases were found on motorways.

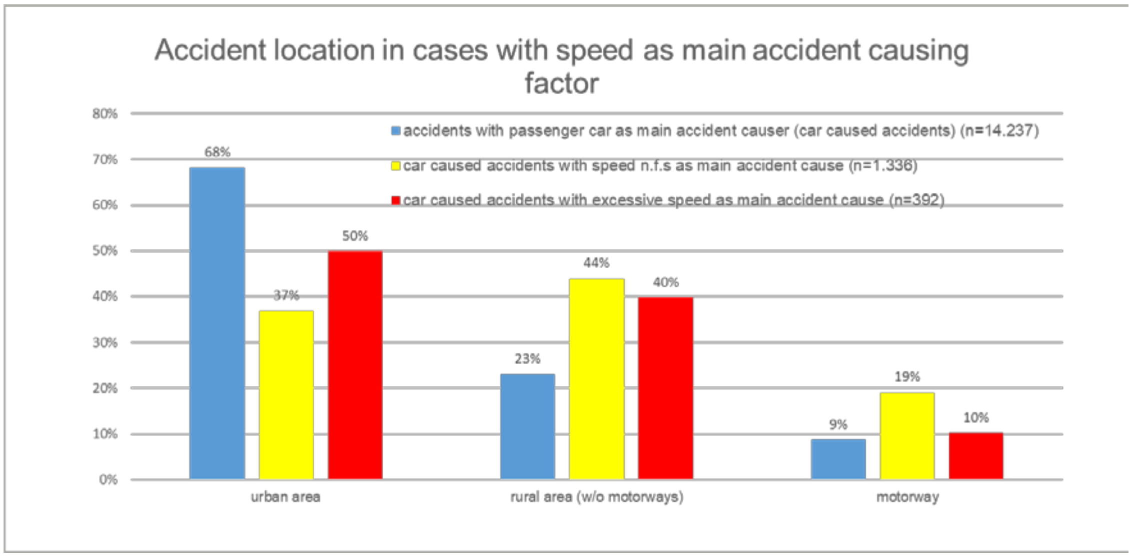


Figure 3-6: Accident location [13]

78% of the car caused accidents took place during daylight. For accidents with excessive speed as main causing factor this share decreased to 58%.

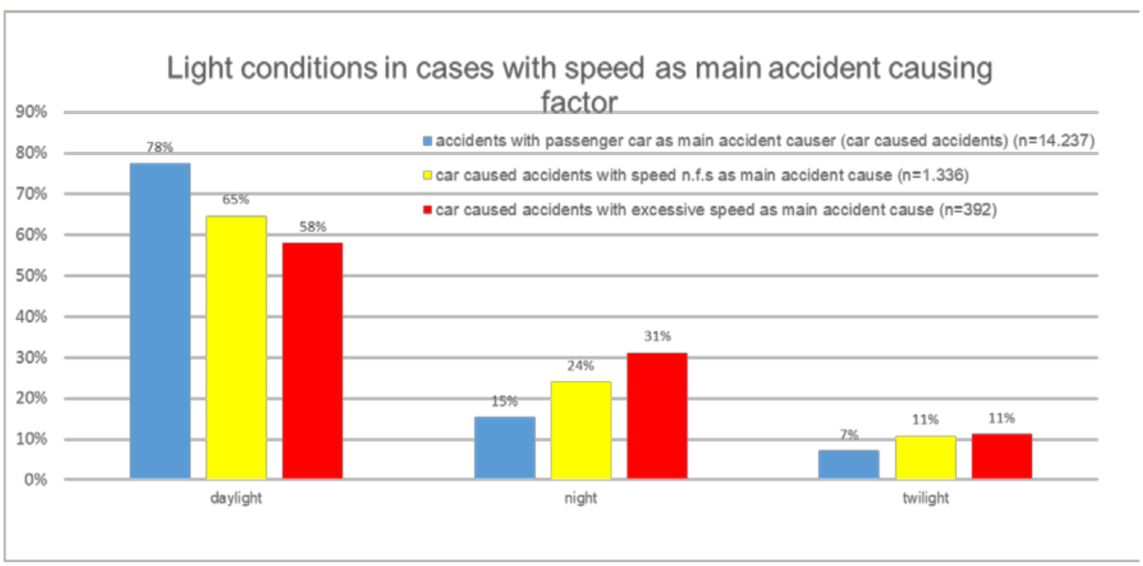


Figure 3-7: Light conditions [13]

Night time accidents are more often associated to accidents due to excessive speed.

Table 4 shows the distribution of the road surface conditions, documented within the GIDAS dataset. It could be found that 52% of the speed accidents occur on damp, wet or other slippery roads. This is more than twice as often as for the “normal” car caused accident.

Table 4: Road surface [13]

Car=main causer n= 14.221 (18 unknown)		Car=main causer Main accident causing factor= speed n.f.s. n= 1.333 (3 unknown)	
Road surface	**rel. frequency**	**Road surface**	**rel. frequency**
Dry	77%	Dry	48%
Damp	10%	Damp	16%
Wet	11%	Wet	19%
Icy	1%	Icy	10%
Snow	1%	Snow	7%

In 56% of the accidents which were caused by excessive speed, speed limiting traffic signs were available. In 44% of the cases, the speed was limited by the location (e.g. urban area in Germany = 50 kph) (Table 5), which meant that the driver had to derive from the actual car position the applicable speed limit (no speed related traffic signs present).

A further inspection of the accident locations deliver the fact that urban speed limits are rarely indicated by traffic signs (26.4%). The speed limit of 100 kph (usually rural roads, sometimes on motorways) was indicated in 60.4% of the accidents.

Table 5: Speed limit indication [13]

Car=main causer Main accident causing factor= excessive speed n= 381 (11 unknown)	
Kind of speed limit	**Rel. frequency**
No limit	0%
Traffic sign	**55%**
Dynamic traffic signs	**1%**
Limit defined by location (urban, rural,..)	44%

Summary of the GIDAS analyses

Several aspects were evaluated with a subset of GIDAS data. The most important findings were highlighted in the next section.

Car-caused accidents with excessive speed as main causing factor:

- 50% occurred inside urban areas; 40% on rural roads, 10% on motorways
- 42% took place during twilight or night
- 52% occurred on damp, wet or other slippery roads
- In 56% of the accidents speed limiting traffic signs were available; 44% of the speeds were limited by location.

The characteristics of the investigated cases give insights, which framework has to be considered while searching valuable measures to avoid or mitigate these accidents.

4. **Studies of benefit-cost ratio calculations**

The safety measures of the Mobility Package III, proposed by the European Commission, were mainly based upon a preliminary study conducted by TRL for the Commission, which was published in 2015. Therein an indicative cost-benefit analysis of 55 possible measures, which could be introduced in the EU, was conducted.

4.1. Benefit-cost ratio analysis of ISA by TRL

The benefit-cost ratios (BCR) were **only calculated for six member states of the EU 28**, namely Belgium, Great Britain, France, the Netherlands, Spain, and Sweden [1]. The BCR was calculated for two different implementation scenarios: a market driven scenario, which meant a mix of advisory and voluntary ISA (possibility to switch on/off by the driver) and an authority scenario representing mandatory ISA, where the term ‘mandatory’ describes here mandatory activation, thus no possibility to switch ISA off [2]. As shown in Table 6 the calculated BCR is positive for both scenarios, even though the BCR is higher for the mandatory activation system.

Table 6: Benefit-cost ratio of ISA according to TRL study [1]

'Green' Measures					
Code	**Measure**	**Feasible?**	**BCR**	**Legislate?**	**Recommendations/Notes**
ISA	Speed limiters controlled by road speed limit (speed assist, intelligent speed adaptation)	✓	>1	●	BCR>1 for 6 Member States, for voluntary activation (switched on/off by the driver) and mandatory activation, and public acceptability of the systems considered to be growing. BCR higher for mandatory activation system, but both have positive BCR

The detailed overview of the BCRs depending on the member state and scenario is given in Table 7.

Table 7: Estimated BCRs for mandatory ISA in different implementation scenarios [1]

Country	BCR "Market scenario"	BCR "authority scenario"
Belgium	3.5:1	4.8:1
Great Britain	3.1:1	4.2:1
France	2.4:1	3.5:1
Netherlands	2.6:1	4.1:1
Spain	2:1	2.8:1
Sweden	2.5:1	3.5:1

For the TRL study in 2015, the estimated BCRs were derived from a study undertaken by Carsten (University of Leeds) in 2005 as part of the PROSPER project [2].

The costs were based on the ***premise that by 2010 all new vehicles will come with a satellite navigation system as standard*** [2]. Looking into the equipment rate for ***new cars in Germany in 2017, only 60% of the new vehicles are equipped with navigation system and 16% come with traffic sign recognition*** [3] (Table 8).

Furthermore the BCR calculation of [2] assumed that, as predicted by the SpeedAlert project [14], ***speed limit data incorporated into digital road maps will be available on a pan-European basis by 2010***.

Table 8: Equipment rate of new cars in Germany 2016/2017 [3]

Equipment	New cars buyer	
Safety	2017	2016
Adaptive cruise control	18 %	17 %
Bending light system	35 %	34 %
Alarm system	18 %	16 %
Drowsiness detection	20 %	13 %
High-beam assistent	18 %	18 %
Light sensor	62 %	56 %
Night view assistent	5 %	5 %
eCall	12 %	7 %
Emergency brake assistent	30 %	27 %
Rain sensor	67 %	65 %
Tyre pressure sensor/monitor	100 %	100 %
Side-impact airbag	74 %	79 %
Lane departure warning system	24 %	19 %
Lane change assistent	13 %	12 %
Traffic sign recognition	16 %	9 %
Xenon lights	28 %	29 %
Comfort	2017	2016
Intelligent parking assist system	24 %	23 %
Parking aid/Parktronic	68 %	62 %
Electric tailgate	21 %	19 %
Electric seat adjustment	30 %	26 %
Hands-free system (fitted)	60 %	52 %
Head-up Display	8 %	7 %
Air conditioning	93 %	93 %
Navigation system	60 %	59 %
Radio	95 %	76 %
Sliding roof	20 %	20 %
Seat heater	67 %	64 %
Sport seats/leather seats	35 %	38 %
Sport-/Leather-/Multifunctionsteeringwheel	74 %	71 %
Parking heating	10 %	10 %
Cruise control	71 %	69 %
Central locking	93 %	95 %

Source: DAT, Status: January 2018

This information is also available via www.kfzgewerbe.de/presse/publikationen/zahlen-fakten

Table 9: Costs of ISA equipment in Euros (Year 2005) – PROSPER [2]

Fitment	ISA Category 1	ISA Category 3A/3B
Fit to new vehicle	25	100
Retrofit	140	207

In Table 9 the costs of ISA equipment used for the BCR calculation in the 2005 study were displayed in Euros, where ISA Category 1 stands for advisory ISA, and ISA category 3A/3B means voluntary and mandatory ISA. According to [2] in addition to the costs of the in-vehicle equipment, there were various organizational or public costs associated with implementation of ISA.

These are:

- creating the digital map databases that form the basis of ISA,
- keeping these maps current, and
- dissemination of the base maps and subsequent updates.

But as stated in the PROSPER report "***However <u>no</u> extra costs have been included in the analysis***" [2].

Reasons given in [2] were:

1. Relative to the total equipment costs, these costs are very small.
2. It is assumed that electronic processing of speed limit changes for legal purposes will replace current paper methods at no extra administrative cost.
3. It is assumed that national and later pan-European digital traffic services will be provided for many other purposes than ISA support.
4. The adoption of voluntary ISA will dramatically lower police speed enforcement costs, but the savings from this have not been included in the analysis.

Furthermore the projected benefit rates were based on the fact, that ***within ten years 100% of old cars are <u>retrofitted</u> EU wide***, as displayed in Table 10.

Table 10: Penetration of ISA into passenger cars under market-driven scenario (Belgium) [9]

Year	ISA Category 1		ISA Category 3A	
	% of new vehicles fitted	% of older vehicles retrofitted	% of new vehicles fitted	% of older vehicles retrofitted
2010	50.00	5.00	0.00	0.00
2011	54.00	14.50	1.00	0.00
2012	58.00	24.00	2.00	0.00
2013	62.00	33.50	3.00	0.00
2014	66.00	43.00	4.00	0.00
2015	70.00	52.50	5.00	0.01
2016	74.00	62.00	6.00	0.01
2017	78.00	71.50	7.00	0.02
2018	82.00	81.00	8.00	0.02
2019	86.00	90.50	9.00	0.03
2020	90.00	99.96	10.00	0.04

4.2. Questions arising on BCR calculation

The VUFO did not conduct a benefit cost analysis within this study. However, a lot of open questions emerged, looking into the conducted BCR calculations.

The most important question is: *“Is the analysis from 2005 still relevant to be used in 2018 discussions regarding safety development?”*

Which meant in detail:

How realistic is a pricing from 2005 of 25€ to 100€ for an ISA system (Table 9)?

The current market price in 2018 is in the range of 500€ – 2,700€ for the end user, whereby higher prices are based on the fact that ISA is only offered in a whole driver assistance package [6]. Stated by the European Transport Safety Council (ETSC) “a recent cost assessment for the European Commission found that a camera-based system, shared between several systems such as Automated Emergency Braking (AEB), Lane Keeping Assistance (LKA) and Intelligent Speed Assistance (ISA), would cost in the range of €47–62 per vehicle” [15]. And “the total cost for components (camera, ECU, brackets, trim, wiring) and OEM design and development, tooling costs, etc. was estimated at €186–249, based on individual costs extracted from NHTSA, 2012” [15].

Another question arising is, ***why no societal costs were included in the analysis***. In this context societal costs meant costs for map data creation, provision, and maintenance including updates of urban areas, speed zone variations, construction sites etc. Further aspects are the costs for implementing harmonised traffic signs across Europe and providing adequate traffic sign maintenance to avoid errors in recognition.

Since the projected benefit rates were based on the assumption of an EU wide 100% retrofit within ten years (Table 10), ***the question appeared if a complete, (large-scale) retrofit is technically even possible***.

5. **Target group and possible safety benefit**

5.1. Effectiveness estimates by TRL

TRL furthermore analysed the effectiveness of ISA and came to the conclusion in [4], that "fitting ISA to M1 vehicles will yield the greatest casualty benefit compared to the other ISA vehicle categories. ***However, other measures (including ESC, LKA, AEB and AEB-PCD) that could be fitted to M1 vehicles were predicted to have a greater overall casualty benefit than ISA***."

In this analysis ISA was defined as mandatory, with no possibility to switch-off, but with the possibility to override the system. It is assumed that the vehicle is informed of the posted speed limits at all times, variable speed limits are not regarded by the system. The effectiveness values for ISA were derived using the in-depth collision case studies from the Road Accident In-Depth Studies (RAIDS) database, where a maximum of 100 cases were reviewed, and extrapolation to STATS19 (Official accident statistics of the UK). ***From VUFO's point of view, this case number is by far not sufficient to derive statistically robust statements for such a system***.

Table 11 [4] shows a "predicted saving of 8,219 casualties (168 fatalities, 1,060 seriously injured and 6,991 slightly injured) over a 5-year period if M1 vehicles were to be fitted with a mandatory ISA system that can be overridden by applying the accelerator pedal" [4]. The effectiveness was quantified based on the confidence level of the case assessors as displayed in Figure 5-1. The variance in the prediction ranges from a minimum saving of 24 fatalities (low estimate-high confidence) up to 249 fatalities (upper estimate – high+medium+low confidence) saved over a 5-year period (Table 11).

Table 11: ISA - M1 vehicles; calculation of Effectiveness Estimate (EE) by TRL [4]

ISA M1	Fatal			Serious			Slight			Total		
	Lower Est.	Predicted Est.	Upper Est.	Lower Est.	Predicted Est.	Upper Est.	Lower Est.	Predicted Est.	Upper Est.	Lower Est.	Predicted Est.	Upper Est.
RQ1 TP	1469	1469	1469	7680	7680	7680	43916	43916	43916	53065	53065	53065
Existing Measure Savings	112	283	410	520	683	878	2246	2947	3789	2878	3913	5077
Other Measure Savings	119	246	279	451	1121	1443	1799	4527	6029	2369	5894	7751
Assessed Measure Mitigation	35	56	108	153	296	632	-188	-352	-740	-	-	-
Assessed Measure TP	1203	884	672	6556	5580	4727	40059	36794	34838	47818	43258	40237
Assessed Measure Savings	24	168	249	131	1060	1749	801	6991	12890	956	8219	14888
Total Savings	255	697	938	1102	2864	4070	4846	14465	22708	6203	18026	27716
Remaining Casualties	1179	716	423	6425	4520	2978	39258	29803	21948	46862	35039	25349

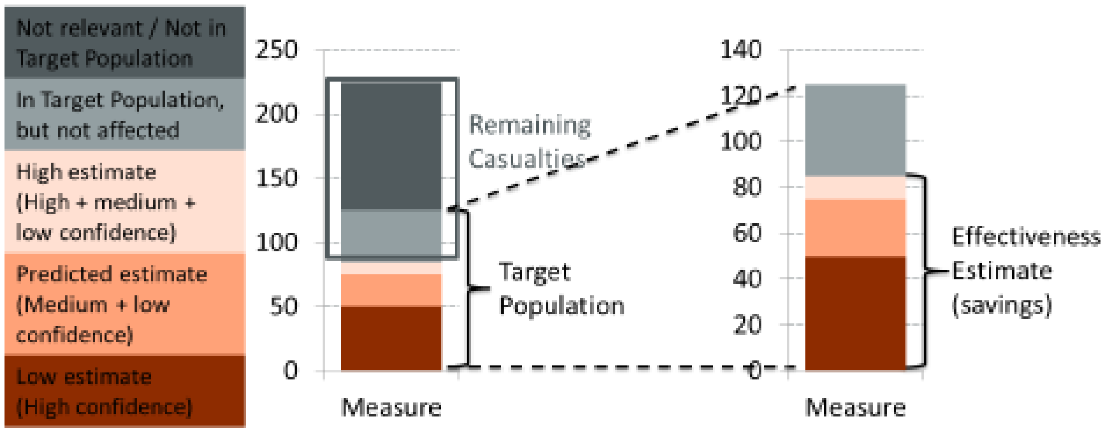


Figure 5-1: Illustration of effectiveness values derived from case-by-case analysis, TRL [4]

Thus, in [4] a range from saving 1.9% to 37% fatalities (with a mean of 19%) is given depending on the confidence of the investigator in the case-by-case analysis. The document [16] of the European Commission displayed 19% fatality savings indicating that this would apply on high confidence level (Table 12), although the quoted TRL report contradicted this statement

Table 12: Effectiveness of proposed measures for M1 vehicles equipped [14]

Measure	Fatal (avoid)	Fatal (mitigate)	Serious (avoid)	Serious (mitigate)	Slight (avoid)	Confidence	Source / justification
ISA-VOL	19.0%	6.7%	19.0%	8.4%	19.0%	High	TRL calculations based on (Barrow *et al.*, 2017) and (ACEA TF-ACC, 2017a).

5.2. ISA effects on speed

The results of ISA trials and studies all point in the same direction. According to the SWOV Institute for Road Safety Research the general conclusion is that ISA systems appear to have a number of positive safety effects on driving speed [5]: ISA equipped vehicles show an average speed reduction of approximately 2 to 7 kph, as well as a reduction in speed variance and speed violations (Table 13). The size of these reductions depends on the type of ISA, with more controlling types of ISA being more effective. Only one trial in Finland showed an increase in average speed (Peltola & Kulmala, 2000), where the effects of ISA on icy roads were investigated. The used ISA system gave a speed advice that was already lower than the posted speed limit, but still the mean speed of ISA drivers was higher than that of drivers without ISA. One explanation could be that the ISA speed advice exceeded the speed that drivers would have chosen themselves [5].

A SWOV driving simulator experiment in 2007 also showed that ISA has a significant speed reducing effect and observed that the effect was especially significant in situations where speed limits were of low credibility [5]. Furthermore, there were fewer speed violations and smaller differences in speed when driving with ISA [5].

Table 13: Overview of the ISA effects on mean speed and standard deviation of speed [5]

(↓decrease, ↑ increase, ? not investigated). Adapted after Morsink et al. (2006) [5]

Study	Methodology	Country	Effect on mean speed	Effect on standard deviation of speed	Speed violations
Comte (2000)	Driving simulator	UK	↓	↓	?
Peltola & Kulmala (2000)	Driving simulator	FIN	↑	↓	?
Hogema & Rook (2004)	Driving simulator	NL	↓	↓	↓
Van Nes et al. (2007)	Driving simulator	NL	↓	↓	↓
Brookhuis & De Waard (1999)	Instrumented vehicle	NL	↓	↓	↓
Päätalo et al. (2001)	Instrumented vehicle	FIN	↓	?	↓
AVV (2001)	Field trial	NL	↓	↓	?
Lahrmann et al. (2001)	Field trial	DK	↓	?	?
Biding & Lind (2002)	Field trial	S	↓	↓	↓
Regan et al. (2006)	Field trial	AUS	↓	↓	↓
Van der Pas (2012)	Field trial	NL	↓	↓	↓
Vlassenroot et al. (2007)	Field trial	B	↓	↓	↓

6. **Acceptance of Intelligent Speed Adaptation**

6.1. Definition of acceptance

A key success factor in the future implementation of ISA is in understanding how users will experience and respond to the system. Before the measurement of acceptance can be addressed, a consistent definition of acceptance is needed. There is no universal definition for acceptance or acceptability, but a lot of institutes and researchers have analysed this issue in the last decade. The most common definition was presented by Vlassenroot et.al. [17], who differentiated between acceptance and acceptability. The paper presented acceptance as behavioural responses and attitudes after the introduction of a new device and acceptability as the attitudes to it before its introduction.

According to this definition acceptance describes to what extent users are willing to use a certain system, hence acceptance is linked closely to usage.

Whereas acceptability was described as related to the question of whether the system is good enough to satisfy all the needs and requirements of the potential users before a future introduction. Acceptability describes the prospective judgement of measures to be introduced in the future.

Furthermore Vlassenroot et.al. stated in [18] that even if acceptance for a certain ISA system exists and can be measured, this would not necessarily lead to the public support of this measure or system.

6.2. Methods to measure acceptance

Important for indicating the acceptance is, which attributes of a new system are important for the process of evaluation and to what extent. Vlassenroot et.al. [17] distinguished between general indicators and system specific indicators influencing the acceptance / acceptability of a system (displayed in figure Figure 6-1). As main general indicators problem perception and recognition, social or personal aims, and responsibility awareness were considered to influence the acceptability of ISA. Indicators that were marked as relevant to define how people think about ISA were perceived efficiency, perceived effectiveness, perceived usefulness and satisfaction, equity, and willingness to pay.

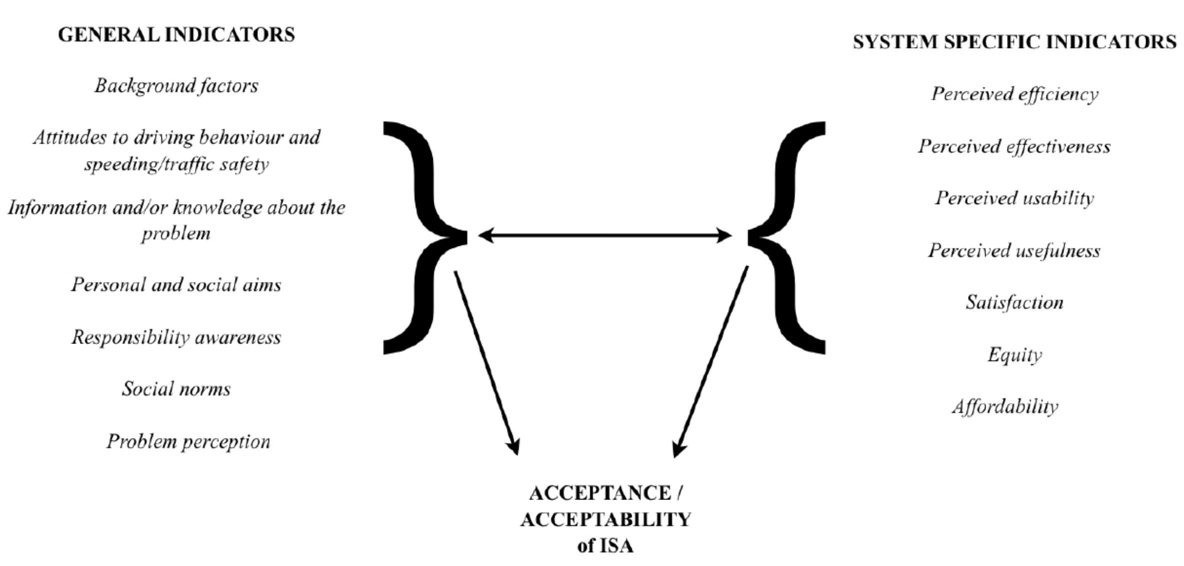


Figure 6-1: General and system specific indicators influencing acceptance or acceptability [17]

When measuring acceptance of ISA (in a trial experiment) the most important four system specific attributes according to Vlassenroot et.al. [17] were:

- Effectiveness on speed (37%)
- Equity in ISA equipment for everyone (31%)
- Usefulness or Satisfaction (13%)
- Personal and social aims (e. g. perceived usability, Satisfaction, Affordability).

SWOV observed the most significant factors for the user's acceptance of ISA in the type of ISA system, the type of road environment, and the type of driver [5]. Vlassenroot et.al. [17] also stated that ISA acceptance is mostly related to the driver's attitudes and behaviour about speed and speeding.

6.3. Acceptance of ISA in trials

Table 14 gives an overview of the results of different studies concerning ISA acceptance and shows that acceptance can strongly differ depending on the trial. Acceptance seems to grow with a successful execution of the trial and less malfunctions of the ISA system and could reach up to 80%. Even for mandatory systems high acceptance could be observed, even though the acceptability was low with 5% before testing [19].

Table 14: Overview driver acceptance in different studies

Question	Percentage	Source
Percentage of people who would keep ISA after testing	30…80%	[20], [21]
Getting positive attitudes toward (mandatory) ISA after testing	60…73%	[22], [23]
(general) Acceptability of mandatory system before testing	5%	[19]

Beside these results, there are some general facts to face when talking about the acceptance of ISA systems. Guo et. al. declared in [24] that those drivers, who would benefit the most from ISA systems (e. g. speeders) are less likely to use it. According to [20] there were participants of trials having the opinion, that even though using ISA led to an increase in own safety, it also led to an increase in travel time, a reduction in driving enjoyment and an increase in obstructing traffic. Other points mentioned were an increase of irritation and a feeling of being controlled. The PROSPER project [21] pointed out the occurrence of a trade-off situation between effectiveness and acceptance. ***This meant that the system with the least effects on driving behaviour (informative system) had a higher acceptance than a more intruding and controlling ISA with a more positive effect on driving behaviour concerning speed and road safety***.

Vlassenroot et.al. [17] suggested to introduce ISA as a system that would be helpful enough to maintain the speed but that would not restrict the ‘freedom or driving experience’, since the more restrictive ISA becomes, the less accepted it is. In addition it was stated ISA would only be successful, when placed free, and not to pay for, in the car [17].

SWOV referred in [5], that ISA acceptance is also depending on the characteristics of the specific feedback given by the system and that continuous visual and auditory feedback is preferred to the haptic feedback. According to [5] “the acceptance of ISA differs for different road types, their related speed limits and the driving speeds”. The Dutch trial in 2001 showed that acceptance was highest for urban roads with 30 and 50 kph speed limits [5].

The USA NHTSA (US federal highway safety agency) warned in [25] based on results of different studies, that ISA systems, which restrict speed, might have the following unintended behavioural consequences. Drivers whose speed is regulated by an ISA system may try to compensate for “lost time” by accepting shorter gaps in cross traffic flow, and by maintaining closer following distances. Another potential problem could be complacency, and over-reliance on the system. Furthermore, drivers who use ISA systems with mandatory, fixed speed limits may tend to drive near that fixed limit even when conditions dictate a lower speed to be safe.

7. False positive / negative detections by the ISA system

7.1. Infrastructure of traffic signs across the EU

Traffic sign recognition for ISA systems is highly depending on the availability of standardized speed limit signs and the comparability of speed limit signs across Europe. The countries of the EU appear to follow the principles of the Vienna Convention of Road Signs and Signals according to the UNECE protocol agreed in 1949 and revised in 1968. These provides over 250 commonly agreed road signs, signals and road markings to standardize the signing system for road traffic internationally.

Figure 7-1: Contracting parties of the Vienna Convention of Road Signs and Signals [26]

Anyhow, there are national interpretations and variations of the detailed design of traffic signs from country to country since the convention allows some variations in design, font, use of colour and signification. According to the Convention [26], *prohibitory and restrictive signs (e.g. speed limit signs)* are supposed to be circular and the diameter shall *not* be *less* than 0.60m outside built-up areas and they shall have a white *or* yellow ground.

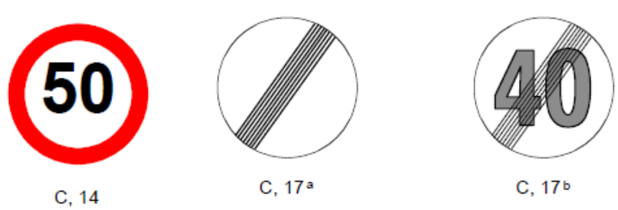


Figure 7-2: Restrictive signs and end of all prohibition signs - Vienna Convention [26]

For the *end of all prohibition* signs it was determined that they shall be circular on white *or* yellow ground. Furthermore they shall have no border *or* only a black rim and a diagonal band, sloping downward from right to left (black *or* dark grey *or* consist of black *or* grey parallel lines). The end of speed limit sign shall have in addition, in light grey the symbol of the prohibition or restriction.

The joint project *Roads that cars can read* of EuroRAP and Euro NCAP studied national variations in signing and marking for Germany, Great Britain, Netherlands, France, Poland, Greece, and Serbia and found out that speed limit signs show consistency in entering the speed limit but less so when leaving it [27].

Furthermore [27] stated *“Most countries believe they adhere to the Vienna Convention on Signs but there can be marked variation between countries even on the most common signs”.* This had also been declared by ACEA in [28] by saying that road signs are not harmonised across Europe and information on speed limits is not reliable enough.

EuroRAP and Euro NCAP questioned manufacturers in 2015, if those cross-border differences are relevant to recognition accuracy, who identified this as a highly relevant point and identified solutions to achieve a more optimal performance of traffic sign recognition [29]. The proposals for traffic signs of the assigned working group were the following:

- Harmonisation of traffic signs across Europe (colours, shapes, fonts) that will require a review of the practical implementation of Vienna Convention signs in Europe
- Drafting best practice guidelines for the mounting position, numbers of signs, angle etc.
- Use of more durable materials which do not lose their visibility features over time
- Proper maintenance of signs
- Variable Traffic Signs must be developed so they can be read by cameras as well as the human eye

7.2. Accuracy/Error rate on the recognition of traffic signs

Exceptional conditions like bad weather, traffic signs covered by dirt or trees, unfavourable lighting conditions, old or vandalised signs etc. can have a great influence on the performance of traffic sign recognition. As *Roads that cars can read* identified in [29], the sign's visibility is determined by the amount of light reflected back to the driver (European standard EN 12899).

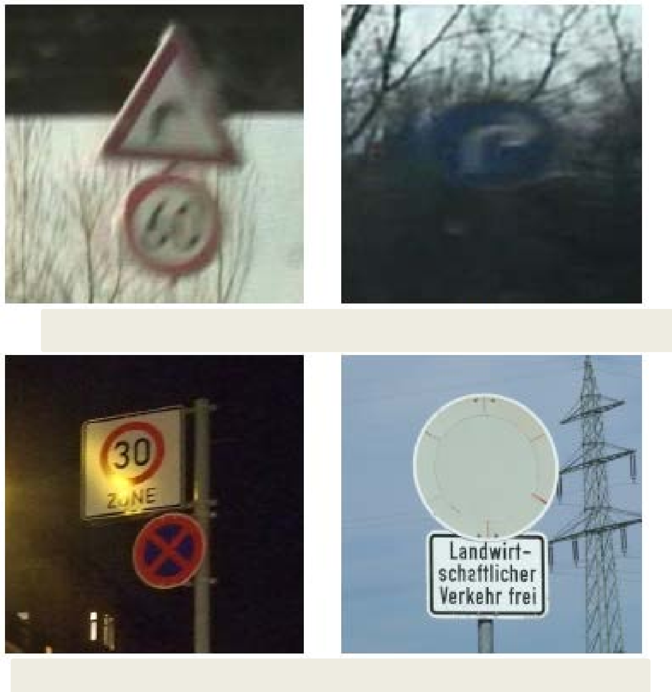


Figure 7-3: Exceptional conditions influencing traffic sign recognition [33]

Since traffic sign recognition technology works through a built-in camera that sees and interprets the traffic sign's colour, shape, message etc., to be effective, the sign has to be clearly visible to both the human eye and the in-car technology that is reading it [29]. Therefore vehicle manufacturers (ACEA) ranked the factors impeding the effective recognition of conventional traffic signs [29]:

- **High factors**: Vandalism/graffiti, sign position, obscured signs, e.g. foliage
- **High-medium factors**: Confusion with traffic signs on immediately adjacent roads, signs wrongly positioned, sign angle to the driver
- **Medium factors**: Quality of the sign surface, inconsistent placement of the signs, cross border differences in sign colour and shape
- **Medium-low factors**: Confusion of multiple signs at the same location, ambient illumination

ACEA again confirmed in [28] that camera-based systems cannot anticipate all scenarios, such as traffic signs misplaced or covered, conditional speed limits (e.g. those that apply only in the event of rain or during school hours) or implicit speed limits (urban/rural/highway).

Looking into different studies concerning traffic sign recognition showed an accuracy of 75-98% depending on the test environment (Table 15). Unfortunately, only few worst-case scenarios under bad weather or lighting conditions could be found and most European ISA trials are based on speed information from map data not traffic sign recognition.

The average error rate was about 10% under dry ("normal") conditions, whereas under exceptional conditions like rain or during the night the average error rate was assumed to be about 15-25%.

Table 15: Accuracy of traffic sign recognition - literature study

Test Environment	Accuracy	Sources
Simulated & best-case scenarios	90-98%	[30], [31], [32]
Real test on streets	75-97%	[33], [31], [34], [35], [36], [37]
Rainy weather	75%	[38]
Night-time	83-89%	[36], [38]

Another important aspect for traffic sign recognition revealed by Roads that cars can read [27] was the fact that none of the considered European countries was reported as having national standards for maintenance or reported as having any form of national monitoring of maintenance standards.

The European Union Road Federation revealed 2018 in [39], that for example, Germany has 25 million traffic signs of which 33% are considered non-readable and 25% being older than 15 years.

Figure 7-4: Examples of defective signs via Schilderüberwachungsverein [39]

Hence the UNECE has launched a dedicated expert group that will look into compliance with the Vienna Convention at EU level and propose means of ensuring greater coherence for traffic signs across Europe.

7.3. Map data

Beside traffic sign recognition the required speed information for ISA can be gained from digital road maps and the vehicle position detected by GPS. Unfortunately both technologies are not always and sufficiently reliable everywhere. As Gicquel [40] pointed out, dynamic map information is much richer and diverse than simple GPS navigation and both the spatial precision and the needed frequency for updates are different from what is available in today’s cars.

In general TomTom and HERE Technologies are big names on the market concerning live map data. TomTom constructs live maps via radar sensors that surround research vehicles and their maps are constantly being updated from data gathered by cars through a radar [41].

HERE builds its maps based on a roadway mapping system developed over the past decade (BMW, Daimler, Audi). HERE presented 2018 its HD live map concept and collects the data from HERE´s global fleet of 500 research vehicles. HERE and its regional mapping partners NavInfo of China, Increment P (IPC)/Pioneer of Japan and SK Telecom of Korea announced in May 2018, that they have formed the OneMap Alliance to offer a global, standardized and dynamic high definition (HD) map from 2020 [42].

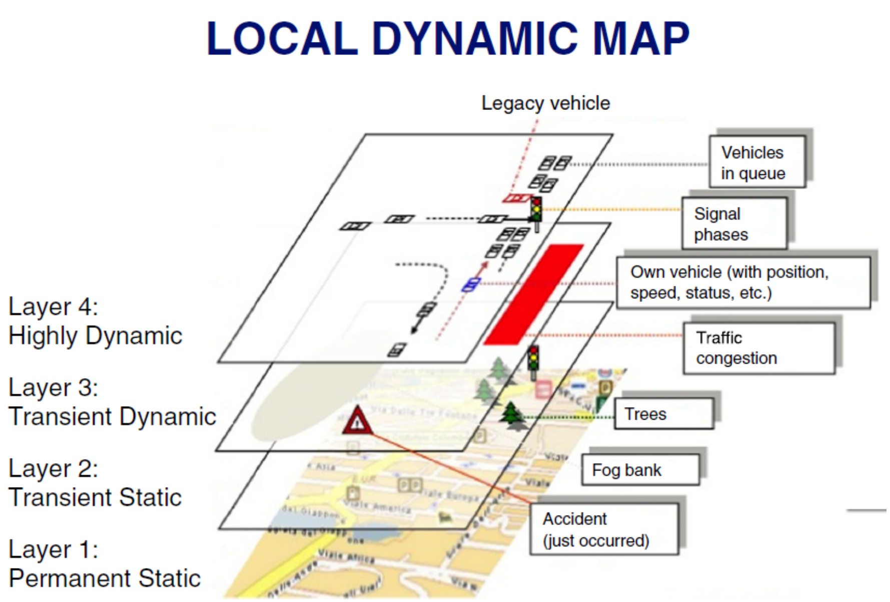


Figure 7-5: Layout of a local dynamic map [43]

Also the Belgian Institute for Road Safety highlighted the importance of local dynamic maps (LDM) in [44] and said: “Dynamic maps are crucial”. This statement was based on the experience of the Belgian ISA trial. The tested ISA system used a digital map and despite the fact that frequency and duration of the GPS signal losses could unfortunately not be derived from the logged data, 70 % availability in time could be accepted as a rough estimate.

The main issues of current map data identified by [44] were:

- Limitation of static maps: absence of online update possibility → design and speed limits of the road network quickly get obsolete

- GPS positioning inaccuracy: retrieval of a wrong road segment (with another speed limit) wrong speed limit attribute in the database or a change in the road network speed limits since the last map update

In addition, the Belgian Institute for Road Safety stated with the GPS as the leading technology, the major ISA challenge can be divided into the positioning capability (accuracy & availability) and the digital map management [44]. The recommendation was to improve GPS with the differential technology, higher dead reckoning and map matching performances and perhaps the future combination of GPS and Galileo. For the management of a dynamic digital map a dual challenge was seen, frequently gathering the source information and quickly transmit it to a large amount of vehicles using standardized telecommunication protocols [44].

The European Commission found explanations for the non-availability of EU-wide continuous and high-quality real-time traffic information services in [45] mainly in a lack of (digital) road and traffic data and the fact that existing road and traffic data is not being shared. In addition, accessible road and traffic data is fragmented, non-interoperable (due to the use of various formats / standards) and of insufficient quality [45]. Furthermore, the European Commission conducted a survey of 50 organizations across Europe, where 27 indicated that the five most frequent difficulties were related to [46]:

- Problems with getting access to existing data (70%);
- Difficulties with finding out which data is available (56%);
- The data needed is not available (51%);
- Data sets from different suppliers are not compatible (47%);
- Existing data is of insufficient quality (47%)

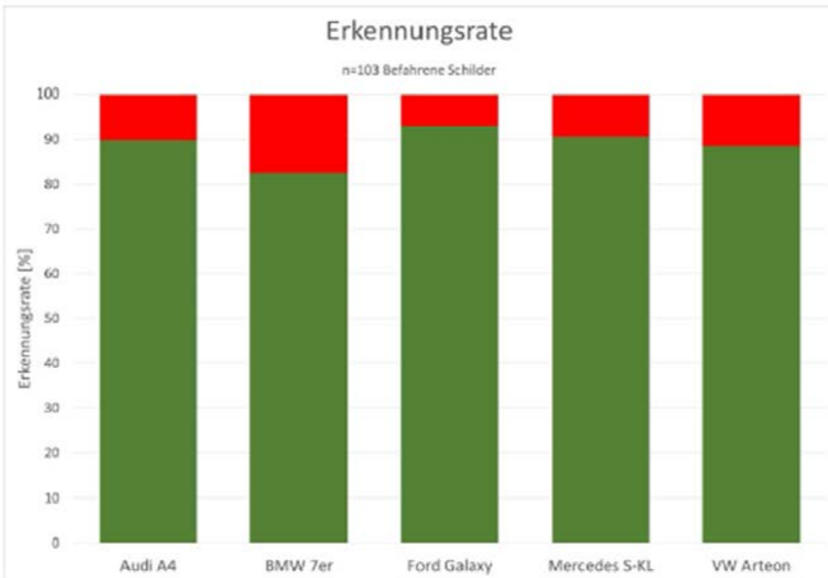
A good overview of the local dynamic map technology and the state-of-the-art was given in [43] and LDM was seen as a key technology for data integration in cooperative ITS systems. In 2009 the European Commission invited the European Standardisation Organisations ETSI, CEN, CENELEC to prepare a coherent set of standards, specifications, and guidelines to support European Community wide implementation and deployment of cooperative ITS systems, which ETSI and CEN accepted.

ETSI initiated this by defining LDM in an initial standard as “a conceptual data store located within an ITS station [...] containing information that is relevant to the safe and successful operation of ITS applications.” [47], [48]. With a more international focus, the ISO reports [49], [50] defined comparable standards to ETSI, which included an LDM architecture, data models, and an embedding into the ITS architecture [43]. CEN/TC 278 is responsible for managing the preparation of standards in the field of Intelligent Transport Systems (ITS) in Europe, where Working Group 7 (WG7) has the responsibility for the standardization of geographic road network data (ITS spatial data) [51].

8. **Overview of current ISA systems**

8.1. ADAC test of current ISA systems

In 2018, ADAC tested five vehicles equipped with ISA in real traffic situations concerning stationary and temporary traffic signs, town signs, and dynamical/variable speed limits. **All tested cars used GPS and camera**. The error rate of traffic sign recognition was about **10%** (Figure 8-1).



red=no/incorrect detection, green=correct detection

Figure 8-1: Detection rate of the tested vehicles [6]

Conclusions made by ADAC were on the one hand that the tested systems were very different concerning mode of operation and driver integration, which meant that some training would be required to use them adequately. It should also be kept in mind that the systems only assist and do not release from driving task, which was highlighted by the relatively high error rate. ADAC also pointed out that current and error-free map data are indispensable and traffic sign recognition has to become more reliable in poor weather conditions [6].

8.2. Euro NCAP Rating 2017 & 2018 for vehicles with ISA

The analysis of all vehicles tested by Euro NCAP in 2017 and 2018 showed that only 16 of the tested vehicles come with ISA functionality [52]. As displayed in Figure 8-2 the speed control function had to be manually set for 6 of the 16 tested vehicles and was system advised for 10 of the vehicles equipped with ISA.

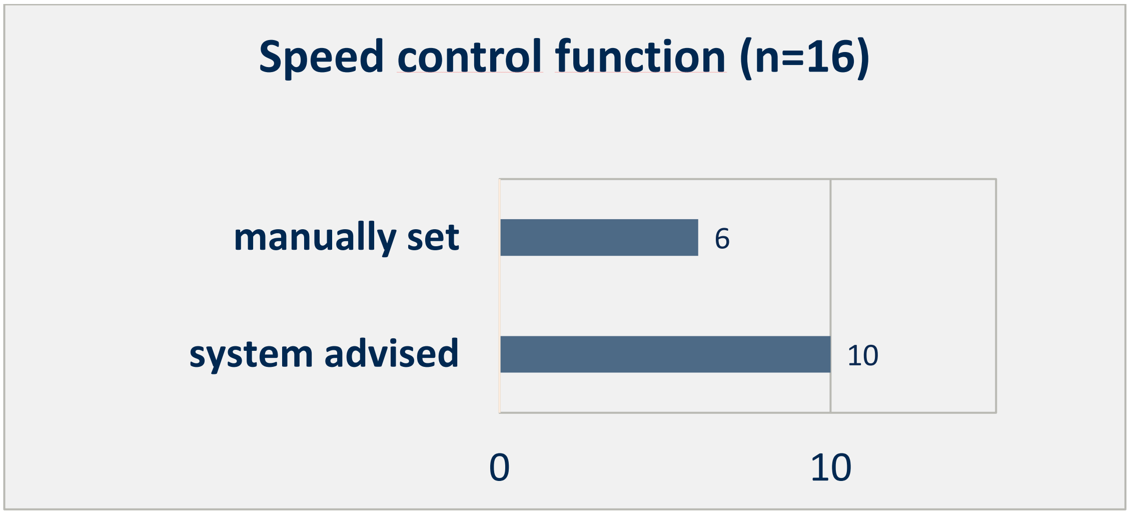


Figure 8-2: Speed control function for vehicles with ISA [52]

Whereas 13 ISA systems were camera based and 1 map based, only 2 vehicles had an ISA system relying on both camera and map data. But Euro NCAP stated that a **full score at rating is only possible for a combined method of camera and map**. The maximum number of points reached was 2.5 (see Figure 8-3).

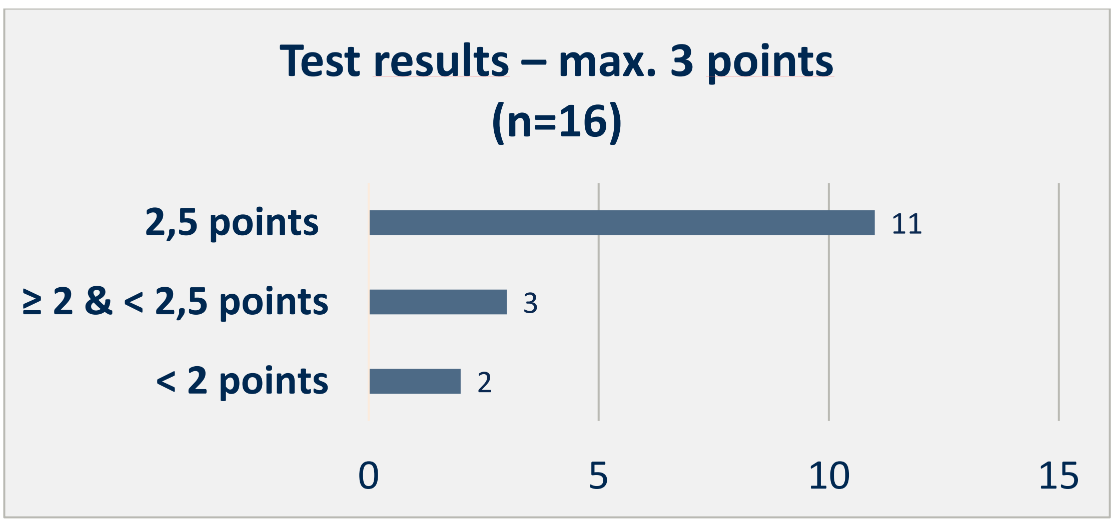


Figure 8-3: Euro NCAP test results for vehicles equipped with ISA [52]

9. Conclusions

Available statistics:

Only a few countries provide statistics and detailed information regarding vehicle speed as a cause/contributing factor of accidents. The accessible information is mostly general and not necessarily linked to accident statistics. Nevertheless some numbers could be derived and reported. The accident data shows a proportion of 3% related to excessive vehicle speed as root cause average in Europe. The issue with these percentages is the methodology of the recording process. All national accident databases are based on police reports. The policemen are usually not reconstructing accidents and thus, are not able to state the exact initial speed value of the vehicles.

From a scientific point of view the available accident statistics from IRTAD or comparable statistical portals cannot be used for in-depth studies.

GIDAS Analyses

- 50% of the investigated accidents occurred inside urban areas
- 42% of the accidents took place during twilight or night
- 52% occurred on damp, wet or other slippery roads.
- In 56% of the accidents speed limiting traffic signs were available and 44% of the speeds were limited by location.

Review of the given benefit cost ratios:

The costs were based on the premise that by 2010 all new vehicles will come with a satellite navigation system as standard [2].

- Equipment rate for new cars in Germany in 2017, only 60% of the new vehicles are equipped with navigation system [3].

Furthermore, the BCR calculation of [2] assumes that speed limit data incorporated into digital road maps will be available on a pan-European basis by 2010, which is not the case in 2018.

The pricing was calculated in 2005 within a range of 25€ to 100€ for an ISA system.

- ETSC: “a recent cost assessment for the European Commission found that a camera-based system, shared between several systems such as AEB, LKA and ISA, would cost in the range of €47–62 per vehicle” [15].
- ETSC: “the total cost for components (camera, ECU, brackets, trim, wiring) and OEM design and development, tooling costs, etc. was estimated at €186– 249, based on individual costs extracted from NHTSA, 2012” [15].
- No societal costs were included in the TRL analysis. (map data creation, provision, and maintenance including updates of urban areas, speed zone variations, construction sites etc.)

Since the projected benefit rates are based on the assumption of an EU wide 100% retrofit within ten years, the question appeared if a complete retrofit is technically even possible.

TRL analysed the effectiveness of ISA and came to the conclusion in [3], that "fitting ISA to M1 vehicles will yield the greatest casualty benefit compared to the other ISA vehicle categories. **However, other measures (including ESC, LKA, AEB and AEB-PCD) that could be fitted to M1 vehicles were predicted to have a greater overall casualty benefit than ISA."**

The effectiveness values for ISA were derived using the in-depth collision case studies from the Road Accident In-Depth Studies (RAIDS) database, where a maximum of 100 cases were reviewed, and extrapolation to STATS19 (Official accident statistics of the UK). **From VUFO's point of view, this case number is by far not sufficient to derive statistically robust statements for such a system.**

The prediction of the system related safety benefit ranges from a minimum saving of 24 fatalities up to 249 fatalities saved over a **five-year period** (Table 11) [4].

ISA trials showed a positive effect of ISA on driving speed with an average speed reduction of approximately 2 to 7 kph [5].

Since acceptance is essential for the potential success and effectiveness of ISA, factors influencing the acceptance have been presented. The PROSPER project [21] pointed out the occurrence of a trade-off situation between effectiveness and acceptance.

- Systems with the least effects on driving behaviour (informative system) had a higher acceptance than a more intruding and controlling ISA with a more positive effect on driving behaviour concerning speed and road safety.

The joint project *Roads that cars can read* of EuroRAP and Euro NCAP [27] stated *"Most countries believe they adhere to the Vienna Convention on Signs but there can be marked variation between countries even on the most common signs".*

Measures identified by vehicle manufacturers in 2015 are [27]:

- harmonize traffic signs across Europe
- give guidelines for mounting position etc.
- durable materials
- proper maintenance of signs
- develop variable traffic signs, which can be read by cameras and the human eye

Traffic sign recognition error rates:

- ~10% under dry, "normal" conditions
- ~15-25% under exceptional conditions like rain or during night assumed to be about 15-25%
- An ADAC test in 2018 showed an error rate about 10% in traffic sign recognition [6]. The cars ADAC tested were all equipped with camera and GPS.

Beside traffic sign recognition the required speed information for ISA can be gained from digital road maps and the vehicle position detected by GPS. But local dynamic map information needed for ISA is much richer and diverse than simple GPS navigation [40]. This means that a highly frequent update of the map would be needed to ensure ISA detection robustness.

- Belgian Institute for Road Safety highlighted the importance of local dynamic maps (LDM) in [44] and said: “Dynamic maps are crucial”.
- Frequency and duration of the GPS signal losses could not be derived from the logged data, 70 % availability in time could be accepted as a rough estimate.
- Main issues are the absence of online update possibility and GPS inaccuracy (retrieval of wrong road segment with wrong speed limit).

In Euro NCAP testing a full score at rating is only possible for a combined method of camera and map. The evaluated Ratings from the years 2017 and 2018 show that 2 of the 16 tested cars, fitted with an ISA system, have implemented both technologies as source of the speed limit information.

10. **List of literature**

[1] TRL, Benefit and Feasibility of a Range of New Technologies and Unregulated Measures in the fields of Vehicle Occupant Safety and Protection of Vulnerable Road Users, 2015.

[2] O. Carsten, F. Tate and R. Liu, “Project for Research On Speed adaptation Policies on European Roads, Assessment of Road Speed Management Methods, External Deliverable (D4.3), Project no. GRD2200030217,” 2006.

[3] Wirtschaftsgesellschaft des Kraftfahrzeuggewerbes mbH, “Facts&Figures 2017,” Edition 2018.

[4] A. Barrow, A. Edwards, L. Smith, R. Khatry, A. Kalaiyarasan and D. Hynd, “Effectiveness estimates for proposed amendments to the EU's General and Pedestrian Safety Regulations,” TRL, 2017.

[5] SWOV, SWOV Fact sheet - Intelligent Speed Assistance (ISA), Leidschendam, Netherlands: SWOV Institute for Road Safety Research, 2015.

[6] ADAC, “Intelligente Geschwindigkeitsassistenten - 5 Fahrzeuge mit Intelligent Speed Adaptation, Version 4.0,” 2018.

[7] T. R. B. (TRB), “Managing speed; review of current practice for setting and enforcing speed limits,” *Special report 254. , National Academy Press, Washington, DC,* 1998.

[8] E. R. S. O. European Commission, Speed and Speed Management,, 2015.

[9] TRL, In depth cost-effectiveness analysis of the identified measures and features regarding the way forward for EU vehicle safety, 2017.

[10] EURO NCAP, TEST PROTOCOL – SPEED ASSIST SYSTEMS Version 2.0, EURO NCAP, 2017.

[11] E. Commission, “Eur-Lex.Europa.eu,” 2018. [Online]. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018PC0286&from=EN. [Accessed 05 10 2018].

[12] I. -. OECD, “IRTAD - International Traffic Safety Data and Analysis Group,” [Online]. Available: https://www.itf-oecd.org/IRTAD. [Accessed 21 09 2018].

[13] VUFO, “GIDAS German In-Depth Accident Study,” [Online]. Available: www.gidas.org. [Accessed 19 09 2018].

[14] SpeedAlert, “Final Report,” ERTICO, Brussels, 2005.

[15] European Transport Safety Council, “ETSC,” 27 September 2017. [Online]. Available: https://etsc.eu/briefing-intelligent-speed-assistance-isa/. [Accessed 21 August 2018].

[16] European Commision, “Commission staff working document impact assessment; Interinstitutional File: 2018/0145 (COD); SWD(2018) 190 final,” Brussels, 17.05.2018.

[17] S. Vlassenroot, J. De Mol, V. Marchau, K. Brookhuis and F. Witlox, Acceptability of Intelligent Speed Adaptation (ISA) - Conceptual framework and first results, Duurzame Mobiliteit, 2010.

[18] S. Vlassenroot and J. De Mol, MEASURING PUBLIC SUPPORT FOR ISA: DEVELOPMENT OF A UNIFIED THEORY, Netherlands: Institute for Sustainable Mobility (IDM).

[19] K. Chorlton, S. Hess, S. Jamson and M. Wardman, Deal or no deal: Can incentives encourage widespread adoption of Intelligent Speed Adaptation devices?, UK: Accident Analysis and Prevention, 2012.

[20] E. Adell, Driver Experience and Acceptance of Driver Support Systems - A Case of Speed Adaptation, Sweden: Lund University, 2009.

[21] A. Varhelyi, E. Adell, A. Rook, J. Hogema, S. Broekx, L. int Panis, M. Hjälmdahl and S. Vlassenroot, Project for Research On Speed adaptation Policies on European Roads - Driver Behavioural Effects from ISA, Europe: PROSPER, 2006.

[22] H. Katteler, Driver acceptance of mandatory intelligent speed adaptation, Netherlands: Radboud University Nijmegen-IST, 2005.

[23] O. Carsten, EUROPEAN RESEARCH ON ISA: WHERE ARE WE NOW AND WHAT REMAINS TO BE DONE, UK: ICTCT workshop Nagoya.

[24] W. Guo, P. Blythe, S. Edwards, K. Pavkova and D. Brennan, Effect of intelligent speed adaptation technology on older drivers' driving performance, UK & Australia: IET Intelligent Transport Systems, 2013.

[25] NHTSA, Summary Report: Workshop on Vehicle Technologies to aid Teen Drivers, Springfield: U.S. Department of Transportation - National Highway Traffix Safety Administration, 2006.

[26] UNECE, "Convention on Road Signs and Signals of 1968 European Agreement Supplementing the Convention and Protocol on Road Markings, Additional to the European Agreement," United Nations Publication, ECE/TRANS/196, 2006.

[27] EuroRAP, EURONCAP, "Roads that cars can read, A Consultation Paper," 2011.

[28] ACEA, "ACEA: Position Paper – General safety regulation revision 2018," 2018.

[29] EuroRAP, EURONCAP, "Roads that cars can read, Proposals for Consultation, A Quality Standard for Road Markings and Traffic Signs on Major Rural Roads," 2015.

[30] S. Aziz, E. A. Mohamed and F. Youssef, Traffic Sign Recognition Based On Multi-feature Fusion and ELM Classifier, Marocco: Procedia Computer Science, 2018.

[31] S. P. Das, A. K. Talukdar and K. K. Sarma, Sign Language Recognition using Facial Expression, India: Procedia Computer Science, 2015.

[32] A. Shustanov and P. Yakimov, CNN Design for Real-Time Traffic Sign Recognition, Russia: Procedia Engineering, 2017.

[33] B. Höferlin and K. Zimmermann, Towards Reliable Traffic Sign Recognition, Xi'an, China: IEEE, 2009.

[34] L. Bruno, G. Parla and C. Celauro, Improved Traffic Signal Detection and Classification via Image Processing Algorithms, Italy: Procedia Social and Behavioral Sciences, 2012.

[35] F. Larsson and M. Felsberg, Using Fourier Descriptors and Spatial Models for Traffic Sign Recognition, Linköping, Sweden: Scandinavian Conference on Image Analysis, 2011, 2011.

[36] K. Lim, Y. Hong, Y. Choi and H. Byun, "Real-time traffic sign recognition based on a general purpose GPU and deep-learning," PLOS ONE, 2017.

[37] T. Goedemé, Traffic Sign Recognition with Constellations of Visual Words, Belgium: 5th International Conference on Informatics in Control Automation and Robotics ICINCO 2008, 2008.

[38] M. Y. Radzak, Study on Traffic Sign Recognition, Kuala Lumpur, Malaysia: International Journal of Research Studies in Computer Science and Engineering (IJRSCSE), 2015.

[39] ERF (European Union Road Federation), "Improved Signage for Better Roads, An ERF Position Paper towards improving Traffic Signs in European Roads," 2018.

[40] P. Gicquel, Autonomous vehicles need reliable dynamic map data, USA: Genivi Alliance, 2015.

[41] TOMTOM, "its-sweden.se," 29 03 2011. [Online]. Available: http://its-sweden.se/wp-content/uploads/2013/07/2011_03_29_11_access_to_public_data.pdf. [Accessed 09 08 2018].

[42] Geospatial World, "www.geospatialworld.net," 23 05 2018. [Online]. Available: https://www.geospatialworld.net/news/here-technologies-joins-forces-to-establish-a-global-mapping-standard-for-self-driving-cars/. [Accessed 07 08 2018].

[43] Eiter et. al., TU Wien, Siemens, "Towards a Semantically Enriched Local Dynamic Map," International Journal of Intelligent Transportation Systems Research, 2018.

[44] J.-M. I. Page, A FINAL TECHNICAL REPORT ON THE BELGIAN INTELLIGENT SPEED ADAPTATION (ISA) TRIAL, Belgium: Belgian Institute for Road Safety, 2014.

[45] European Commission, "Commission Staff working document, The provision of EU-wide real-time traffic information services," 2014.

[46] European Commission, "Commission adopts new rules to improve EU-wide traffic information services for road users," 2014.

[47] ETSI, "ETSI EN 302 895 (V1.1.0): Intelligent transport systems -Extension of map database specifications for Local Dynamic Map for applications of Cooperative ITS. Technical report," 2014.

[48] ETSI, "ETSI TR 102 863 (V1.1.1): Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Local Dynamic Map (LDM); Rationale for and Guidance on Standardization. Technical report," 2011.

[49] ISO, "ISO/TS 17931:2013: Intelligent transport systems – Extension of map database specifications for Local Dynamic Map for applications of Cooperative ITS. Technical report," 2013.

[50] ISO, "ISO/TS 18750:2015: Intelligent transport systems – Cooperative systems - Definition of a global concept for Local Dynamic Maps. Technical report," 2015.

[51] "http://www.itsstandards.eu/spatial-data," [Online]. Available: http://www.itsstandards.eu/spatial-data. [Accessed 17 08 2018].

[52] "www.euroncap.com," [Online]. [Accessed 06 08 2018].

[53] G. Waibl, R. Batt, J. England, D. J. Thomas, K. Mora, B. Frith, G. Rive, D. S. Jamson, P. O. Carsten and D. F. Lai, An investigation into the deployment of an advisory ISA system in New Zealand, NZ Transport Agency research report, 2013.

[54] E. Commission, "European Commission, https://ec.europa.eu/transport/road_safety/specialist/knowledge/speed/new_technologies_new_opportunities/intelligent_speed_adaptation_isa_en," [Online]. Available: https://ec.europa.eu/transport/road_safety/specialist/knowledge/speed/new_technologies_new_opportunities/intelligent_speed_adaptation_isa_en. [Accessed 21 09 2018].

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B. Appendix – Citation of EU document – Definition of ISA

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EUROPEAN
COMMISSION

Brussels, 17.5.2018
COM(2018) 286 final

2018/0145 (COD)

Proposal for a

REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

on type-approval requirements for motor vehicles and their trailers, and systems, components and separate technical units intended for such vehicles, as regards their general safety and the protection of vehicle occupants and vulnerable road users, amending Regulation (EU) 2018/… and repealing Regulations (EC) No 78/2009, (EC) No 79/2009 and (EC) No 661/2009

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Article 3

Definitions

For the purposes of this Regulation, the definitions laid down in Article 3 of Regulation (EU) 2018/… shall apply.

In addition, the following definitions shall apply:

(1) 'vulnerable road user' means a road user using a two-wheel powered vehicle or a non-motorised road user, such as a cyclist or a pedestrian;

(2) 'tyre pressure monitoring system' means a system fitted on a vehicle which can evaluate the pressure of the tyres or the variation of pressure over time and transmit corresponding information to the user while the vehicle is running;

(3) 'intelligent speed assistance' means a system to aid the driver in observing the appropriate speed for the road environment by providing haptic feedback through the accelerator pedal with speed limit information obtained through observation of road signs and signals, based on infrastructure signals or electronic map data, or both, made available in-vehicle;

(4) 'alcohol interlock installation facilitation' means a standardised interface facilitating the fitment of aftermarket alcohol interlock devices in motor vehicles;

(5) 'driver drowsiness and attention monitoring' means a system assessing the driver's alertness through vehicle systems analysis and warning the driver if needed;

(6) 'advanced distraction recognition' means a system capable of recognition of the level visual attention of the driver to the traffic situation and warning the driver if needed;