ROAD SAFETY REPORT 2024

Traffic Environments for People

DEKRA

Accident Statistics:
If we are to achieve "Vision Zero", much work still needs to be done worldwide

The Human Factor:
Drivers never process traffic situations based solely on rational criteria

Infrastructure:
Road design must not lead to actions that endanger safety

Safe Infrastructure Saves Lives

Jann Fehlauer
Managing Director, DEKRA Automobil GmbH

According to various studies, the amount of traffic on our roads is continuing to rise. At the same time, the number of victims of road traffic accidents is falling in many parts of the world – but not by enough to achieve the World Health Organization's and EU's stated goal of halving this number by 2030. For example, although the number of traffic fatalities across the EU fell in 2023, the drop was only minimal – one percent – compared with the previous year. According to the EU Commission, the downward trend has leveled off for some years now in several member states.

As a result, in March 2024 the European Court of Auditors also published a special report entitled "Reaching EU road safety objectives", in which it explicitly stated that it is time to "move up a gear." Given the trends of recent years and "without additional efforts" (in the report's words), the number of fatalities in the EU would only fall by a quarter by 2030. The goal of reducing the number of fatalities and severely injured people to almost zero by 2050 would, therefore, also become a distant prospect.

In the auditors' view, the member states need to place a renewed focus on the design and maintenance of their road networks. Investments in infrastructure should be targeted at the stretches of road that have the highest concentration of crashes and the greatest potential for preventing them. This is all the more important given that the EU funds available for this are set to reduce in the coming years.

Accidents are caused by many different things. However, the design and condition of the road infrastructure can adversely affect how an accident occurs and how severe it is. There is still a lot of work to do worldwide in this regard – a point made clear by a tool developed by the International Road Assessment Programme (iRAP), for example. This registered charity has Consultative Status with the United Nations' Economic and Social Council and publishes a "Safety Insights Explorer" for more than 80 countries at present, setting out the health and economic consequences of road accidents, the safety of our roads, and the positive impact that can be made by investing in infrastructure. The data is collected for vehicle occupants, pedestrians, cyclists, and riders of two-wheeled motor vehicles.

The DEKRA Road Safety Report 2024 also focuses on these types of road user, as well as the associated challenges in ensuring that our roads are as safe as possible. In the report, we shine a light on the various problem areas and discuss potential solutions, with reference to accident analysis, traffic psychology, vehicle technology, infrastructure design, and legislation. This particular issue of the report also provides information about a survey we conducted looking at cyclists' knowledge of traffic signs for cycling infrastructure, and a crash test we performed with a cargo bicycle. Like in previous issues, numerous national and international experts have also shared their thoughts in statements.

The DEKRA Road Safety Report has been published annually since 2008, and once again we believe it helps to ensure that the number of road users killed or injured on our roads worldwide continues to fall. With this latest report, we are aiming once again to get people thinking and provide advice for politicians, traffic and infrastructure experts, manufacturers, scientific institutions, associations, and all road users.

I hope you find this report a stimulating read.

Infrastructure Plays a Decisive Role in Ensuring Effective Road Safety

Kristian Schmidt
EU Coordinator for Road Safety

Road safety in the EU has improved significantly in recent decades. The number of deaths has fallen from around 50,000 twenty years ago to around 20,000 today. However, while some Member States continue to make progress, EU-wide fatality rates have stagnated in recent years. In response, the European Commission proposed new measures for safe roads, among which are updated rules for infrastructure safety management.

The EU's road infrastructure safety management directive puts safety at the centre of the planning, design and operation of road infrastructure. The revised directive extends the scope of the 2008 version to cover motorways and primary roads outside the Trans-European transport Network (TEN-T) and all non-urban roads built with EU funds. This is necessary due to the high volumes of traffic and low safety levels on many non-TEN-T roads linking key economic centres across the network. In fact, the majority of deaths occur on non-urban roads, including rural roads and motorways. Thus, actions here will help to reach the target of halving road deaths by 2030 and moving towards zero fatalities by 2050.

In the future, infrastructure safety will be assessed more systematically and more proactively for more roads in the EU, helping to target investment. This network-wide risk mapping is needed in order to be proactive: it is not an option to only wait for fatal accidents to happen before acting, as with the previous black spot mapping. Furthermore, transparency and follow-up will be improved. These rules also tie in with the EU's general vehicle safety regulation, which aim to improve vehicle safety and better protect vulnerable road users.

The underlying concept to this approach is the Safe System, taking into account the frailty of the human body when planning road infrastructure. The Safe System is based on the premise that people will continue to make mistakes and that actors at all levels are jointly responsible for ensuring that crashes do not cause serious or fatal injuries. Infrastructure is a crucial part of the mix of factors that we are addressing with the Safe System approach. It is determining in about 30% of serious road accidents. While well-maintained roads lower the risk of accidents, forgiving roads – laid out to mitigate the consequences of errors – reduce the severity of those which do occur.

In the coming years, the Commission will provide guidance for the design of forgiving roadsides and self-explaining and self-enforcing roads, as well as guidance on quality requirements regarding infrastructure for vulnerable road users. Such guidance will be developed in close cooperation with Member States' experts.

Last but not least, applying these principles is also a good public management strategy for ensuring that tax-payer money is not spent on building unsafe roads.

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Transport Infrastructure Policy Requires a Holistic Approach

No matter the type of road user, the reason for the journey, or the distance covered: suitable, reliable transport infrastructure is essential for satisfying a fundamental criterion of mobility – getting safely from A to B. The World Health Organization (WHO) estimates that up to 50 million people are currently injured every year in road traffic accidents, around 1.2 million of which are fatalities. The causes of these accidents are manifold, but in many cases the design and condition of the road infrastructure adversely affect how the accident occurs or how severe it is.

More than ever, road infrastructure finds itself having to reconcile differing requirements relating to the users, the means of transport, the vehicle (if one is used), the reason why each user opted for their particular method of travel, and the social and political backdrop. This is compounded by a rapid transformation in mobility patterns in many parts of the world. Advances in sensor systems, computing power, and battery capacity have given rise to new travel methods or revolutionized existing ones. Infrastructure modifications cannot keep pace with this transformation.

If we look at the different vehicle types currently available, the challenges facing transport and road environment planners today soon become clear. The trend seen with cars where each new model in a particular series is wider, longer, taller, and heavier than its predecessor, is nothing new. However, as SUVs and vans experienced a boom at the turn of the millennium, these growing dimensions quickly reached unprecedented levels. The requirements concerning the size of parking spaces and the width of road lanes suddenly changed. This has and continues to lead to dangerous situations, particularly in built-up areas. Drivers of these wider vehicles mount the sidewalks to park, there is no longer enough space for larger emergency vehicles to pass by, and the vehicles themselves block lines of sight, particularly when it comes to children.

A similar trend followed just a few years later for bicycles when they started to be fitted with electric motors. Pedelecs are much

Milestones Along the Way to Greater Mobility and Safety

1820 · 1900 · 1910

1817

- *On June 12, Karl von Drais travels along the first section of bicycle path in Germany between Mannheim and Schwetzingen*

1839

- *The first horse-drawn streetcar in Europe enters service between Montbrison and Montrond in France*

1863

- *The world's first subway opens in London*

1868

- *The world's first traffic light system is installed in London – it was operated by gas light and exploded after just a short time.*

1870

- *The now-common rolled asphalt road surface (a mixture of sand and petroleum bitumen) is developed in North America – it does not become widespread in Europe until the start of the 20th century*

1878

- *The first electric street lighting in Paris – Nuremberg and Berlin follow in 1882*

1881

- *The world's first electric streetcar runs in Berlin (built by Siemens).*

1895

- *The first regular service in Germany with a fuel-driven bus between Siegen and Netphen*

1896

- *The world's first car tunnel opens in Stuttgart on June 29 (the "Schwabtunnel")*

1899

- *The world's first traffic circle opens in Görlitz (at Brautwiesenplatz); New York (Columbia Circle, 1904) and Paris (Place de l'Etoile, 1907) follow*

1900

- *Paris Metro opens on the occasion of the Paris Exposition world expo*

1907

- *The "Offenbacher Alleenring" outer ring road with segregated cycling infrastructure is built in Offenbach/Main – the oldest bicycle path still in existence in Germany*

1910

- *The first Germany-wide speed restriction is introduced on April 1*

Infrastructure Is Key to Good Road Safety Records

Dr. Volker Wissing
German Federal Minister for Digital and Transport

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1915 • 1920 • 1925 • 1930 • 1945

1911

- *Road markings to separate different road lanes are invented – nowadays they form the basis for lane keeping systems. In 1921 the first road markings are introduced in the English town of Sutton Coldfield to eliminate an accident blackspot.*

1914

- *The world's first electric traffic signals with green and red bulbs are introduced in Cleveland (Ohio). In Europe, the first traffic lights specifically for pedestrians start up in Copenhagen in 1933.*

1917

- *In the USA, the first automatic traffic signal is patented. In Detroit, the first traffic control tower is installed at an intersection.*

1920s

- *In the USA, the first patrols to ensure children can safely cross the road start working in front of schools.*

1930s

- *"Lollipops" and patrol officers are introduced in England.*

1922

- *Europe's first tri-color light signal system is presented in Paris*

1924:

- *Siemens installs the first automatic traffic lights at Potsdamer Platz in Berlin.*

1925

- *The organization Deutscher Kraftfahrzeug-Überwachungsverein e.V. (now DEKRA) is founded in Berlin.*

1931

- *The League of Nations in Geneva adopts the "Convention concerning the Unification of Road Signs." It is ratified by 18 countries, but not Germany.*

1934

- *Reflective road studs ("cat's eyes") are invented by British inventor Percy Shaw*

1948

- *The first road markings with broken lines are introduced in London*

1949

- *The pedestrian crosswalk or "zebra crossing" appears internationally for the first time in the Geneva Protocol on Road Signs and Signals.*

heavier and, on average, faster than traditional bicycles, and in many cases they are also longer and wider. Cargo bike derivatives are sometimes more than 2.5 meters long and their unladen weight may well exceed 60 kg. Traditional cycling infrastructure cannot cope with these new requirements, and there are often no suitable parking spaces in front of shops and educational institutions or in residential areas. Machines such as e-scooters and self-balancing vehicles likewise come with their own specific requirements and risks.

Wide Range of Different Mobility Concepts

Similar trends can be seen with commercial vehicles. Whether it's construction site trucks or long-haul vehicles, the decision nowadays is usually to push things right up to the legal limits. Courier and express delivery vans – which have experienced a boom due to online shopping – pose the next challenge. This particularly affects the infrastructure in built-up areas, which is already heavily used.

The wide range of different mobility concepts and vehicles also means a wide range of requirements from the various infrastructure users. Pedestrians want wide, well-lit sidewalks that have no edges to trip over and are far enough away from the road so that passing vehicles do not spray them with surface water when it is raining. Cyclists also want a protected environment where they are not constantly at risk of being run off the road by vehicles that overtake them too closely, having to dodge pedestrians, or colliding with car doors that the occupants have opened without looking to see if the road is clear. Car drivers want to get to where they are going quickly without constantly having to let oncoming traffic pass due to parked vehicles, or constantly being stuck behind cyclists that seem to them to be moving slowly. Courier and parcel delivery drivers ideally want there to be a large enough parking space in front of every delivery address. Residents want a parking space, ideally slap bang in front of their front door, and traffic-calming measures, but also enough space so that garbage and moving trucks or, should the worst happen, emergency vehicles can get to them easily.

As the mode of transport that people use changes, the requirements involved often also change. Another important aspect is the need to design suitable infrastructure for people with different impairments. Examples include guidance systems for those with a visual impairment and ensuring there are no rental e-scooters obstructing their path, minimal or no curbs for people with reduced mobility, sidewalks that are wide enough to take rollators and wheelchairs, barrier-free crossings at intersections, and readily available unoccupied disabled parking spaces close to the destination.

On the other hand, most people share a common desire for shorter waiting times at traffic lights, priority at intersections, and clear routes whenever possible. These things are very difficult to implement. Infrastructure projects also generally cannot be realized quickly, and they need to last a long time after the work is complete – not least due to the high costs involved. Infrastructure projects generally involve a huge amount of planning because they need to meet current as well as expected future requirements effectively, ensure that no type of road user is unknowingly excluded, and comply with the legal framework and budget.

Applicable Legal Framework Poses a Major Challenge

In most countries, the planning phase is followed by an equally time-consuming approval phase before implementation can start. However, due to the rapidly changing requirements arising from the mobility revolution and the fact that municipal authorities often lack the necessary funds, a pragmatic approach has been taken over the past few years, resulting in new transport concepts being developed and implemented quickly. The fact that they are often not fully thought through or do not fit into existing concepts is another matter.

This approach was given additional impetus as a result of the coronavirus pandemic. Many places saw a big drop in car traffic, enabling them to take measures such as turning sections of road into cycle paths ("pop-up cycle lanes") or blocking off entire sections of road completely to motor vehicles. The transition away from car-centric cities to net zero cities which focus on people and the environment has also led to a rethink, particularly when it comes to urban environments. The things that citizens want have now changed, leading to corresponding changes in the political

1950 • • • • 1955 • • • • 1960 • • • • 1965 • • • • 1970 • •

1951

- *In collaboration with the Indiana State Police, a team of accident researchers led by engineer Hugh de Haven in the USA start the first comprehensive analysis of car accidents.*

1953

- *In Germany, legislators introduce pedestrian crossings nationally for the first time with Paragraph 26 of the German Road Traffic Act (StVO).*

1955

- *The first section of traffic barriers is installed in Germany.*

1956

- *At the International Police Exhibition in Essen, Telefunken presents the first traffic radar device to monitor a vehicle's speed.*
- *German vehicle registration regulations stipulate "fitness-to-drive assessments" for the first time. From 1960, they are called "medical-psychological examinations".*

1957

- *A speed limit of 50 km/h is introduced in built-up areas in Germany*

1961

- *In East Germany, traffic psychologist Karl Peglau develops special characters for pedestrian lights showing a walking and standing pedestrian.*

1964

- *In June 1964, the German Road Traffic Act (StVO) gives priority to pedestrians at zebra crossings.*

1966

- *On February 1, a German TV broadcaster (ARD) starts broadcasting the series "Der 7. Sinn" (The 7th Sense). It is shown once a week and clearly explains aspects relating to road safety, rules of conduct, and tips for car drivers and adult road users. The last episode, for the time being, is broadcast in December 2005.*

1968

- *In Vienna, the international Convention on Road Traffic and Convention on Road Signs and Signals are signed.*
- *In London, the Victoria Line enters service as the world's first fully automatic, computer-controlled subway line.*

1972

- *A speed limit of 100 km/h for cars is introduced on rural roads in Germany. Trucks over a permissible gross weight of 3.5 metric tons with trailer and trucks over 7.5 metric tons without trailer may not drive faster than 60 km/h on rural roads.*

The 30 km/h Default Speed Limit in Cities Is an Idea Whose Time Has Come

Antonio Avenoso
Executive Director, ETSC

One-by-one major towns and cities in Europe are realising that when motor vehicles share space with people walking and cycling, the only sensible speed limit is 30 km/h. Brussels, Madrid, Paris, Amsterdam...these four capitals have all, in recent months and years, switched to 30 km/h as the default speed limit. Spain, and Wales in the United Kingdom have gone as far as making it the default for urban roads nationwide. Bologna in Italy is the latest major city to join the 30 km/h club, with the new limit enforced since the beginning of this year.

There are very many benefits from lower speeds. They include lower noise pollution, air pollution, and of course improved safety. If there are concerns over negative impacts, they tend to be unfounded or overblown. Journey times, for example, hardly change for typical journeys in cities after the introduction of 30 km/h.

Some look at the headline speed reductions that take place, and question the benefits. In Wales, the latest analysis shows that average speeds dropped by 2.4 mph (3.9 km/h) on average after urban roads were switched from 30 mph (48 km/h) to 20 mph (32 km/h). But the science shows that even small reductions in average speed can bring dramatic road safety benefits. An ETSC report once found that an average speed reduction of just 1 km/h across the EU could result in 2,100 lives saved each year. Such is the critical importance of speed in reducing the frequency and severity of crashes.

Of course, 30 km/h limits are not new. Graz in Austria made the shift more than three decades ago. However, the more recent trend away from small 30 km/h zones or applying the lower limit only in a central area is now evolving into a much simpler city-wide or even nationwide default for urban areas. This may reduce the possibility of traffic being displaced outside of the zone, but another obvious additional benefit is the sheer simplicity. Drivers don't need to be constantly on the lookout for speed signs. In Brussels, speed signs are now only placed on roads with a higher limit of 50 km/h. Everywhere else, drivers are expected to know 30 is the default.

What should be the next steps? Firstly, towns and cities should be given the power to implement 30 km/h default limits without national governments making that difficult. In Germany hundreds of cities have clubbed together to ask the government in Berlin to get rid of bureaucracy that makes it tricky to lower limits from the current default of 50 km/h anywhere apart from streets with schools or similar.

It would be naïve to think that 30 km/h limits will end road death and injury in cities. But it should be seen as a simple, cost-effective move that has benefits beyond safety. It also signals loud and clear the acceptance of a reality that has been forgotten in many corners of Europe: that cities should be designed for the benefit of all citizens, not just those that choose to travel by car.

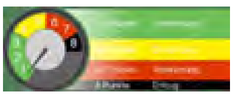
1975 · *1980* · *1985*

1973

- *A blood alcohol concentration limit (BAC) of 0.08 is introduced in Germany*
- *The German Federal Highway Research Institute (BASt) starts the "Data collection at accident sites" project at the Hanover Medical School (precursor to the "German In-Depth Accident Study" or GIDAS).*

1974

- *The points system (Art. 4 German Road Traffic Regulation [StVG]) for repeat offenders, still in use today, is introduced in Germany. An amendment is introduced in 2014.*



- *In France, a general speed limit of 90 km/h applies on rural roads.*
- *From January 1, the Federal Republic of Germany makes three-point safety belts mandatory on the front seats of newly registered cars. From May 1, 1979, safety belts must be installed on the back seats of all new cars.*

1976

- *From January 1, the Federal Republic of Germany makes wearing a helmet a mandatory requirement for motorcyclists. It also applies to riders of mopeds from the middle of 1978. From August 1, 1980, a fine can be levied for any breaches of this rule. From October 1, 1985, riders of motorized bicycles also need to wear a helmet.*

1978

- *Beginning of the "Child and Traffic" program by the German Road Safety Council.*

- *An experimental safety vehicle is developed at four German universities (until 1982). This concept is designed explicitly for the safety of pedestrians and cyclists.*

1980

- *Introduction of traffic calming zones in the Road Traffic Act in Germany*

- *Between 1980 and 1990, more and more reflectors are required on bicycles in Germany. Until 1980 it was only necessary to have reflectors on the pedals and a small red reflector (cat's eye) at the rear. Since 1992, a larger number of reflectors have been required, including on the sides.*

1983

- *A blood alcohol concentration limit (BAC) of 0.08 is introduced in France*
- *Trials of 30 km/h zones in a pilot project in Germany (Buxtehude)*

The 1st, 4th, and 7th generations of the VW Golf are good examples showing how vehicles have become larger and larger over the decades. The Golf 1 was around 3.7 meters long and around 1.6 meters wide, the Golf 4 was approx. 4.15 meters long and 1.7 meters wide, whereas the Golf 7 was almost 4.4 meters long and 1.8 meters wide.

landscape and, in turn, at the relevant official departments and authorities. Nowadays, infrastructure is no longer simply planned with the aim of ensuring that people reach their destination quickly by car and there are enough parking spaces. Instead, it is much more a case of discussing how many parking spaces can be eliminated in favor of bicycle paths and footpaths, and where bus lanes should be created.

The applicable legal framework often poses a challenge here. In many cases the laws originate from a time where the focus was on using cars. Moreover, it is difficult or even impossible to formulate corresponding laws at a national level such that they do not hamper individual projects that make a lot of sense at a local level. It goes without saying that traffic rules need to be consistent and must be communicated clearly to all road users. However, if a little more freedom were to be granted at municipal level, especially for transport-related trials or to provide special protection for vulnerable road users, then in many places this could improve road safety and sustainability without entailing any notable disadvantages or risks.

The legal requirements stipulating that there needs to be a minimum number of pedestrians per hour before a pedestrian crossing (zebra crossing) can be installed, do not always make sense in front of schools and kindergartens. In many places, the requirement that there needs to be a minimum number of regular buses per hour before a bus lane can be installed, raises the question of how local public transport can be made more attractive so as to encourage more people to make this modal shift. Ultimately, we end up in a farcical situation if high accident figures and/or breaches of air pollution limits mean a lower speed limit is mandated, but then the accident figures/air quality improve(s) to such an extent that there is no longer a legal basis for the lower speed and it needs to be revoked.

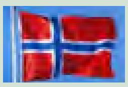
1985 • *1990* • *1995*

1984

- *Seat belts in the back seat required in Germany*
- *In Germany, a fine is introduced for any breaches of the rule on the compulsory use of safety belts*

1985

- *Bergen (Norway) is the first city in Europe to introduce a charge for driving into city centers.*



1986

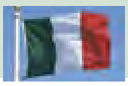
- *The European EUREKA research project PROMETHEUS (PROgraMme for a European Traffic with Highest Efficiency and Unprecedented Safety) conducts the first research into the possibilities afforded by automated driving.*
- *"Probationary driver's licenses" are introduced in Germany.*

1988

- *International Traffic Safety Data and Analysis Group (IRTAD) founded*

irtad
International Traffic Safety Data and Analysis Group

- *In Italy, a speed limit of 90 km/h is introduced on rural roads.*



1990

- *As from 1990, the traffic circle experiences a renaissance as a traffic control measure to improve safety on German roads. 50 percent of all traffic circles worldwide are located in France.*

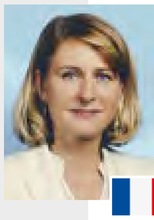
- *In France, a speed limit of 50 km/h in built-up areas is introduced, as are 30 km/h zones*
- *In the Netherlands, rumble strips have been used since the early 1990s, which reduces the number of traffic fatalities there by around a third by 2007.*

1995

VISIONZEROINITIATIVE
TRAFFIC SAFETY BY SWEDEN

- *"Vision Zero" is applied to road traffic for the first time in Sweden. The underlying notion: people make mistakes, so the transport system must be designed to allow for mistakes without endangering the lives of the users. The aim: zero traffic fatalities or serious injuries.*
- *In France, the blood alcohol concentration limit (BAC) permitted for road traffic is reduced to 0.05.*

Taking Action in Response to Major Developments in Our Society



Florence Guillaume
Interministerial Delegate – Directorate for Road Traffic Safety

Humans, the vehicle, and the road environment: these are the three action areas if we want to save lives on the road. When it came to the road environment, road safety policies of 50 years ago focused solely on the accident blackspots in the road network. These policies have gradually been expanded to include entire stretches of road.

As a result, infrastructure has established itself as one of the three key pillars in the fight against fatal traffic accidents. Whether it's segregated roadways, eliminating all obstacles to the left and right of the road where possible, clearly visible lanes, shoulders that provide a buffer should a vehicle come off the road, etc., road safety is now an essential part of the road structure and incorporated from the outset in all stages – development, planning, and use – to compensate for driving errors. The progress achieved in terms of the road infrastructure has directly helped to halve the number of fatalities on the road over the past 20 years.

2024 will pose the particular challenge of responding to the major developments in our society: the unavoidable clean energy revolution and ensuring the safety of active travel modes (bicycle, personal light electric vehicles, walking). Redesigning road environments in light of this new dynamic on the road means continuing to do everything in our power to cleverly subdivide the available space, thereby ensuring that all categories of road user can use it side by side without issues, in particular using the physical infrastructure for each means of transport (road/bicycle path/footpath).

The "Plan Vélo 2023-2027" cycling plan therefore envisages new bicycle paths amounting to some 80,000 kilometers in the medium term. As it will not always be possible to provide these due to space or funding constraints or the presence of existing buildings/structures, more and more traffic calming zones will be created in the form of 30 km/h zones, pedestrian priority zones, or pedestrianized areas. Of course, these shared-use traffic zones must be managed and organized such that the various users act with due care and attention when using them. In 2023, more than 3,402 people* died on France's roads. This figure shows how crucial collective mobility is. It is something that concerns us all.

* Preliminary figures for 2023 from ONISR (French road safety observatory)

2000 *2005*

1997

- *Cyclists in Germany are permitted to cycle on the road on routes with no suitable bicycle path.*

1998

- *In Paris, the newly constructed driverless Metro line 14 opens.*

- *On September 7, the first sign with a "Czarny Punkt" or black spot denoting a particularly dangerous road is installed in Poland on national road 2 near Blonie. 20 other signs follow that same year.*

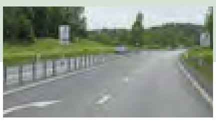
- *A blood alcohol concentration limit (BAC) of 0.05 is introduced in Germany*

1999

- *The EU regulation on driver's licenses enters into force.*

2000

- *Sweden begins to upgrade rural roads with a central steel cable barrier according to the 2+1 principle. Up to 80 percent fewer accidents occur on these roads.*



2002

- *Together with industry and other interest groups, the EU launches the eSafety initiative. It aims to speed up the development, deployment, and use of smart integrated safety systems and make use of information and communication technologies in smart solutions in order to improve road safety and reduce the number of accidents on Europe's roads.*
- *In Italy, daytime running lights become mandatory on freeways and in non-built-up areas.*

- *The road safety project ROSEBUD funded by the EU Commission starts. It compiles and further develops methods for cost-effectively evaluating road safety measures.*
- *In Germany, a variety of partners join the German Road Safety Council (DVR) and statutory accident insurance carrier BG Verkehr to get involved in the "Hats geklickt?" ("All clicked in?") safety belt campaign.*

2003

- *Congestion charge introduced in London*
- *The "Euskirchen" traffic barrier system is approved; it provides better protection for motorcyclists involved in collisions. Building on this design, DEKRA later develops the "Euskirchen Plus" system on behalf of the German Federal Highway Research Institute (BASt). It further improves the level of protection, including for the occupants of cars in the event of a high-speed impact.*
- *Radar speed checks deployed in France*

Many Different Requirements Need to Be Considered

As a result, infrastructure policy requires a holistic approach. It is not just about fulfilling the original aim of ensuring people can travel from A to B safely and effectively – we need supra-regional transport concepts that take account of the different types of road user, their specific requirements, and the policy intentions with respect to the mobility revolution. These concepts must be taken up and implemented for local projects. Essential considerations, both for standalone projects and the overarching concept, must be: safety (road safety and general safety), the sustainability of the measures and mobility options that are being promoted, achieving net zero during implementation and when the solution is "in operation", maximizing usability, care and maintenance, and creating livable spaces with a high-quality environment. Potential future changes to mobility patterns and the type of vehicles that people choose to use also need to be considered, so as to ensure changes can be made with a minimum of effort later on.

However, such measures can only be implemented in a meaningful way if the existing space is reallocated. This is because there is generally only a finite amount of space available to work with, which cannot be extended. Yet this is also precisely where major political problems lie. Getting rid of parking spaces, reducing traffic lanes, lowering the speed limit, installing asphalted bicycle paths in parks, introducing bans on overtaking cyclists, excluding certain road users from bicycle boulevards, or blocking off main roads for cyclists all constitute restrictions on people's existing rights. It is not an easy nut to crack – neither for politicians (who are dependent on votes) nor anyone affected (who will each have their own opinion about how they should be able to travel and about sustainability, along with various other needs). As a result, far too often we see a search for compromises which essentially do not achieve any of the goals that were set and ultimately

Re-Imagining Traffic

"Reallocate" is the name of a four-year project which launched in May 2023, financed by the European Union and coordinated by University College Dublin. It aims to transform inner-city roads into integrated, green, safe, and future-proof urban spaces, thereby helping to achieve the ambitious goal of the EU Mission "100 climate-neutral and smart cities by 2030." "Reallocate" will see integrated and innovative solutions for sustainable urban mobility developed in ten cities. This will enable the exchange of knowledge, experience, and ideas and inspire other cities to replicate the solutions and adapt them to suit their own specific circumstances. The project is focusing particularly on innovative urban design, measures designed to influence people's behavior, and smart technological and data-driven solutions for reducing the actual and perceived risks for road safety. The concepts are designed to meet the needs of different groups and municipalities within a city and seek a new balance in how roads and public space are allocated. The projects are planned to take place in Barcelona, Bologna, Budapest, Gothenburg, Heidelberg, Lyon, Tampere, Utrecht, Warsaw, and Zagreb. DEKRA Automobil GmbH and DEKRA Assurance Services GmbH are among the 37 project partners from 12 European countries. The expert organization's remit includes analyzing the planned pilot projects to determine the level of road safety which could be achieved, and reviewing the measures taken to determine how successful they were.

REALLOCATE

2005 • • • • 2010 • • • • 2015

2004

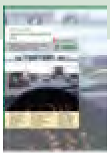
- *On April 6, the EU Commission launches the "European Road Safety Charter" in Dublin. Its declared goal is to halve the number of traffic fatalities by 2010 compared with 2001 figures. DEKRA is among the first signatories to the charter.*

2007

- *The ETAC study is published, investigating the main causes of traffic accidents involving heavy trucks.*

2008

- *The first DEKRA Road Safety Report is published, focusing on cars. Further reports are published in subsequent years, focusing on topics including trucks, motorbikes, pedestrians and cyclists, people and technology, rural roads, urban mobility, passenger transportation, transport of goods, the mobility of young people, and old-age mobility.*



- *Germany's first fully automatic, driverless subway runs through Nuremberg.*

2011

- *In its "Road safety: Policy orientations on road safety 2011–2020" document, the European Commission sets the goal of halving the number of annual traffic fatalities by 2020 compared with 2010 figures.*

2013

- *For new trucks and coaches, Lane Departure Warning Systems (LDWS) and Advanced Emergency Braking Systems (AEBS) become mandatory in the EU – initially only for commercial vehicles with air brakes and a permissible gross weight of > 8 t; from November 1, 2018 they become mandatory for all new commercial vehicles with a permissible gross weight > 3.5 t.*

2014

- *In May, Internet company Google presents a prototype of a self-driving car.*

2015

- *From July 1, technical inspection organizations in Germany must use the vehicle inspection adapter during periodical technical inspections on cars. It is used to test electronic vehicle components and is intended to keep pace with the increasingly complex technology in cars.*

- *From September onward, a section of the A9 freeway in Germany becomes an official test track for automated and connected driving.*

Ideally, the different types of road user would be incorporated in a holistic infrastructure planning approach.

cause confusion and dissatisfaction overall, and in the worst case lead to more accidents and casualties. A good and frequently seen example of this is when lines are painted on the road to mark out a bicycle lane. These lanes are mostly too narrow for cyclists, they encourage car drivers to make dangerous overtaking maneuvers, and they only go as far as the next intersection before suddenly stopping because an overarching active travel concept has not been implemented. The only figures that look good in this respect are the municipal statistics on the amount of cycling infrastructure installed.

In order to adopt a holistic approach to infrastructure planning, all stakeholders must be consulted early on in the planning phase so that their specific needs can be defined. This also concerns deciding how the (re)construction costs and the resulting follow-on costs and work should be allocated. Depending on the nature of the specific project, this could fall not only to the relevant contracting road enterprise and the official departments responsible for environmental protection and mobility, but also the public transport providers affected, the organizations responsible for road cleaning, the police, the rescue services, and affected telecommunications service providers and utility companies. Depending on the scale of the measures, it may also be necessary to consult accident commissions, associations that champion the interests of pedestrians, cyclists, and people with impairments, and the affected citizens.

2020 — 2025

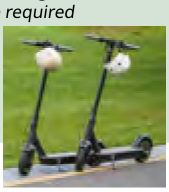
2017

- *In France, children under 12 must wear a helmet when they ride a bicycle*

- *In Germany, the Act on Automated Driving (amending the Road Traffic Regulation) enters into force. It permits automated systems (Level 3) to take over driving duties if certain prerequisites have been met. A driver must still be present, but when the vehicle is in automated mode, they are permitted to turn their attention away from what is happening on the road and controlling the vehicle.*

2019

- *E-scooters approved for use on German roads from June 2019. The following rules apply: type approval, maximum speed 20 km/h, minimum age 14, no driver's license required*



- *Regulation (EU) 2019/2144 (the "General Safety Regulation") is adopted, meaning improved safety for vulnerable road users and the use of driver assistance systems gradually become part of type approval regulations.*

2020

- *In Germany, the Act on Autonomous Driving enters into force. This enables fully automated motor vehicles (Level 4) to operate normally on public roads within defined Operational Design Domains.*
- *In Germany, an amendment to the Road Traffic Act (StVO) enters into force. Among other measures, it requires drivers to maintain a minimum distance from the side of cyclists when overtaking them.*

- *The United Nations declares that 2021–2030 will be the "Second Decade of Action for Road Safety."*

2022

- *From July 6, 2022, all new models of vehicles in the EU must be equipped with an Intelligent Speed Assistant, fatigue warning system, automated emergency braking system, emergency lane guard assistant, reversing assistant, and tire pressure monitoring system (this then applies to all new vehicles from July 2024).*

2023

- *The German Federal Ministry for Digital and Transport (BMDV) and the German Road Safety Council (DVR) aim to foster #mehrAchtung (#greaterRespect) on the roads and therefore launch a new road safety initiative as part of the "Runter vom Gas" (Take your foot off the gas) campaign.*

Much Work Still Needs to Be Done Worldwide

Whether it's speed restrictions, barriers between the carriageways in each direction, 2+1 roads, additional structures to protect against collisions with a tree, designing cycling infrastructure in compliance with the regulations, and much more: there are many different (infrastructure) measures for increasing road safety. It is important to continually review whether expectations are being met or whether there is room for further improvement.

For years now, we have seen many positive developments relating to road safety. This is particularly impressive when we consider that the amount of road traffic and the number of registered vehicles have both increased substantially. For example, according to the European Automobile Manufacturers' Association (ACEA), there were around 244 million motor vehicles on the EU's roads in 2010. By 2021 this number had increased by 17.3 percent to over 286.2 million – of which just under 250 million are cars. In the same period, the number of traffic fatalities fell by 32.8 percent from 29,600 to 19,900 **(Figure 1).** In 2022 this figure increased to just under 20,600, and for 2023 the EU is assuming a figure of around 20,400 traffic fatalities.

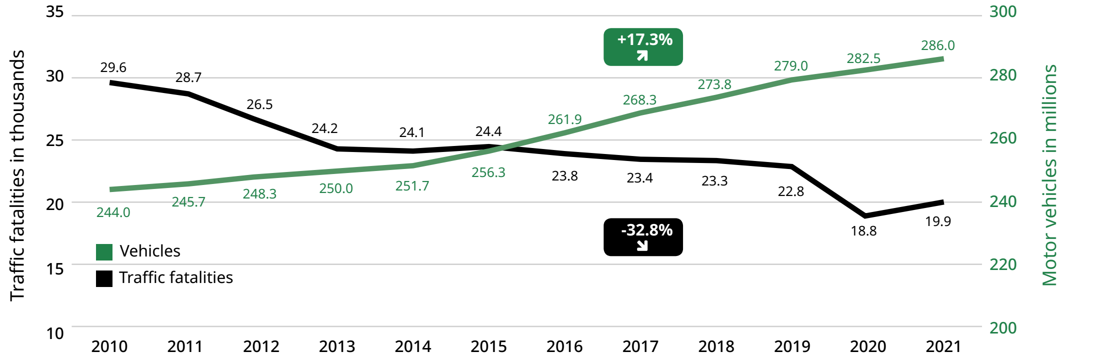
A look back at the figures since 2002 confirms that the overall trend is positive. The 17th Road Safety Performance Index Report published by the European Transport Safety Council (ETSC) showed that the number of traffic fatalities per one million inhabitants was over 83 in most European countries in 2002. In 2012 it was mainly only in Eastern Europe where it was still over 65, and in 2022 it was already between 26 and 38 in many countries **(Figure 2).** Norway and Sweden lead the rankings, achieving figures of 21 and 22 traffic fatalities per one million inhabitants respectively.

If we look at the issue on a global scale, the World Health Organization (WHO) estimates that there were 1.19 million traffic fatalities in 2021 – a drop of only 5 percent compared with 1.25 million traffic fatalities in 2010. On the other hand, however, we also need to remember that according to the WHO, the number of motor vehicles more than doubled in this period, to more than a billion.

1

Comparison of Number of Vehicles and Traffic Fatalities in the EU

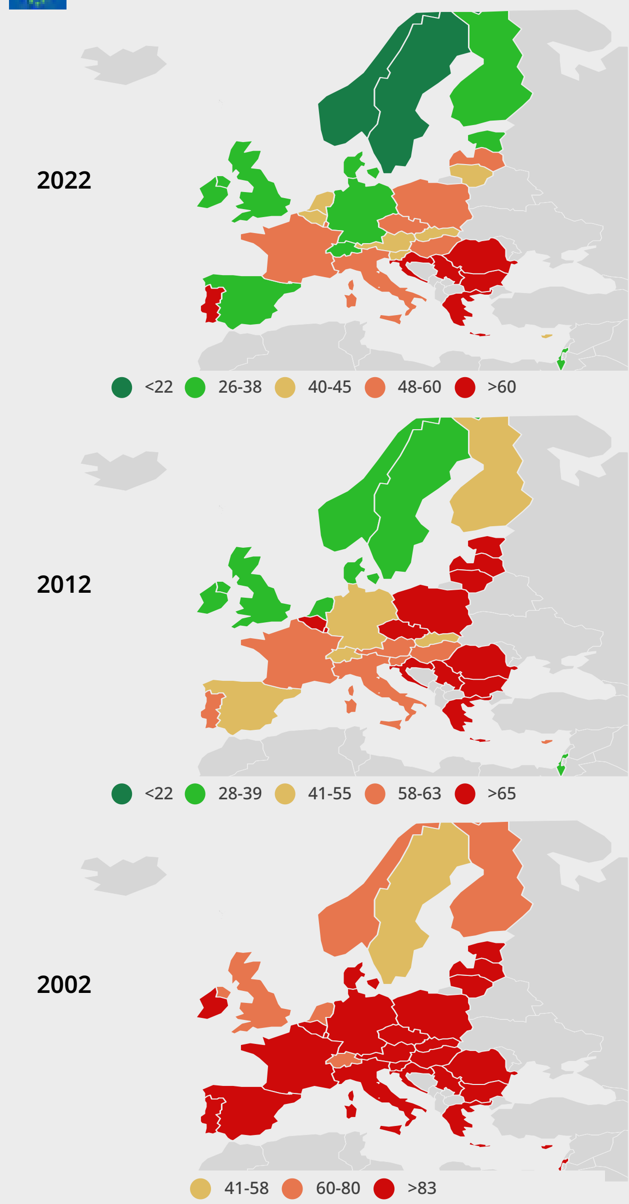
The number of traffic fatalities has fallen significantly since 2010 – despite there being more vehicles on our roads



Source: ACEA/CARE

2

Traffic Fatalities per One Million Inhabitants



Source: ETSC/CARE

Continued Rise in the Volume of Road Traffic

At present, it is almost impossible to predict how things will develop going forward. However, and as mentioned in the introduction to this report, as things stand today it will likely prove difficult to achieve the goal the WHO and EU have set themselves of halving the number of traffic fatalities in the period 2021 through 2030, particularly as the amount of road traffic is expected to increase further. According to the WHO, by 2030 alone the number of motor vehicles could double again compared with 2021. In its "Transport Outlook 2023", the International Transport Forum (ITF) even talks of a sharp global rise in the demand for mobility by 2050. Within each country's national borders/on a regional level, around 50 percent of journeys are still expected to be made by car at that point.

According to the latest transport market forecast from the German Federal Ministry for Digital and Transport (BMDV), by 2051 passenger traffic in Germany is set to increase by 13 percent compared with 2019 figures, to almost 1,400 billion passenger kilometers. The BMDV states that major increases of over 50 percent are to be expected in rail and air traffic, whereas motorized road traffic is only expected to grow slightly. Bicycle traffic is expected to increase markedly (plus 36 percent). These forecasts notwithstanding, cars and motorbikes are likely to remain the most popular means of transport by some margin in Germany – and surely in many other countries as well. According to the BMDV, these two forms of mobility have been responsible for more than two thirds of all journeys in Germany to date. In terms of goods traffic, the Ministry is forecasting that traffic will increase from 679 to 990 billion tonne-kilometers. Trucks are set to remain the predominant means of transport and will even play a bigger role, growing by 54 percent.

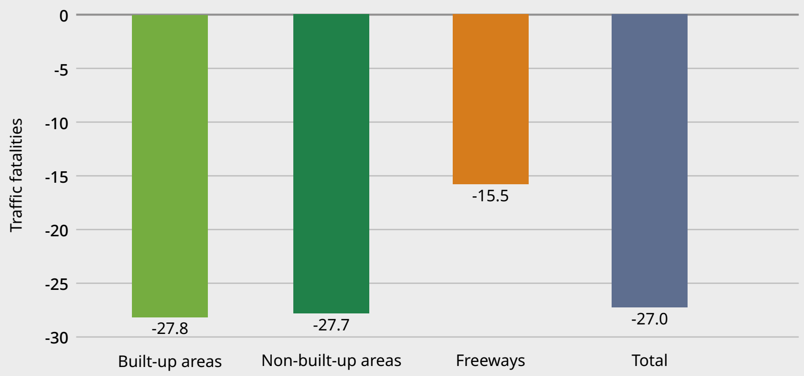
Rural Roads Continue to Record the Most Traffic Fatalities

Turning back to accident statistics, if we look at the trend in selected member states of the International Traffic Safety Data and

3

Trend for Traffic Fatality Numbers by Road Type in Selected Countries (In Percent)

2022 compared with 2012



Data includes figures from Austria, Belgium, the Czech Republic, Denmark, Finland, France, Germany, Great Britain, Hungary, Ireland, Italy, Japan, South Korea, Lithuania, Luxembourg, the Netherlands, New Zealand, Poland, Portugal, Serbia, Slovenia, Sweden, and Switzerland.

Source: IRTAD

Analysis Group (IRTAD) at the International Transport Forum (ITF), for example, we see that the number of traffic fatalities fell by 27 percent in 2022 compared with 2012 **(Figure 3).** As stated in the ITF's "Road Safety Annual Report 2023", which is based on data from 25 countries, the number of traffic fatalities on inner-city roads and rural roads fell by almost 28 percent each between 2012 and 2022, on freeways by 15.5 percent. However, the road-type-specific data shows that rural roads are the deadliest roads almost everywhere. In 17 countries, more than half of all traffic fatalities occurred in accidents on rural roads in 2022. This figure even reached two thirds in Finland, Ireland, and New Zealand. In Germany, the figure for 2022 was 57 percent – it has been more or less stable for some years now. It was only in South Korea, the Netherlands, Japan, and Portugal where inner-city roads were more likely to be the scene of a fatal accident than other types of road **(Figure 4).** According to the ITF, and mirroring DEKRA's repeated findings in its Road Safety Reports from recent years, the main reasons why rural roads are so dangerous are inadequate road infrastructure combined with the fact that drivers often drive at an inappropriate speed.

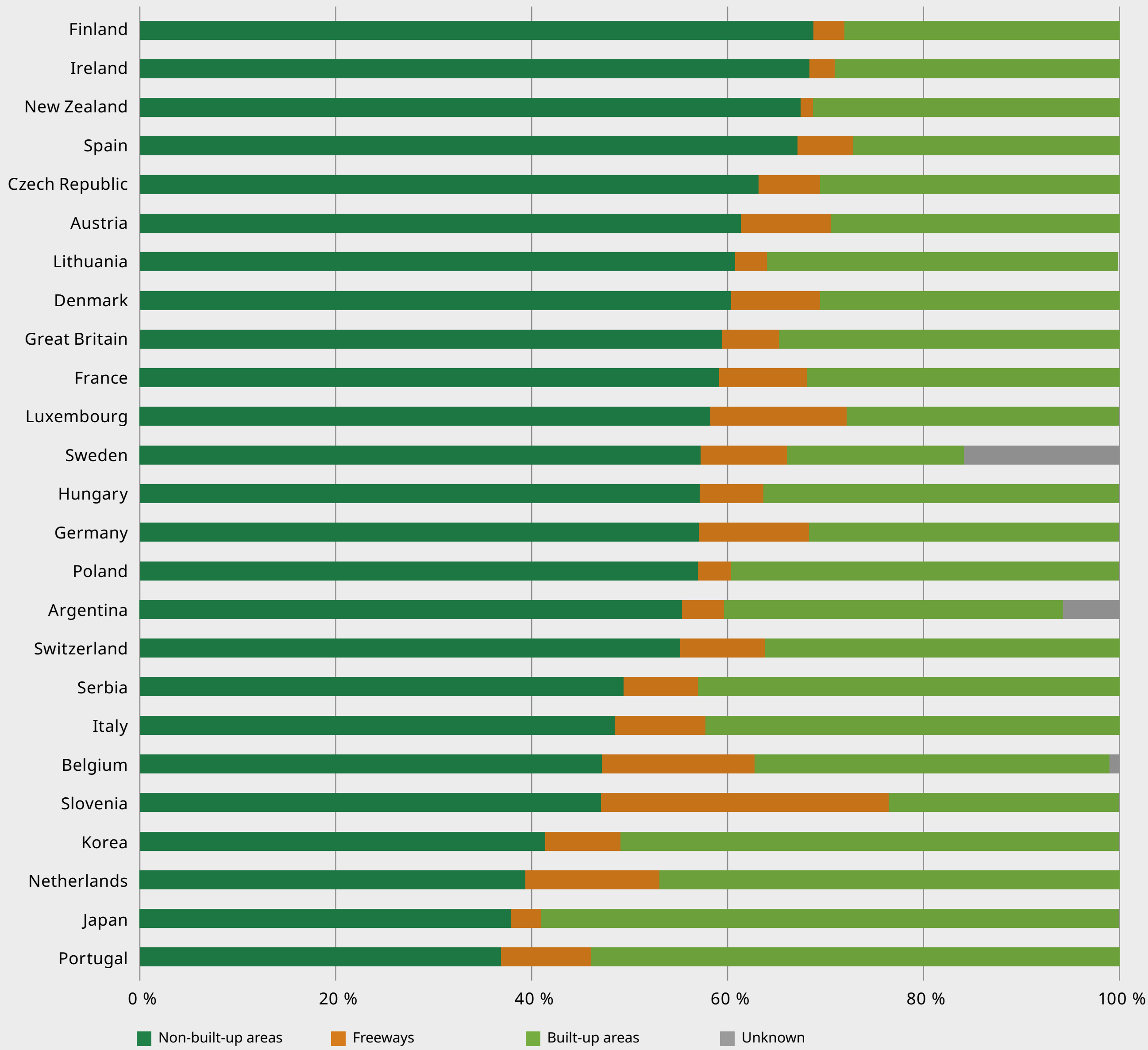
As a result, France, for example, deliberately introduced a speed limit of 80 km/h on two-lane rural roads in 2018, which led to a clear fall in the number of traffic fatalities on these roads. Despite this, numerous départements have now returned to the old limit of 90 km/h. However, the French Centre for Studies and Expertise on Risks, the Environment, Mobility and Urban Planning (CEREMA), which is under the supervision of the Ministry for Ecological Transition and Territorial Cohesion, assumes that lowering the speed limit to 80 km/h could prevent around 200 deaths a year. According to the 2022 annual accident report from the French road safety observatory ("Observatoire national interministériel de la securité routière", ONISR), if we look at the 45 départements which raised the speed limit to 90 km/h in all of part of their road network, the number of traffic fatalities outside built-up areas increased by 1.4 percent in 2022 compared with 2019, whereas it fell by 1.8 percent in the rest of the country.

Winding rural roads like this can tempt some car drivers or motorcyclists to adopt a high-risk driving style.

In Germany, the German Road Safety Council has called for a speed limit of 80 km/h on narrow rural roads in February 2024. Where structural conditions permit, the speed limit for trucks could also be changed from the current 60 km/h to 80 km/h. Back in June 2023, the German Road Safety Volunteer Organization ("Deutsche Verkehrswacht") also called for the standard speed on rural roads to be lowered to 80 km/h in order to reduce serious accidents. They said this should be accompanied by exemptions so that a speed limit of 100 km/h, for example, could still be approved for appropriately expanded or upgraded roads. At the same time, the standard speed limit for trucks should be increased to 80 km/h to reduce the pressure to overtake on rural roads. Here too, exemptions should be defined so that a lower speed limit could be mandated on poor-quality roads, for example. Should these new rules be introduced, their impact is to be investigated in detail in a research project.

4

Traffic Fatalities by Country and Road Type in 2022



Source: IRTAD

Make Walking and Cycling Safe, Enjoyable and Obvious

Saul Billingsley
Executive Director, FIA Foundation

Make Roads Safe. This was the message of the campaign the FIA Foundation ran back in the noughties when we were trying to move road safety up the international policy agenda. The campaign slogan had a double meaning. Make travelling by road safer, for sure. But also 'make infrastructure safe'.

The impact of the built environment on road safety is all-pervasive but often almost invisible to policymakers. But if we stop and think about how our highways and roads are located, their scale, their social impact, how they connect but also divide, we can see that if we want to improve road safety, and tackle climate change, and fix racial or economic inequalities, and bring communities together, we have to challenge some fundamental assumptions about roads.

Urban street networks evolved organically for the most part. They were human and animal in scale, built for walking and horse and carts. Urban highways are an alien imposition, a revolutionary act of violence which tore apart communities and introduced an inhuman scale and speed to urban living. They often had a political subtext. It's no accident that South African townships, Brazilian favelas, American racial ghettoes, and the Parisian banlieues are bordered by high-speed roads. The impact of these urban frontiers, in dislocation and crime, in pollution and noise, in social exclusion and of course in road traffic carnage, is well documented.

There is no excuse for high-speed urban highways still to be built in modern cities. Yet built they are. As megacities across Africa, Asia and South America grow the urban highway expands through them. These have all the same negative outcomes. They become horribly congested during the day. At night they are killing grounds, badly lit racetracks where pedestrians dice with death. Facilities for walking and cycling are typically few and poorly designed. Research has found that in low-and-middle income countries more than 90% of roads with posted speeds above 40 km/h do not have a pedestrian sidewalk. But this data also shows that there are fixes we can make, and at scale.

The data comes from the International Road Assessment Programme (iRAP), which works to assess the safety of roads across more than 100 countries. Working closely with governments, development banks, city authorities and highway concessionaires, iRAP is transforming how planners, engineers and politicians understand infrastructure safety and its wider contribution to social and health objectives. Another of our partners, Amend, works to deliver mass action community safety improvements on World Bank-funded road corridors in Africa. EASST works with governments and cities in Central Asia to reduce speeds and improve road design. AIP Foundation is assisting the Vietnamese government with new national guidance on safe infrastructure and speed limits for school zones. ITDP has published research showing that every dollar diverted from new highways to cycle lanes reaps a disproportionately positive carbon benefit.

We have the recipe for sustainable urban mobility. Build at a human scale (fifteen-minute cities, for example). Invest in mass transit and providing high quality and responsive public transport, rather than inefficient and expensive new highways. Reduce speed to within a safe envelope for the road environment, which in cities will usually be a maximum of 30km/h. Make walking and cycling safe, enjoyable and obvious. Above all, empathise. If you don't want to live next to the concrete pillars of an elevated freeway, why would you think it is ok for someone else?

In their demands, the German Road Safety Volunteer Organization cites data analysis conducted by German Insurers Accident Research ("Unfallforschung der Versicherer") from 2022, which stated that around 70 percent of accidents on rural roads occur when the speed limit is higher than 80 km/h. There are currently only very limited possibilities for deviating from a standard speed limit of 100 km/h. The German Road Traffic Act only permits exemptions where this is "imperative due to special circumstances", such as in areas that have proven to be accident blackspots.

Construction Measures Must Always Focus on Safety

It is clear that road design plays a decisive role in accident statistics, alongside many other factors. Careful planning and implementation of road design measures can help to prevent accidents entirely, which is the ideal scenario, or at least minimize the risks resulting from an accident, as well as optimize the flow of traffic. The requirements relating to the road and roadsides depend on numerous parameters, including what the road is designed for (e.g., whether it is for supra-local traffic), the expected traffic density, and the modal split/use of the road by different means of transport. There are also external influences that vary depending on the specific location, such as topography, existing or planned buildings/developments, landscape conservation and environmental protection requirements, and legal building standards. Last but not least, it is important to consider who bears the costs for the planning/design work, conversions/construction, and subsequent maintenance. However, no matter whether it concerns mixed traffic on local and rural roads or the road is reserved for specific groups of users such as with pedestrian zones, express bike lanes, or freeways, the focus must always be on safety.

A good example of a successful road redesign project is the "Bruce Highway" in Australia. It runs for around 1,700 kilometers and is the most important north–south road corridor in the state of Queensland on the east coast of the country. Over the past few years, large stretches have been optimized to improve road safety. The project is a 15-year infrastructure program which is set to run until 2028, and its measures include wide center lines, improvements at intersections, safety barriers, traffic barriers at the edge of the road, and in some cases the expansion of the road to create a freeway-like system with up to four lanes in both directions.

The results are clear to see. If we look at the stretch between Cooroy and Curra alone, which is only 60 kilometers long, the number of traffic fatalities fell drastically. According to the Royal Automobile Club of Queensland, 22 people lost their lives there in a road traffic accident in the years 2005 through 2009. In the years 2018 through 2022, this had dropped to just three – a reduction of 86 percent.

The "Bruce Highway" in Australia before and after being upgraded to improve safety.

2+1 Roads Have Proven Their Worth

There is no question that the systematic expansion of roads to include two lanes and physically segregated carriageways in each direction can help with the long-term prevention of accidents involving oncoming traffic – in particular on busy stretches that are used heavily by commercial vehicles. Where it is not necessary or possible to expand both sides of the road to two lanes, but safe overtaking options still need to be provided, the principle of "2+1 roads" has proven to be an effective solution. This concept was developed in Sweden at the start of the 1990s and involves providing stretches with two lanes in one direction and one lane in the other, alternating between the two carriageways

Investing in the Safety of Our Roads Saves Lives

Rob McInerney
CEO, International Road Assessment Programme (iRAP)

How much would you be willing to invest in a problem that is the single biggest killer of young people globally? A problem that kills and injures an estimated 100,000,000 people a year according to the Global Burden of Disease. A problem that costs over US$ 2 trillion a year globally, equivalent to 3-5% of annual GDP in most countries.

I often wonder what our road and transport system would look like if the full cost of road trauma had to be paid by our public road authorities. Roadsides would be made safe and survivable, more than a white line would separate high-speed oncoming traffic, pedestrians and cyclists would have safe paths and crossings, motorcycle lanes would be in place, roundabouts would be everywhere, safe and efficient public transport would be in place and speed limits would minimise harm for all.

The reality is different. As highlighted in the latest WHO Global Status Report on Road Safety only 21-23% of existing roads currently meet the 3-star or better global standard for pedestrians, cyclists and motorcyclists. A slightly better 40% for vehicle occupants. Sadly, we still see brand new 1 and 2-star roads being built around the world – particularly for pedestrians and cyclists who are the most sustainable forms of transport.

The United Nations Sustainable Development Goal 3.6 aims to halve road deaths and injuries by 2030. To support this the UN Member States have agreed on two Global Road Safety Performance Targets. Target 3 to ensure all new roads are 3-star or better for all road users and Target 4 to ensure at least 75% of travel on existing road networks is at the same equivalent 3-star or better standard for all road users. The next step is to legislate for these minimum standards.

This is where iRAP partnerships with Government and industry strive to assess and certify all new road designs to make sure they are 3-star or better for all road users . Where that is achieved the Minister, design and construction teams can ribbon-cut the new infrastructure and celebrate their life-saving success with the public.

The other good news is that investing in 3-star or better road upgrades will save lives, save money and create jobs. The iRAP Business Case for Safer Roads1 demonstrates reaching 75% of travel at a 3-star or better standard by 2030 will deliver $8 of benefits for every $1 invested with the potential to save at least 1 in every 3 deaths and serious injuries worldwide. Given the world's road authorities spend an estimated US$800 billion on land transport infrastructure every year, one of our easiest solutions to the road trauma pandemic is to make sure all of that investment is 3-star or better.

in each direction. The conventional 1+1 running on the sections in between varies in length, from a direct transition all the way up to several kilometers with a ban on overtaking.

Experience gained with this expanded road design has shown that the number and severity of accidents are reduced and drivers are quite happy to accept the ban on overtaking. In Sweden, the number of fatal accidents and the number of accidents resulting in serious injury was reduced by 50 to 80 percent after expanding two-lane roads to a 2+1 configuration. Alongside Sweden, larger stretches of this expanded road design can also be found in the USA, Australia, New Zealand, and Germany. Moreover, a major 2+1 pilot project was launched in the north of the Canadian province of Ontario in April 2022. A modified version of the 2+1 road design is also suitable for stretches of road that commuter and rush-hour traffic use heavily in one direction in the morning and in the other direction in the afternoon. By assigning the center lane to each side based on how heavy the traffic is in each direction, the traffic flow can be optimized while taking up less space. Electronic display systems or barriers that can be moved mechanically specify which direction has been assigned to the center lane. The most prominent example of the use of movable lane dividers can be found on the Golden Gate Bridge between San Francisco and Marin County. This system enables the six lanes to be used in a 4+2, 3+3, and 2+4 configuration as required.

2+1 roads have proven effective in numerous countries worldwide. However, motorcyclists may be at high risk of injury if they crash into the barriers between the carriageways in each direction.

Star Rating for Roads

In order to halve the number of traffic fatalities in the period 2021 through 2030, the United Nations agreed on twelve voluntary performance targets back in November 2017. In this form, they are more or less also considered part of the Global Plan for the Second Decade of Action for Road Safety 2021-2030. When it comes to infrastructure, Targets 3 and 4 are particularly relevant. Target 3 states that by 2030, all new roads should achieve technical standards for all road users that take into account road safety or achieve a three-star rating or better (the definitions are shown in **Figure 5).** Target 4 states that by 2030, more than 75 percent of travel on existing roads should be on roads that meet technical standards for all road users and take into account road safety. However, there is still a lot to do in this respect – in some cases only around a fifth of roads designed for pedestrians, cyclists, and riders of two-wheeled motor vehicles have at least a three-star rating**.**

5 **Star Rating for Roads Based on Risk**

For...	Pedestrians	Cyclists	Motorbike riders	Car occupants
*	No sidewalk, no safe crossing, 60 km/h traffic	No bicycle path, no safe crossings, poor road surface, 70 km/h traffic	No motorcycle lane, undivided road, trees close to road, 90 km/h traffic	Undivided road with narrow center line, trees close to road, winding road 100 km/h traffic
***	Sidewalk present, pedestrian refuge, street lighting, 50 km/h traffic	On-road bicycle path, good road surface, street lighting, 60 km/h traffic	On-road motorcycle lane, undivided road, good road surface, more than 5 meters to any roadside hazards, 90 km/h traffic	Wide center line separating oncoming vehicles, more than 5 meters to any roadside hazards, 100 km/h traffic
*****	Sidewalk present, signaled crossing with pedestrian refuge, street lighting, 40 km/h traffic	Off-road dedicated cycling facility, raised platform crossing on major roads, street lighting	Dedicated separated motorcycle lane, central hatching, no roadside hazards, straight alignment, 80 km/h traffic	Safety barriers separating oncoming vehicles and protecting against roadside hazards, straight alignment, 100 km/h traffic

Source: iRAP

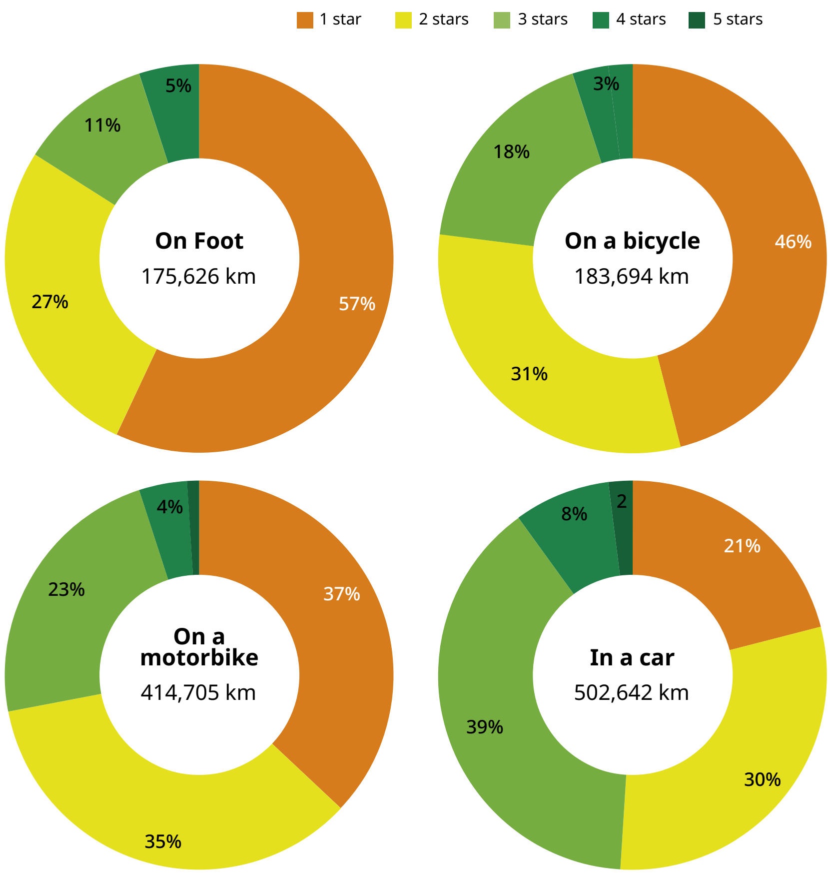
Across the globe, there are sometimes major differences in road safety standards

In line with the United Nations' Global Plan, the International Road Assessment Programme (iRAP) has developed its own "Plan for the Second Decade of Action for Road Safety." It states that by 2030, at least 200,000 kilometers of roads should be made safer and at least two million people should be saved from death or serious injury on the road. According to iRAP, this would require an investment of around 200 billion US dollars. iRAP is a registered charity that was founded in 2006 in the United Kingdom and receives financial support from the FIA Foundation. It has Consultative Status with the United Nations' Economic and Social Council and is an umbrella organization for local road rating programs and partners such as BrazilRAP, EuroRAP, ThaiRAP, MyRAP, IndiaRAP, usRAP, KiwiRAP, ChinaRAP, AusRAP, and SARAP. Its declared goal is to promote measures to improve road safety and the quality of roads all across the globe. To this end, the iRAP collaborates with governments, industry, development agencies, universities, and non-governmental organizations in order to inspect high-risk roads, develop targeted road safety plans, and assess the benefits of the investments made.

6

iRAP Star Ratings

Globally, according to analyzed route length (km)



Source: iRAP

Tool Shows Road Safety in 84 Countries

One tool developed by iRAP is the Safety Insights Explorer. By its own definition, it shines a light on the true scale of road crashes, the safety of the world's roads, and the positive impact that can be made with investment in infrastructure. Split according to world region and individual countries, it contains not only estimates of the number and type of injuries according to age and gender, but also the associated costs, as well as star ratings for roads **(Figure 6)** for different types of road user (vehicle occupants, pedestrians, cyclists, and riders of two-wheeled motor vehicles).

To date, iRAP has rated more than 1.4 million kilometers of road in over 100 countries. The ratings in the Safety Insights Explorer cover more than 500,000 kilometers of roadway in 84 countries. It also contains a scenario that demonstrates the positive impact of investment, with reference to achieving the 75 percent goal stated by the United Nations. The costs associated with fatalities and serious injuries in road traffic are vast – iRAP estimates them at around 2.2 trillion US dollars each year, of which around 630 billion US dollars is attributable to fatalities. In terms of serious injuries, brain injuries, paraplegia, limb fractures, and internal injuries make up the lion's share of the costs, at around 1.2 trillion US dollars.

When it comes to the road ratings, there are sometimes huge differences between the countries listed. In the USA, for instance, 30 percent of the road kilometers rated for the "Vehicle occupants" category have a 3-star rating, 33 percent have a 4-star rating, and as much as 17 percent have a 5-star rating. Roads with a 2-star or 1-star rating make up around 20 percent. In Kenya, only around 25 percent achieve a 3-star rating or better. 48 percent are listed with a 1-star rating. The road kilometer ratings for cyclists are also quite revealing. In the USA, only a combined 10 percent achieve either a 4 or 5-star rating. By contrast, this figure is 60 percent in the Netherlands, and only one percent in India. India has similarly poor ratings for pedestrians and the riders of two-wheeled motor vehicles. As a result, it also comes as no surprise that India is among the countries with the most traffic fatalities in the world. We could list countless other examples at this point. However, further details are available online at www.irap.org/safety-insights-explorer.

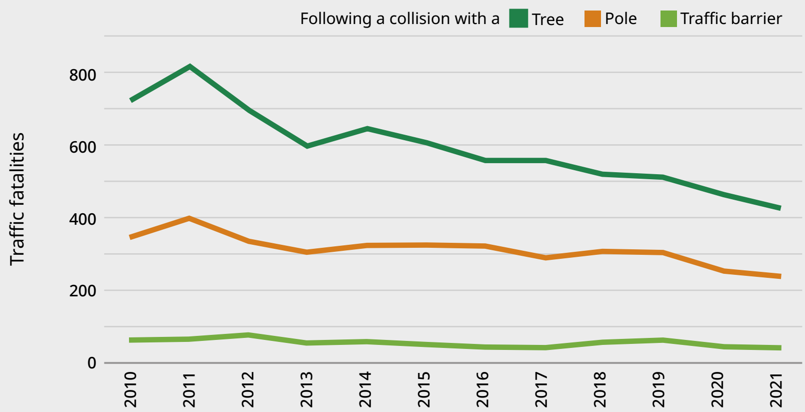
Danger Due to Objects at the Roadside

The fact is that every road category has its own specific risks influencing the occurrence and consequences of accidents. This becomes clear if we look at Germany by way of example. The freeways – the famous "Autobahnen" – are mostly built out to a very good standard and are subject to high safety standards, meaning there are no slow-moving vehicles, cyclists, or pedestrians. In terms of municipal roads, you can find virtually all types of road condition and road user, whereby the comparatively low speed limit significantly improves safety. Rural roads are particularly critical – they are built out to varying degrees and are used by all types of road user, who travel at high speed. The safety features of these roads vary greatly too – you can find everything from single lanes without a properly surfaced edge all the way through to fully built-out, freeway-level roads. In some cases the oncoming traffic is not spatially or physically separated or there are no passive protective structures, or there might be sharp corners or objects such as trees or poles directly at the roadside. These pose a risk of accidents with a high likelihood of injury for all types of road user.

In particular, coming off the road and colliding with an object at the roadside is generally a critical but also commonplace scenario on rural roads **(Figures 7 to 9)**. Since trees, poles, large rocks, and in some cases also relatively deep drainage ditches barely absorb any energy in the event of a collision, most of the energy needs to be absorbed by the crashing vehicle. When traveling at speeds typical for rural roads, the parts of the vehicle that absorb energy, such as the crumple zones, are quickly overwhelmed. Accordingly, vehicle occupants and riders are at high risk. If we look at Germany, for example, the German Federal Statistical Office states that in 2021, these types of collisions with an object were responsible for a total of 990 fatalities and over 14,000 seriously injured people. If we focus on collisions with traffic barriers, it is important

7

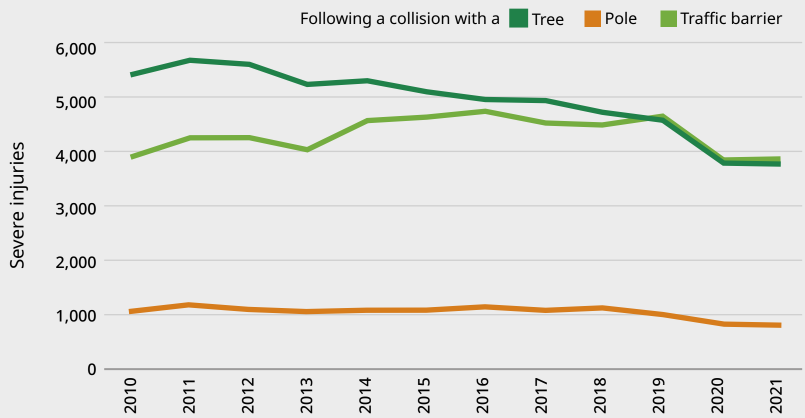
Fatalities (all road types)



Source: German Federal Statistical Office

8

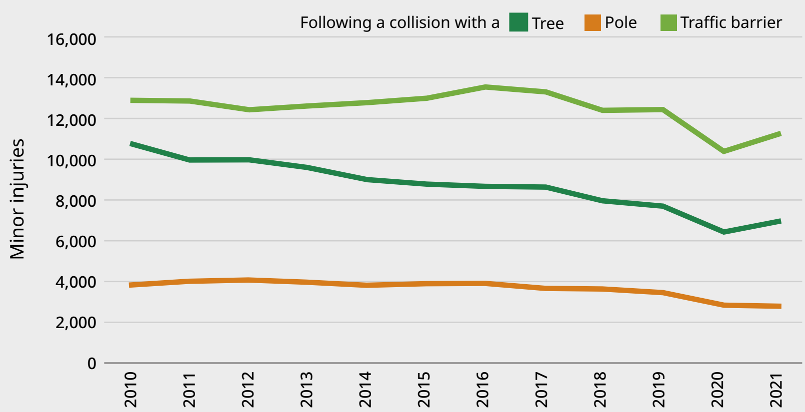
Severe injuries (all road types)



Source: German Federal Statistical Office

9

Minor injuries (all road types)



Source: German Federal Statistical Office

Tree-lined roads look pretty but also pose a number of risks for users of all types of motor vehicle.

to note that these often concerned motorcyclists and that the statistics include cases of multiple collisions.

Percentage of Collisions With Trees Remains High

Despite considerable efforts, although the number of people involved in an accident with trees, poles, and traffic barriers is reducing over time, there has been barely any change to the percentage of collisions with trees as a share of the overall accident statistics. In Germany, fatal accidents involving a tree made up 20 percent across all locations in 2010. In 2021 this figure was still 17 percent. This means that in Germany, around one in every six people killed loses their life in a collision with a tree. Similarly, if we look at the statistics for people who suffered serious and minor injuries, the percentage of collisions with trees also barely changed over the same period. In fact, the percentage of fatal accidents is even higher on rural roads with no freeway. In 2021, the number of people killed by a collision with a tree accounted for 24 percent of all those killed on rural roads. By way of comparison, if we look at France, the ONISR annual accident report states that 1,733 people lost their lives on rural roads in 2021 – 37 percent of whom died as a result of a collision with a tree.

Most of the collisions with a tree on rural roads were single-vehicle accidents where no other road user was involved. These accidents were caused by things such as excessive or inappropriate speed, distractions, or a lapse in attention. In this context, even a small mistake out on the road can have fatal consequences. The figures are worrying and highlight just how crucial it is for roadsides to have a safe design. They also underline how urgent it is that we take measures to minimize the consequences of an accident, in particular if there are collision hazards next to the road, primarily on rural roads.

Due to differing design specifications, different approaches have been taken for the design of rural roads and the vegetation at the roadside in different countries. However, the vegetation at the roadside also protects road users in different ways (such as guarding against erosion), improves the look of the road, reduces noise, and creates habitats for animals. Careful selection and positioning of plants can also help to influence wind flows and prevent snow drifts as well as glare when the sun is low. Moreover, it can make it easier to identify the course of the road ahead. However, in order to minimize potential hazards, it is essential to choose the right plants, look after them, and inspect them at regular intervals. Although trees can improve drivers' attention levels by making it easier

Before taking corresponding measures, a targeted analysis of the existing road environment is always required

for them to see where the road is going and highlighting where the road boundaries are, they are also unyielding objects that vehicles can easily collide with.

Targeted Use of Bushes and Shrubs

For this reason, DEKRA has long called for action to be taken in this respect: that trees and poles in the direct vicinity of roads should be protected by effective protective structures or obstacles removed wherever possible. Where neither of these can be carried out, the speed should be reduced in the areas concerned. However, protective structures only offer the optimum degree of protection if they are installed sufficiently far away from the object. Additionally, any trees planted next to a road must be far enough away from the road. If care is taken to not plant trees directly next to the road when they are still saplings, then further down the line there will also be no need to install expensive guards and traffic barriers in front of them, which lowers the costs.

One potential alternative for road design, particularly in rural areas, is the targeted use of bushes and shrubs. Not only do they look attractive, they can also help to improve safety. In the past, DEKRA's crash tests have shown that the loads exerted on vehicle occupants if their vehicle collides with a bush are around eight times lower than if their vehicle were to collide with a tree. However, bushes and shrubs require additional maintenance and care as their energy-absorbing properties can change over time. Furthermore, they must not make it harder for drivers to spot wild animals. There is also a risk that wild animals will be tempted to come very close to the road because they can hide in the bushes – making them an even bigger hazard and putting themselves in danger.

Collisions with trees are often fatal, especially on rural roads.

DEKRA crash tests already showed many years ago (in this case 2001) that shrubs and bushes can be a better solution.

Similar findings were obtained in a study by the University of Warmia and Mazury in Olsztyn, Poland, which investigated the protection provided by vegetation at the roadside. Possible solutions for absorbing some of a vehicle's collision force include providing areas of vegetation, namely shrubs and bushes, at dangerous bends in the road, and only installing energy-absorbing structures such as traffic barriers behind these shrubs.

In order to ensure that nature and traffic can coexist in harmony with one another, targeted long-term plans are required so as to safeguard and further improve road safety and create a sustainable and attractive road environment. Comprehensive, targeted analysis of the existing road environment, particularly rural roads, is the only way to ensure that the areas next to roads are not only safe, but also have a sustainable design. For this to succeed, it is essential to strike the right balance between environmental awareness and risk minimization.

Road Infrastructure Can Pose Additional Risks

Whether it's traffic light posts, street lamps, traffic signs, or other signposts: our roads and roadsides accommodate a wide variety of objects that are essential for ensuring that traffic moves safely, efficiently, and in an orderly manner. At the same time, these objects may also be obstacles that cause accidents or worsen the consequences of an accident. Back in 2017, DEKRA's Road Safety Report already included a crash test that impressively demonstrated the risks that could arise if a falling motorcyclist ended up colliding with the rigid posts of curve marker signs.

Bollards in the middle of bicycle paths are not a good solution.

By replacing the steel structure with a plastic signpost, the risk of injury was significantly reduced without making the board less effective at warning approaching drivers. However, the accident statistics repeatedly show that rigid objects can also be dangerous obstacles when traveling at the comparatively slow speed of a pedestrian or cyclist.

Far too often, the organizations responsible for our roads and paths place too little value on keeping the routes themselves clear. If a traffic light post is positioned in the middle of a sidewalk/bicycle path, this saves the cost of the longer crane boom that would otherwise be needed. Similarly, temporary construction site signs can easily be placed on the sidewalk – ultimately, pedestrians can move around these objects more easily than motor vehicles, and the time and money required for traffic lights or diversions can be saved. However, far too often we simply accept that these actions put users of wheelchairs, rollators, or prams and children riding bikes at risk because they need to move onto the road to pass these objects – usually at points with no dropped curb. These kinds of obstacles are also a real problem for people with a visual impairment.

Today, we frequently see roads being converted to improve the provision of active travel modes. While simple visual markings have often been used to demarcate the infrastructure (such as bicycle paths or footpaths), bollards are now also a popular choice. They ensure that the active travel infrastructure can be clearly identified in all weather conditions and effectively prevent it from being misused for the parking of vehicles or to bypass other objects, thus protecting the users it was defined for. However, posts are also used when a visual barrier is required at crossings and intersections or when cars, for example, need to be prevented from entering bicycle paths and/or footpaths.

Older studies from the Netherlands make clear that collisions with posts and other objects that restrict the roadway play a big role in bicycle accident statistics. For example, the results of studies conducted by the Dutch Ministry of Infrastructure and Environment in collaboration with the Dutch Consumer Safety Institute show that around half of all bicycle

Things can sometimes get very tight for cyclists, for example at crossings.

Child-Friendly Road Infrastructure Design as a Basic Planning Principle

Manfred Wirsch
President, German Road Safety Council (DVR)

In the general administrative regulation on the German Road Traffic Act (VwV-StVO), Vision Zero tasks all participating authorities with designing a safe transport system for all road users. Children are particularly vulnerable road users and are, therefore, particularly reliant on a safe transport system. However, they are not the only ones who benefit from self-explanatory and forgiving infrastructure that removes conflicts as far as possible, in line with the "Design for all" philosophy. The VwV-StVO regulation could become a basic planning principle whereby children's abilities and the issues they face are factored in to infrastructure design by means of road construction and traffic regulation interventions, thereby minimizing the risk of accidents for them.

In the past, work to improve road safety has revolved heavily around road safety education and mobility-related training for parents and children. However, this approach often takes the current state of the road traffic as a given and expects children and parents to change their behavior. This basic assumption overlooks the need to provide accessible, child-friendly infrastructure. In accordance with Vision Zero, children and young people have the right to a safe transport system where they can go from A to B by themselves.

If we put ourselves in a child's shoes and think about how they might interact with the road network, the hazards they face become clear to see. Imagine that a pupil is carrying a large satchel and gym bag. He spots his classmates on the other side of the road, and naturally he wants to join them. However, cars and bicycles are flying past and parked vehicles block the field of view. How can he safely cross the road? When we look at things from a different perspective, it becomes clear why the following aspects are so important for child-friendly road infrastructure:

Children need clearly visible and intuitive crossing points. At traffic lights, for example, the green phases should be selected such that children are able to cross the entire road on foot – ideally with their own signal phases to eliminate any conflicts. Central islands should be combined with pedestrian crossings.

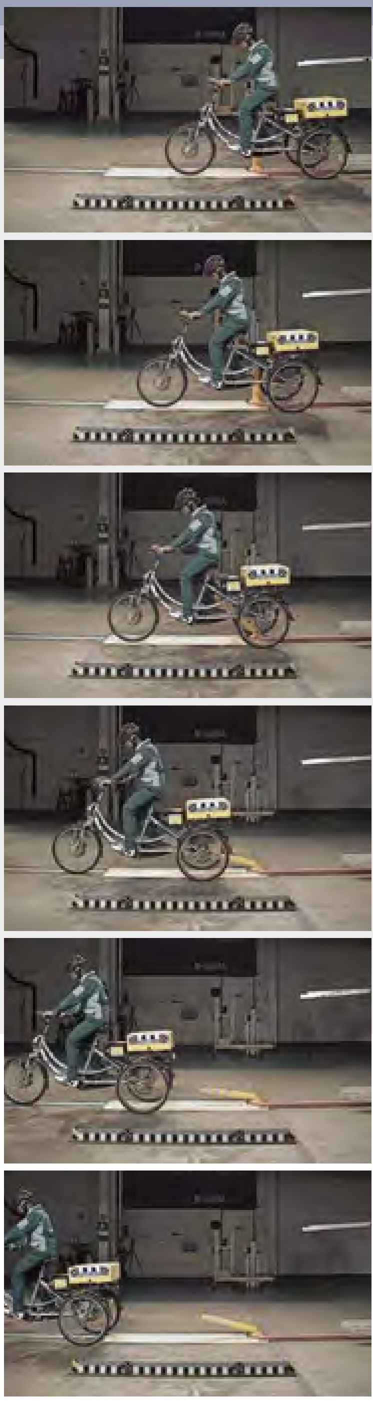
Clear lines of sight on the approach to and at crossings must be ensured, for instance by extending side areas out into the road and through the use of bicycle parking racks or bollards to prevent stopping and parking offenses. The fields of view must be kept clear of parked cars and should be defined depending on the speed limit.

Physically separate routes for pedestrians and cyclists and speed reduction measures are not just required in the immediate vicinity of facilities for children. Construction measures must go hand in hand with traffic monitoring. The road infrastructure should be planned from the outside in.

The DVR resolution "Kinderfreundliche Verkehrsraumgestaltung" (Designing Child-Friendly Road Infrastructure) contains details of these and other recommendations. As part of a major mailing campaign, the resolution was sent to the relevant lawmakers at federal and state level as well as Ministers and it received an overwhelmingly positive response. This gives reason to hope that, in the future, more child-friendly road infrastructure design will not merely be something that results from Vision Zero in administrative law, it will be something that politicians call for.

DEKRA Crash Tests: Cargo Bike Crashing Into a Flexible and Rigid Post

Flexible post



In order to illustrate the risks that rigid bollards pose to cyclists, DEKRA conducted a crash test with a cargo bike. An identical test with the same set-up was also conducted with a flexible plastic post. A two-track e-cargo bike designed as a rear loader/trike was used. A collision speed of 25 km/h was selected, which is the highest level of electrical pedal support permitted in Germany.

In the test with the rigid post, the cargo bike decelerated sharply, which caused the dummy to be propelled off the seat toward the handlebars. The post bent over and acted as a ramp. The rear of the bike was lifted up and the dummy was thrown off. The bike tipped over. In a real-life situation, the rider of the cargo bike could have suffered serious injuries as a result.

In the other test with the flexible post, the bike simply rode over the post and the post then righted itself. The bike did not decelerate to any notable extent and the dummy remained in its seat. The bike remained controllable. A further advantage of flexible bollards is that, in the event of a collision with a motor vehicle, only little damage is caused to both the infrastructure and the vehicle involved. Any motorcyclists that crash into them are also protected.

Rigid post

accidents are caused to some extent by one or more infrastructure-related factors. According to a study published in 2008, posts and similar objects were responsible for twelve percent of these accidents. Given that bicycles are becoming wider and faster, this figure is expected to increase.

As a result, the calls by various cyclists' organizations to stop using bollards entirely seem reasonable at first glance. However, there are also situations where they provide safety benefits if we take a holistic viewpoint. In these cases, it is then crucial that they use appropriate colors so that they are clearly identifiable in all lighting and weather conditions, and that they are of a suitable minimum height. Additionally, the use of flexible bollards should be considered and – where possible – implemented. In the German recommendations for cycling infrastructure ("Empfehlungen für Radverkehrsanlagen", ERA), bollards, barriers, and similar structures are covered in a dedicated sub-chapter, highlighting the fundamental importance of clear space. Installing traffic structures such as barriers, bollards, railings, and the like in the road environment is only justified when the objective in question cannot be achieved by other means and the consequences of failing to install them outweigh the disadvantages in terms of cycling safety. Bollards are not permitted if they could endanger road users or impede traffic – that would quite literally be an obstacle to safe road design.

The Facts at a Glance

- **Despite a fundamentally positive trend, the goal the WHO and EU have set themselves – to halve the number of traffic fatalities in the period 2021 through 2030 – will likely be difficult to achieve.**
- **Rural roads continue to record the most traffic fatalities.**
- **For road building measures, the focus must always be on safety.**
- **On stretches with a high number of accidents, physically separating the carriageways running in each direction and keeping the roadsides clear, as well as adjusting the local speed limit, are often effective safety measures.**
- **The concept of "2+1 roads", which was developed in Sweden at the beginning of the 1990s, has since proven effective in many other countries, as well.**
- **Numerous roads worldwide fall far short of the necessary standards for ensuring the safety of all road users.**
- **A lack of passive protective structures in front of objects such as trees or poles directly at the roadside poses a risk of accidents with a high likelihood of injury for all types of road user.**
- **Traffic light posts, street lamps, traffic signs, or other signposts on the road and at the roadside can also cause life-threatening injuries in the event of a collision. Therefore, when positioning them it must be ensured that they are truly necessary and installed outside of the road area, and that soft structures made of plastic, for example, are used wherever possible.**
- **Bicycle paths and footpaths must be kept clear of obstacles as far as possible. This relates both to permanent obstacles such as poles or posts and temporary objects such as parked vehicles or construction site signs.**

Compelling Examples of Accidents in Detail

No clear overview for either road user

Streetcar Hits Car

Sequence of events:

After dark, a car driver driving in a built-up area approached a railroad crossing and wanted to cross it. Neither closed safety barriers nor a yellow or red light warned of an approaching streetcar, so she continued her journey. As she was crossing the tracks, the car was hit by the streetcar, dragged to the platform, and trapped. The car driver suffered fatal injuries.

1 Sketch of collision position
2 Scene of accident
3 Deformation of streetcar
4 Final position of car
5 Car driver's view to the left – streetcar hidden
6 Streetcar driver's view – signal not recognizable

Parties involved in the accident:

A car, a streetcar

Consequences/injuries:

The car driver was fatally injured; the driver of the streetcar suffered from shock.

Location/lighting conditions/ road conditions:

Built-up area/darkness/dry

Cause/problem:

When the accident was reconstructed, it was discovered that the automatic closing of the railroad crossing as the streetcar approached was not triggered due to a technical defect. The driver of the streetcar was not able to recognize his stop signal, indicating that the barriers were open, until it was far too late because it was lost in the "sea of lights" from the platform behind it and the signal itself was located far too close to the subsequent accident site.

The car driver was not warned of an approaching streetcar, neither by warning lights nor by a closed safety barrier. There was dense vegetation in the approach to the crossing, meaning the car driver was also unable to see the streetcar before she reached the tracks.

Prevention measures, mitigation of consequences/ strategy for road safety measures:

The accident would have been preventable if the technology that triggered the closing of the railroad barriers had worked reliably.

For the car driver, the accident would only have been preventable if she had braked almost to a standstill and slowly entered the railroad crossing gradually.

For the driver of the streetcar, the accident would have been preventable if he had recognized the stop signal and the open barriers in good time or the speed had been reduced significantly without external indicators.

To solve the problem of the streetcar driver not being able to recognize the signal until it was far too late, a pre-signal located sufficiently far away from the railroad crossing would be required. To ensure the clearest possible lines of sight in the crossing area, the vegetation must be cut back at regular intervals.

Unofficial crossing point tempts cyclist to cross the road

Car Hits Bicycle

Sequence of events:

The driver of a car was traveling a little too fast in the left-hand lane of a two-lane federal highway when a cyclist coming from the left wanted to cross the road. To do so, the cyclist used a gap in the central traffic barrier. After briefly stopping in the median, he continued forward and entered the road. Although the car driver responded by slamming on the brakes, he could no longer prevent a collision with the cyclist.

Parties involved in the accident:

A bike, a car

Consequences/injuries:

The cyclist was seriously injured.

Location/lighting conditions/ road conditions:

Non-built-up area/daylight/dry

Cause/problem:

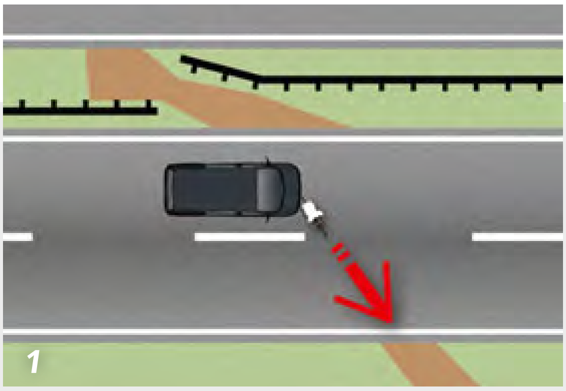
The speed limit at the accident site is 80 km/h and both directions of traffic have two lanes each available to them. There are bicycle paths and footpaths running parallel to the road on both sides. A gap in the central traffic barrier tempts people to dangerously cross the federal highway. On the section of road in question, there is no safe means for cyclists or pedestrians to cross the federal highway.

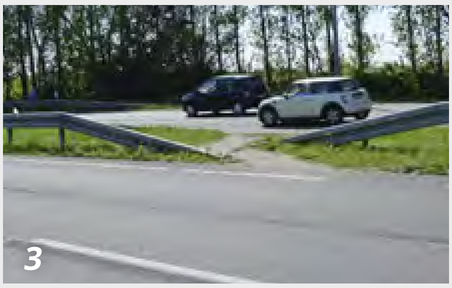
Prevention measures, mitigation of consequences/ strategy for road safety measures:

For the cyclist, the accident would have been preventable if he had let the car drive past.

The car driver would have had the space and time to prevent the accident if he had kept to the speed limit.

The section of road in question is very highly developed over a length of around two kilometers. However, despite the need for one, there is no safe means of crossing the road. As an initial measure, the “unofficial” crossing point has been eliminated but a safe new means of crossing the road has not been provided.





1 Sketch of collision position
2 Scene of accident
3 Unofficial crossing point
4 Damage to car
5 Damage to bicycle
6 Reconstruction of collision position

Unprotected roadside vegetation located directly in line with the course of the road

Car Collides Head-On With Tree

Sequence of events:

A car driver was driving along a rural road in daylight. Shortly before reaching a left-hand bend, she came off the road to the right and collided head-on with a tree that was located virtually in line with the straight section of road prior to the bend.

Parties involved in the accident:

A car

Consequences/injuries:

The car driver was seriously injured.

Location/lighting conditions/ road conditions:

Non-built-up area/daylight/dry

Cause/problem:

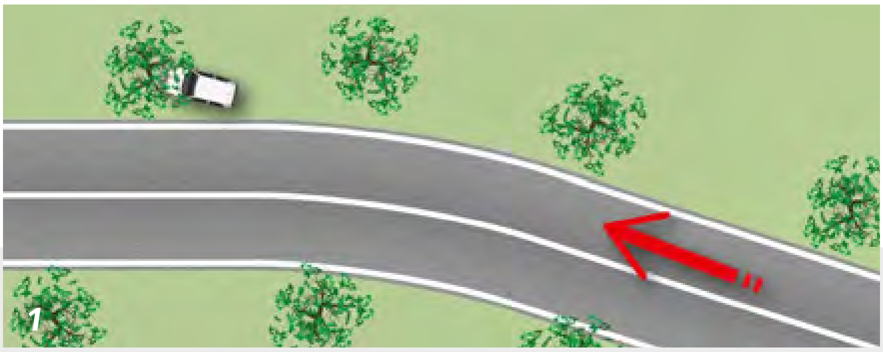
It was not possible to reconstruct the cause of the car coming off the road. In the case of this accident, there were no technical defects on the vehicle or adverse traffic conditions. For reasons that could not be identified, the driver did not respond to the vehicle coming off the road.

The old trees located directly next to the road played a major role in the severity of the crash consequences. The tree located directly ahead poses a particular danger.

Prevention measures, mitigation of consequences/ strategy for road safety measures:

The accident would have been preventable for the driver if she had followed the course of the road.

The severity of the consequences could have been reduced by reducing the local speed limit of 80 km/h. The installation of suitable impact absorbers or traffic barriers in front of the trees, especially in the area of the bend, would have ensured there was forgiving infrastructure.



1 Sketch of collision position
2 Scene of accident
3 Final position of car and damage to tree
4 Damage to car
5 Car interior after crash

Unprotected pole

Motorbike Collides with Concrete Pole

Sequence of events:

A motorcyclist was riding along a road in a non-built-up area in good weather conditions and with good visibility. At the end of a left-hand bend, he lost control of his motorbike and came off the road to the right, grazed a roadside guide post, and then hit a concrete pole.

Parties involved in the accident:

Motorbike

Consequences/injuries:

The motorcyclist was fatally injured.

Location/lighting conditions/ road conditions:

Non-built-up area/daylight/dry

Cause/problem:

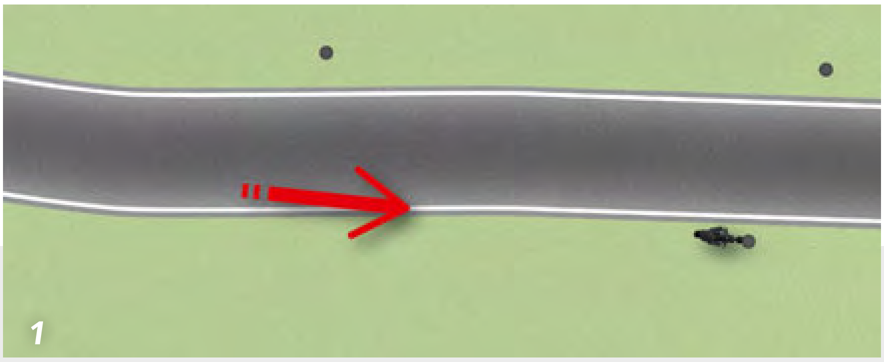
Several technical defects were identified on the motorbike. For example, it had been riding with an impermissible mix of different tires. Taking into account the braking marks found on the road at the crash site, this may have contributed to the accident.

The severity of the consequences was worsened by the unprotected, solid concrete pole located on the bend at the roadside.

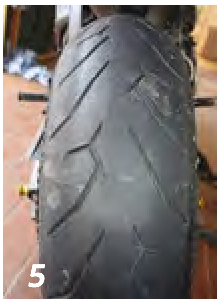
Prevention measures, mitigation of consequences/ strategy for road safety measures:

Vehicles that travel on the road must be in good working order and must not have any prohibited type modifications. It cannot be ruled out that these modifications contributed to the accident.

Forgiving infrastructure at the side of the road, in the form of protective structures such as impact absorbers or traffic barriers in front of the poles, would improve safety for all road users.

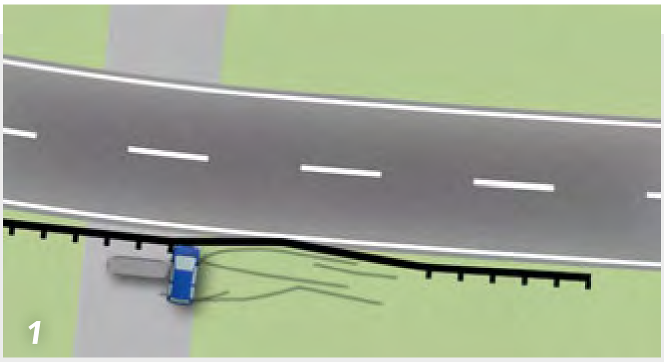


1 Sketch of collision position
2 Scene of accident
3 Damage to motorbike
4 Damage to helmet
5 Rear tire with indications of braking
6+7 Impermissible mix of different tires



Infrastructure provides inadequate protection

Car Hits Bridge Pier





1 Sketch of collision position
2 Scene of accident
3 View in opposite direction of travel
4 Final position
5 Damage to car

Sequence of events:

At the start of a long right-hand bend, a car driver came off the road to the left, crossing the opposite lane until the car reached the adjacent side strip. The right-hand side of the front of the vehicle then collided with the rear of the traffic barrier. This caused the car to spin clockwise and the left-hand side of the vehicle ultimately hit a bridge pier.

Parties involved in the accident:

A car

Consequences/injuries:

The driver was seriously injured.

Location/lighting conditions/ road conditions:

Non-built-up area/daylight/dry

Cause/problem:

It was not possible to reconstruct the cause of the vehicle coming off the road. No technical defects on the vehicle which could have caused it to come off the road were identified. It was not possible to retrospectively determine whether the driver had health problems or was overtired.

The inadequate length of traffic barrier installed on the bend from both directions of travel meant that the bridge pier could be hit as an obstacle. In this case, the traffic barrier even prevented the driver from making a corrective evasive maneuver and, after the car had collided with it, led to the particularly dangerous side impact.

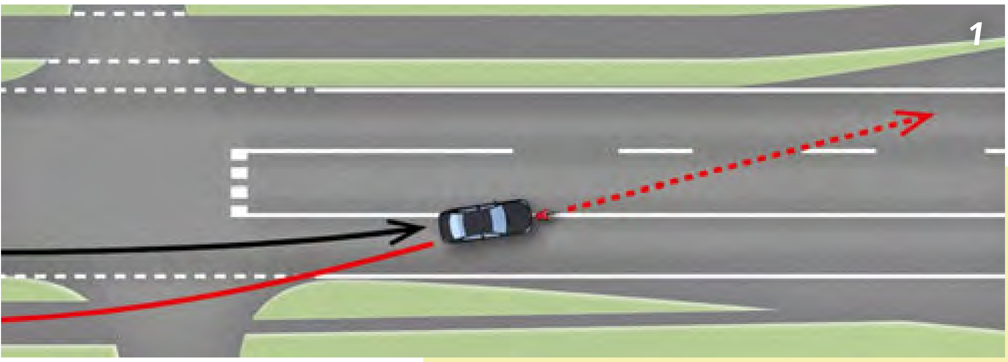
Prevention measures, mitigation of consequences/strategy for road safety measures:

The accident would have been preventable for the car driver if he had followed the course of the road.

The barrier in front of the bridge pier was present. However, it was too short in both directions of travel. The critical sections of the bend with respect to the vehicle coming off the road were inadequately covered, in particular from the opposite direction of travel. Extending the barrier along the entire bend could have prevented the collision with the bridge pier.

Bicycle path ends, facilitating an accident

Car Collides with Pedelec



1 Sketch of collision position
2 Car driver's view
3 Pedelec rider's view
4 Evidence at crash scene
5 Damage to car
6 Comparison

Sequence of events:

After dark, a pedelec rider was riding along a bicycle path running parallel to a road. The bicycle path ends at an intersection, and after the intersection it only continues on the other side of the road. The pedelec rider intended to cross the road diagonally. Despite taking evasive action and initiating emergency braking, a car driver approaching from behind was not able to prevent the collision and hit the pedelec rider.

Parties involved in the accident:

A car, a pedelec

Consequences/injuries:

The pedelec rider was seriously injured.

Location/lighting conditions/ road conditions:

Non-built-up area/darkness/damp

Cause/problem:

The well-built-out bicycle path ends abruptly at an intersection and does not continue on this side of the road. After the intersection, it continues on the other side of the road for both directions. The local speed limit is 100 km/h and not restricted, despite the fact that pedestrians and cyclists often cross the road here and a bus stop is within view.

When he was forced to cross the road, the pedelec rider – who was drunk and not wearing a helmet – did not give right of way to the car.

Prevention measures, mitigation of consequences/strategy for road safety measures:

The car driver had neither the space nor the time to prevent the accident.

For the pedelec rider, the accident would have been preventable if he had watched out for traffic behind him before crossing the road and given right of way to the approaching car. The technical expert was unable to determine the impact of the pedelec rider being drunk. The extent of the head injuries would have been reduced if the pedelec rider had worn a helmet.

The fact that the bicycle path stops at a dangerous intersection without any prior warning, and that riders then immediately need to cross the road, facilitates critical situations. Reducing the local speed limit would help to reduce the risk of accidents at this intersection.

Snapped post becomes a lethal danger

Signpost Pierces Van

Sequence of events:

After dark, a van driver was driving along a freeway with three other occupants when he came off the road at an exit on the right-hand side and ran over a signpost. The post caught on the ground and the vehicle floor, meaning it was able to pierce through the vehicle from underneath, punching through the tank, underbody, and seat bench. The person sitting there was fatally injured. The van ran over another post before it came to a stop in its final position on the grass.

Parties involved in the accident:

A van

Consequences/injuries:

An occupant on the back seat was fatally injured; three other occupants remained unharmed.

Location/lighting conditions/ road conditions:

Freeway/darkness/dry

Cause/problem:

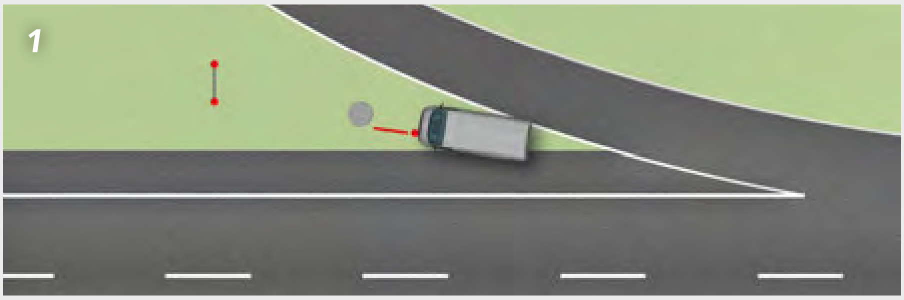
The vehicle came off the road because the driver fell asleep. There were no technical defects on the vehicle. Posts located at the roadside are dangerous obstacles, especially for vulnerable road users.

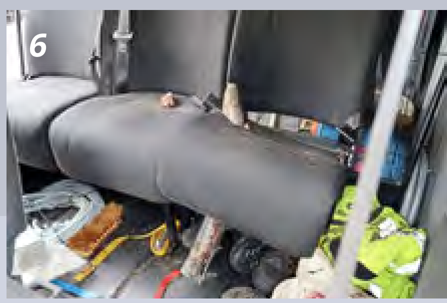
Prevention measures, mitigation of consequences/ strategy for road safety measures

The accident would have been preventable if the driver had taken a break in good time and had not fallen asleep.

The accident may have been preventable with assistance systems such as a lane keeping warning system/assistant or attention assistant.

Forgiving infrastructure reduces the number of posts to the bare minimum required; where possible, steel posts must be replaced with softer structures, e.g., ones made of plastic.

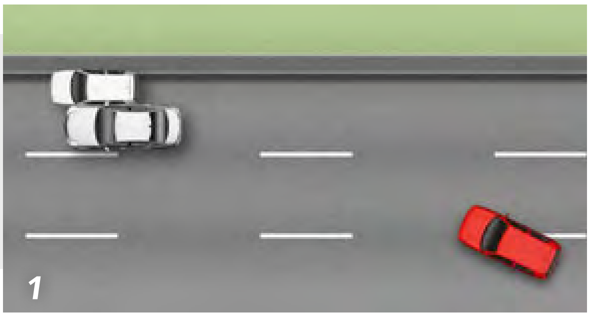


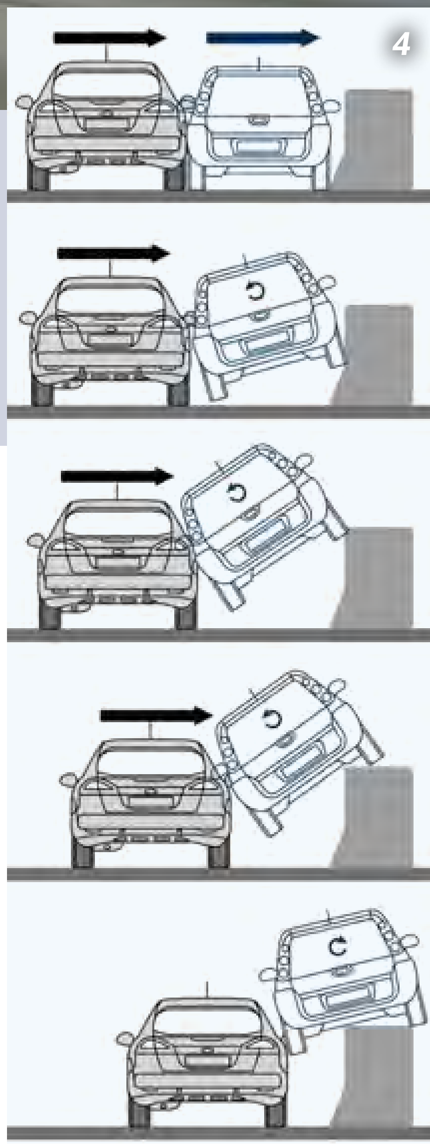


1 Sketch of collision position
2 Scene of accident
3 Final position of van
4 Snapped post and drain foundations
5 Vehicle underbody with post
6 Interior with post

Chain reaction after skidding

Car Is Pushed Over Concrete Barrier





1 Sketch of collision position
2 Scene of accident
3 Damage to car 2
4 Sketch of sequence of events

Sequence of events:

On a freeway bridge, a car began to skid and collided with a second car. As a result, this second car then collided into the side of a third, small car that was driving alongside. This third, small car was pushed against the concrete barrier and was subsequently pushed over it, "supported" by the second car. The small car ended up on its roof under the bridge.

Parties involved in the accident:

Three cars

Consequences/injuries:

The driver of the small car was seriously injured.

Location/lighting conditions/ road conditions:

Freeway/darkness/damp

Cause/problem:

The accident was caused by a combination of excessive speed and a driving error made by the driver of the first car. The shape of the concrete barrier facilitated the small car being pushed up – in that moment, the small car was being "supported" at the side by a larger car.

Prevention measures, mitigation of consequences/ strategy for road safety measures:

The accident was not preventable for the drivers of the second car and small car. For the driver of the first car, the accident would have been preventable if he had kept to the speed limit and paid attention to the traffic on the road.

The small car could have been prevented from falling down off the bridge if the bridge had additionally been protected with a net made of steel cables, for example, or if the concrete barrier had been made taller with a steel railing.

Complex Cognitive Processes

A person's ability to perceive their environment is absolutely crucial for ensuring a high level of safety out on the road. In order to anticipate potential hazards and prevent accidents, we need to be able to register and interpret the relevant information promptly. Aspects such as knowledge and acceptance of and compliance with the applicable traffic regulations also play an important role. Furthermore, the cultural framework and the social environment also influence our driving behavior.

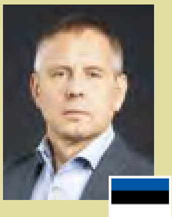
A jungle of road signs, unclear road layouts, dense traffic involving many different types of road user, the condition of the road – there are just some examples of the flood of information that road users are presented with. In order to process it all, the human brain needs to work very efficiently, i.e., decide what is important, prioritize it, prepare actions in response, and ignore anything that is not important. This information can be processed in two different ways: it may be contingent on conscious awareness or take place automatically and intuitively.

These insights can be traced back to the American psychologists Richard M. Shiffrin and Walter Schneider, who investigated how the brain manages to reconcile processing information and controlling our actions from as early as the mid-1970s. According to their research, controlled information processing is considered and conscious and balances different aspects. Tasks such as driving along a narrow, winding mountain pass or searching for your destination in an unfamiliar city require controlled cognitive processes. These are executed slowly and serially and require the road user's concentration and attention.

By contrast, automatic processing (such as driving your car to your work every day) are quick and intuitive, do not require any central processing capacity, and can therefore barely be considered to be "contingent on conscious awareness." They are triggered by the physical characteristics of the signals being processed, such as due to the situation on the road. These stimuli serve to inform us and they directly activate a step-by-step perception analysis. This analysis already starts at the receptors directly in the eye. The information

"Accident Anatomy": Virtual Reality (VR) in Road Safety Courses

Dr. Gunnar Meinhard
Traffic psychologist,
Trafity OÜ (Tartu/Tallinn)



Dr. Birgit Kollbach-Fröhlich
Director,
Medical Psychological Service,
DEKRA Akademie GmbH (Berlin)

For prevention courses to be effective, they need to be designed in an interesting and engaging way. PowerPoint presentations and flipcharts are tried-and-tested methods, but new presentation techniques are now offering a number of advantages. The innovative "Accident Anatomy" project uses VR modules as part of the tried-and-tested Estonian road safety program "Selge Pilt...!?", which means "Clear view...!?."

The VR goggles depict a real car accident in Estonia in which three of seven young adults died. The sequence of events in the accident is shown to scale and accurate to the second using a see-through car and dummies. The accident situation is currently presented in seven modules, with experts providing detailed descriptions of factors including the driving physics, group dynamic, and physical injuries. The driver of the crashed car, played by an actor, also talks about his feelings. These elements all form part of the VR presentation called "Accident Anatomy". The trailer is available on YouTube.

The death or survival of these seven young people was decided in the space of eight seconds over a length of two soccer fields. Thanks to the VR goggles, the course participants are directly involved in what is happening and can experience the "anatomy" of the accident. The use of VR to present the accident adds a technical element and "objectivity" that enables the participants to watch the scenes with interest and take in what the experts are saying.

"Clear view...!?" is a short, one-day prevention course that a doctoral thesis by Meinhard (2019) has proven to be effective (without the use of VR modules). "Accident Anatomy" complements the standard presentations that traffic psychologists have held to date.

Around 50,000 people have taken part in "Clear view...!?" since 2007. As a primary prevention measure, these were young people in vocational schools and secondary schools as well as drivers working for companies such as Danone or Eesti Post, the national postal service. However, drivers with a propensity to commit offenses under alcohol and criminal law also took part as a secondary and tertiary prevention measure. In all groups, the results showed that the participants significantly underestimate standard traffic hazards. Car drivers do not know the impact that two beers have on their blood alcohol concentration level, or how long it takes for it to go down again. Additionally, the participants' estimates of the impact speed when a vehicle crashes after slamming on the brakes are far too low.

Before the in-person session starts, all participants complete a questionnaire about traffic risks. The level of risk associated with each participant is thus empirically assessed using mathematical models and personal feedback is provided, which has so far been in written form. New, interactive VR elements can be included in many different ways here: the VR bar, where you can drink two beers or three glasses of wine, for example, and receive information about how your personal blood alcohol concentration level goes up and down; experiencing "tunnel vision" with a BAC level of 0.11 compared to being sober; experiencing the impact speed when traveling at "just" 20 km/h faster than permitted, or meeting the avatar who delivers the results of the questionnaire.

By immersing them in what is happening, virtual reality enables participants to "get up close to the risks" in a way that cannot be done with current methods such as explanations on a flipchart or films. However, unlike the claims made by VR advertising, this immersion is not a result of the technology but rather something that the mental system does. Virtual reality is, therefore, a means of delving into what happened and experiencing a feeling of immersion. A question for researchers remains whether presenting content in virtual reality causes the participants to change their attitude and, ultimately, behavior more (in terms of improving road safety) than presenting content using standard learning methods.

travels from there through different interim stages before reaching the higher-level centers of the brain.

Traffic-Related Schemes and Scripts

This automatic information processing predominantly involves schemes or scripts. Schemes enable road users to understand what is happening on the road without having to think about it too much, by assigning a meaning to the information they take in. In other words, schemes are neurophysiological "driver assistants" which make available the knowledge that the individual has stored in their memory as "internal images". This knowledge relates to their own capabilities, how the vehicle works and performs, and how certain traffic situations unfold. The schemes

Drivers never process traffic situations based solely on rational criteria

include not only objective "transfer pictures" of the environment, but also subjective experiences and personal judgments.

In turn, scripts are schemes with "stage directions like in a movie script" regarding sequences of events based on the "If…then…" concept. For example, the script for "driving on the freeway" contains a conceptual structure concerning stereotypical sequences of actions, such as driving at relatively high speed in the same direction, like other vehicles are doing. It also contains information about what the driver should and should not expect – such as no pedestrians who are crossing the road and no vehicles coming in the other direction.

Traffic-related schemes and scripts are based on experiences. This means they can change and also include an assessment of the safety of certain traffic situations, which was conducted as part of these experiences. They can be supplemented by motives, attitudes, dispositions in evaluation, and our cultural dispositions that we acquire as we socialize as part of society. A crucial factor in forming uniform behavior patterns is something known as "operant conditioning": if a certain behavior is followed by positive consequences, this increases the likelihood of the person behaving in this way again. If driving far above the speed limit results in a significant subjective time saving or gives the driver a feeling of self-competence, superiority, and freedom, these feelings of success will have a strong reinforcing effect, which is then applied to the "characteristics" of a scheme.

Schemes also control how road users orient themselves up close and far away and how they register information from the environment. When a person visually searches for information relating to their environment, for instance traffic on the road, they do this by visual fixations, i.e., looking specifically at certain objects in the environment. Things that stand out due to their color, that flash or light up, appear suddenly, move, are large, or are differentiated by a key characteristic are particularly relevant. These types of objects or events immediately "catch our eye" and draw our attention.

Easily Recognizable Infrastructure

Drivers never process traffic situations based solely on rational criteria as they may process

A complex jungle of signs, as can be seen here, makes it more difficult for all road users to figure out what is happening on the road and ensure nobody is in danger.

the information incorrectly. This could be due to objective deficiencies such as reduced visibility, caused by things like vehicles and buildings or the weather. It could also be due to individual factors that prevent the person using information to carry out a necessary or logical action. Examples include instances where the driver does not do something because they are tired and, therefore, not paying attention, or because they have misjudged the distance or speed.

This then leads to the question of how the physical design of the road environment can optimize the process of how people register information such that easily recognizable "key stimuli" activate the "correct" schemes. Legislators are working to make our travel on our roads that bit safer by creating clearly understandable and easily recognizable infrastructure, by providing training and road safety education measures, and through the use of instructions and prohibitions along with the associated monitoring and sanctions. This systematic understanding of travel on our roads can trace its roots back almost 100 years to Julian H. Harvey, who proposed the concept of the three "E"s all the way back in 1923: Education (= educational and communication measures, training), Enforcement (= legal framework, controls and monitoring), and Engineering (= technical and design/planning measures for creating road infrastructure). A further aspect with the generic name "Environmental Factors" could be added to this concept. This includes social influences that determine the environment that a vehicle driver finds themselves in, such as the atmosphere on the road, cultural influences that affect our driving behavior, but also risk phenomena such as racing or posing in your car.

Use of Innovative Technologies and Methods In Driver Training

When it comes to Education, feedback-based learning processes are increasingly being used, especially for novice drivers. The term "feedback" originally comes from the field of cybernetics and means a comparison of actual and target values. Feedback is used to compare the actions that were taken with objectives and, if necessary, replace them with other actions that are more purposeful, such as improving how the driver handles the vehicle. A study looked at the driving behavior of young male novice drivers in Israel during their first year of driving (entailing three months of supervised driving and nine months of driving

Mobile People Will Adapt, But They Won't Change

Prof. Kurt Bodewig
President, German Road Safety Volunteer Organization (DVW)

A person's individual behavior (or mistakes) is/are the biggest factor that affects road safety. However, high demands are placed on mobile people as they aim to act appropriately in each situation. A person's physical and mental fitness, knowledge of the rules, and ability to control the vehicle are as important as more abstract concepts like caution, consideration, attention, or rationality. People need these skills to find their way around on the road and safely handle complex situations. The general framework also plays a role. Dense traffic, new vehicles, special rules, or unclear infrastructure represent challenges that we repeatedly face and that require us to adapt. However, at our core, we stay within the limits of what we can do. That is why the approach to accident prevention also has not fundamentally changed.

The German Road Safety Volunteer Organization (Deutsche Verkehrswacht) was founded exactly 100 years ago as a means to champion road safety in Germany. The idea was to engage with people directly and give them what they needed to travel safely from A to B. First and foremost, that was a safe road environment. As early as 1929, the Road Safety Volunteer Organization called for more bicycle paths, for example, to reduce conflicts with the increasing number of cars on the road. Clear guidelines were also required, and they had to be known and understood by everyone. For this reason, providing information about the rules of the road was one of the first measures for targeting individual road users.

With respect to people's behavior, it was not only the potential for preventing accidents that became clear, but also the need to do so. A closer look at the causes of accidents revealed that people bear a lot of responsibility and were being faced with new challenges, some of which were overwhelming.

The work performed by the Road Safety Volunteer Organization developed based on these requirements. To this day, it starts at an early stage with targeted road safety education. We provide information about correct conduct to all age groups, advise on how to safely travel on the road, and offer training courses at regular intervals. Another important factor is raising people's awareness of where their own limits lie, be it reduced fitness levels as people become older, alcohol and how it restricts people's fitness to drive, or strong emotions and how they can impair our concentration and awareness of hazards.

The range of topics we cover and provide measures for has become more and more varied. However, the material facts and the approaches we take have barely changed for many decades, even if road traffic seems to be changing more quickly and intensely nowadays. An increasing volume of traffic, new technologies, and unclear rules were already topics that we had to address in the 1950s, 70s, and 90s. Helping people with the aid of preventative measures is important, and it needs to adapt to new methods of teaching and imparting information. However, it is ultimately (still) always about mobile people. Despite making adjustments, they will remain one thing above all: human.

Driving school teaches learner drivers how to behave safely when behind the wheel of a motor vehicle.

by themselves). It investigated the effects that different forms of feedback had on the drivers' behavior as they moved from supervised driving to driving by themselves. Their driving behavior was evaluated based on data collected using In-Vehicle Data Recorders (IVDR). These types of recorders are also very good at recording events that involved inappropriate driving maneuvers with respect to braking, accelerating, turning, or speeding.

The IVDR systems were installed in the vehicles of the 217 participating families of the test subjects – young drivers aged 17 to 22 – and the families were randomly assigned to one of four groups: (1) Family feedback: all family members received feedback about their own driving behavior and that of the other family members. (2) Parental training: in addition to the family feedback, the parents received personal instruction on how to pay more attention to how their children were driving. (3) Individual feedback: the family members only received feedback about their own driving behavior, not about that of the other family members. (4) Control group: this group received no feedback.

The feedback was provided retrospectively on an in-vehicle display after the test subjects had finished driving. The parents in the "Parental training" group attended a 90-minute "attentiveness training course" which aimed to help them vigilantly monitor how their children were driving and effectively react to their child's driving style. The results show that IVDR feedback plus parental training is the only combination that reduces the event rate among the young drivers. This backs up the repeatedly proven theory that parents are effective and important role models who play a key role in how young drivers acquire their driving skills.

DEKRA Study on Driving Theory Knowledge

However, what actually happens to a person's driving theory knowledge after a certain period? Do they forget their acquired knowledge over time? Do women perform better than men in a retest? A voluntary study of driving license holders, conducted at the end of November and start of December 2023, looked at these and similar questions. A total of 41 people sat a "real" driving theory test under the test conditions that currently apply in Germany. The participants used a tablet PC to answer 30 randomly selected questions from a list of over 1,000 multiple choice questions – including 20 basic knowledge questions and ten class-specific questions, in line with the current rules for obtaining a class B license (cars). The basic knowledge questions covered topics that are relevant for all driving license classes, whereas the class-specific questions only covered topics that are relevant for the driving license class concerned.

Most of the 41 participants were male (33 people; around 80 percent) and around half (21 people) of all participants were younger than 30 years old. Just under 80 percent stated their education level to be the German university entrance diploma or a completed university degree; the remaining participants had a lower or intermediate secondary school certificate. All the participants who stated where they obtained their driving license obtained it in Germany. The analysis revealed that only 3 of the 41 participants would have passed the theory test. The participants had around 32 error points on average, but a maximum of ten are allowed, otherwise the participant fails the test (**Figure 10).**

Participants who had completed the university entrance diploma or a university degree had a good two error points less on average, attributable to a slightly lower number of errors in the basic knowledge section. Among those surveyed, people who had held their driving license for 20 to 30 years and 30 to 40 years had the lowest average error score (19 and 16.7 total error points respectively). All other groups had more than 30 error points on average. People who only had a driving license for cars tended to score worse than people who were also allowed to drive other types of vehicle, and this applied to both basic knowledge questions and class-specific questions. This is reflected in the total error scores, as people who had only one class of driving license had around 37 error points on average, whereas people who had multiple driving license classes had an average of around 29 error points. A presumed difference in the average error score per gender could not be confirmed. Furthermore, splitting the participants according to how often they used their cars also did not reveal any notable differences in terms of their scores in the driving theory test.

Fundamentally, the high error scores and the low number of participants who received a positive test score should not be over-interpreted, and under no circumstances should it be misconstrued as indicating a safety deficit in the traffic system. Drivers' exact knowledge of the rules of the road is only one of several aspects that determines safe behavior out on the road. Systematic road safety education from childhood right through to old age, taking part in road traffic in different roles – e.g., as a pedestrian, cyclist, or front passenger in a motor vehicle –, and comprehensive training at driving school provide a solid foundation, both now and in the future, for people to intuitively drive safely and avoid acting in a way that endangers traffic.

It has also long been recognized that driving training should encompass more than just learning about vehicle handling and traffic regulations; driving training must be a time for imparting higher-level skills, such as a regard for safety, self-control, self-monitoring, and the acceptance of traffic rules. Simply knowing about a traffic rule does not, by itself, determine whether or not drivers follow that rule – there are other factors at play. Examples include the fear of negative sanctions, the likelihood that offenses will be detected, and the circumstances (road design, traffic density, being in a rush, etc.) under which the rule is to be applied.

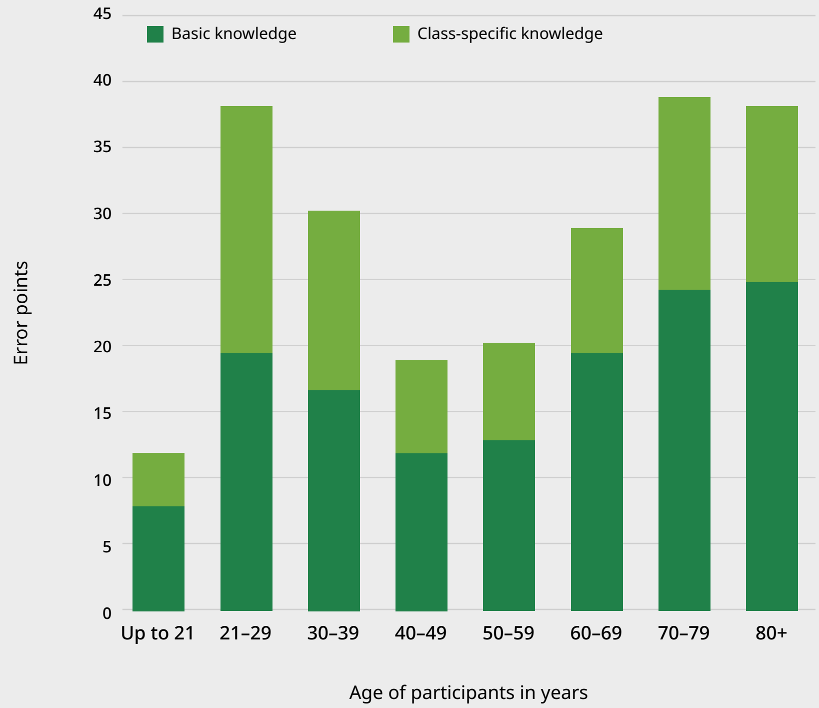
Monitoring Provides Incentives

Another innovative approach for improving safe driving among novice drivers is to combine monitoring systems with incentives. The use of in-vehicle telematics enables safety-specific information regarding the driver's driving behavior to be recorded. This information can then be used as feedback in order to promote safe driving. To provide the incentive, the information collated about the driver's driving behavior (specifically: instances of speeding, heavy acceleration, and heavy braking, plus a combined measure of risky driving that

10

Study on Driving Theory Knowledge: Average Number of Error Points by Age

The best results (comparatively) were achieved by people aged up to 21 years (average of around 12 error points), followed by those aged 40 to 49 years (average of 19 error points) and 50 to 59 years (average of around 20 error points). The worst results were recorded by those aged 21 to 29, those aged 70 to 79, and those aged 80 and over – each of these groups had around 38 error points on average.



Source: DEKRA

Evaluation of Confrontational Stylistic Devices in Road Safety Campaigns

Prof. Maria-Theresia Brauer
Professor of Psychology, University of Applied Police Sciences of the State of Saxony

All across the globe, many different stylistic devices are used in road safety advertising in order to reduce annual accident figures. A popular strategy is the fear appeal, in some cases with harsh, shocking depictions of the terrifying consequences should the driver not follow the rules of the road. It is based on the principle that a feeling of fear is induced in drivers, encouraging them to rethink how they assess risks and change how they travel and drive in order to increase safety. The underlying assumption – that fear induced by showing someone a hazard promotes safe driving – has not been clearly proven by research. Although many meta-analyses have shown a significant positive relationship between a threat and fear, this alone does not cause the message to be accepted.

An evaluation looked at the road safety campaign "Runter vom Gas!" (Take your foot off the gas!) by way of example and investigated whether an open threat that stated the consequences of speeding offenses caused drivers to change their behavior. It also compared the effects with an approach where drivers were targeted with a positive emotional message. The drivers in the intervention group drove along several stretches of road in different weather, visibility, and traffic conditions after they had passed a series of signs (I-IV) from the "Take your foot off the gas!" campaign (strategy to induce fear) and had seen other measures (commercials, online articles). The second research group drove past signs from the "Slow Down and Enjoy the Ride" speed campaign (positive emotional strategy) that was successful in the Australian state of Victoria, and then saw a corresponding, synchronized road safety commercial. A realistic setting was ensured by the use of a state-of-the-art stationary driving simulator, which was equipped with an electromechanical motion system with six degrees of freedom and transmitted the horizontal angle of vision of 210 degrees onto a spherical screen. The results were as follows:

- The "Take your foot off the gas!" campaign established a sense of social responsibility toward other road users.
- Building on this, there was a significant reduction in the average driving speeds in poor weather and visibility. Men, people with a high desire for sensation seeking, and people who adopted a defensive strategy to overcome fear recorded lower reduction figures. When the weather and visibility were consistently good and in hazardous situations, the drivers' speed remained stable with the "Take your foot off the gas!" campaign.
- Across all recipient groups, the reduction figures recorded in hazardous situations at higher speeds (v85) were approx. 50 percent lower than at moderate speeds (vm).
- The "Take your foot off the gas!" campaign did not sufficiently strengthen the drivers' personal expectations of risk as they were often subject to the third-person effect. They denied accident risks that were presented to them or projected them onto other drivers. Boomerang effects decreased as the level of fear reduced.
- The drivers' ability to control their speed was increased more effectively with "Slow Down and Enjoy the Ride": initiators illustrate safe driving under different difficulty factors.
- There was a high level of knowledge about what the "Take your foot off the gas!" campaign was about.
- With the aid of eye tracking technology, it was determined that a higher level of attention was paid to threat stimuli than to factual, positive emotional messages and weak fear appeals. The highest amount of visual attention was paid to salient, high-contrast, and centered messages.

The results are consistent with current meta-analytical findings on the effectiveness of road safety campaigns. The optimistic view that education measures for a target group (e.g., concerning road safety) are expected to be a resounding success, is not justified. Road safety campaigns are just a small part of a larger whole where different road safety measures all act simultaneously, so their impact should always be considered within the context of this larger structure. The effect should only be considered in conjunction with other road safety education programs, accompanied by vehicle-related, infrastructure-related, regulatory, and incentive-based safety strategies. When taken together, this can help to reduce the annual figures for severe or fatal traffic accidents.

was calculated based on these inputs) is combined with financial incentives if they change their driving behavior. An Australian field study led by the Transport, Health and Urban Design Research Lab, University of Melbourne, Melbourne, Australia monitored 175 participants aged between 17 and 35 over a period of 28 weeks.

The participants were randomly assigned to one of three groups: only driver feedback (1), driver feedback + incentives (2), and control group (3) without any feedback or financial incentives. The feedback was obtained from a weekly summary of the participants' own driving behavior, sent by SMS, plus access to more detailed daily feedback via an online dashboard or smartphone app. The participants' driving behavior was evaluated using "DriveScore" – a combined measure of risky driving based on instances of speeding, heavy acceleration, heavy braking, and the time of day that the journey took place. The driving behavior categories were color-coded for easy reference (green = safe, low-risk driving through to red = high-risk driving). The "feedback + incentives" group not only received feedback, they also started with an initial monthly account balance of 200 US dollars, which was reduced whenever they drove in a risky way that exceeded a certain threshold. This was, therefore, a "negative" incentive (a "fine"). The results show that the "DriveScore" reported significantly better figures for test group 2 (feedback + incentives) than the control group.

Campaigns Educate, Inform, and Influence Behavior

A historical example of how PR strategies and media campaigns can educate, inform, and influence people's behavior is the German advertising campaigns from the 1970s encouraging people to fasten their seat belts. The introduction of the seat belt requirement was highly controversial at the time, and this was reflected in how long the debate ran for. As early as 1974, all newly registered cars had to have three-point seat belts fitted on the front seats. In January 1976 it became mandatory for occupants to fasten their seat belt during their journey – but initially there were no sanctions if they did not. It was not until years later, in August 1984, that a fine was introduced if the occupants of the front seats did not fasten their seat belts. In July 1986, a fine was ultimately also introduced if passengers on the rear seats did not fasten their seat belts.

When the mandatory use of seat belts was introduced, advertising and education campaigns were also run to appeal to people to fasten their seat belts. A well-known example of this in Germany was the advertising slogan "Klick – Erst gurten, dann starten" (Click – belt up first, then start the engine) from 1974, which was part of an initiative by the German Road Safety Council and German Federal Ministry of Transport. These campaigns were largely ineffective as the increase in the use of seat belts was only three percent on journeys in built-up areas between January 1974 and August 1975. Even making the use of seat belts mandatory but not applying any sanctions only proved moderately effective. In November 1975, 42 percent of people fastened their seat belts. After making it mandatory to do so – but without any consequences if they did not – this figure initially rose to 62 percent in January 1976, but by March it had already fallen back to 55 percent, and in October it was 49 percent. It was not until sanctions were introduced that the rates of people fastening their seat belts went far above 90 percent.

Different kinds of education and information campaigns, such as this seat belt campaign in Germany from the 1970s, always aim to improve road safety and reduce accident figures – but they have different levels of success.

Fear Appeals Only Have a Limited Effect

A meta-analysis from 2011, which examined 119 effects from 67 studies, underlined that road safety campaigns are fundamentally an effective means of reducing traffic accidents. The analysis shows that, on average, road safety campaigns result in nine percent fewer accidents. If we look at specific effective campaign features, the analyses indicate that two particularly impactful methods were personal communication as well as communicating the campaign's messages using media positioned at the roadside. These establish a close link to the behavior that the campaign is aiming to bring about at the relevant location and time. One example of this from Germany is a campaign started by the German Road Safety Volunteer Organization in the state of Mecklenburg-Vorpommern ("Landesverkehrswacht") in 2019, focusing on collisions with wildlife or trees on rural roads. The sister organization in the state of Lower Saxony had already run a pilot project highlighting the risk of collisions with trees from June 2015 to 2018. Its measures included the billboard campaign "Bäume springen nicht zur Seite" (Trees won't jump out of the way), as well as dialog-based displays located at the roadside showing a tree with a happy or sad face to immediately notify car drivers if they were driving too fast. But let us return to the aforementioned meta-analysis: a larger drop in accident figures was also associated with campaigns that focused on drink-driving. The analyses also showed that enforcement measures alongside the campaign, as well as a short campaign duration of less than a month, proved advantageous.

In this context, fear appeals are only effective under certain conditions. They must describe a threat that is personally relevant to the driver and, at the same time, must include a recommendation on how to reduce or prevent the risk of it occurring. The recommended action must be practicable, perceived as being effective, and reinforce the target group's belief that they are also able to behave in the safe manner described. A number of research results also indicate that such appeals are seemingly least effective on those who most urgently need to change their behavior, such as young men.

A person's gender can influence how effective different emotional appeals are. There are indications that men find positive emotional appeals more convincing than fear appeals, and vice versa for women. These findings underline the need to tailor the content and message of a campaign to the specific motivations and needs of the target groups and any identified sub-groups. PR strategies and media campaigns should be accompanied by other measures such as road safety education programs and legal regulations, possibly involving tighter sanctions, and the desired behavior that they are trying to bring about should be monitored at regular intervals.

Prominent speed cameras located at the roadside are an important way of helping to ensure drivers comply with the speed limit.

Monitoring Compliance with Traffic Rules

Compliance with traffic rules is and remains essential for ensuring road safety. Of particular importance in this regard are the actual observable and measurable compliance with rules from an outside perspective, as well as drivers' acceptance of the rules as a kind of positive, affirmative attitude toward applicable traffic rules together with the intention of following them. Acceptance of rules indicates a person's inner perspective and is, therefore, an important predictor of compliance with rules. Ultimately, drivers run the risk of punishments if they do not follow the rules. Fines seem to be perceived as onerous once they reach a value of 50 euros. If the fine is 150 euros, only one percent of respondents in a study stated that they would be unaffected by it. Sanctions that take the form of restrictions on a person's behavior, such as a one-month driving ban or revoking their driving license, are perceived to be particularly harsh. As a result, we can draw up a ranking of how various levels of punishment are perceived based on the type of sanction involved – fines, points added to a license, driving bans, revoking a driving license. If we look at how net household income affects how harsh people perceive the punishment to be, it can be concluded from the cross-sectional survey that fines are perceived as harsher if the household has a low income, whereas driving bans and the revocation of a driving license are considered to have an equally harsh effect in all income categories, regardless of income.

The severity of punishment and the likelihood of offenses being detected are key aspects of criminological deterrence theory. Here, a person's subjective expectations of whether offenses will be detected vary greatly depending on the context. For example, data from surveys conducted on drink driving show people's views differ greatly depending on what time of day it concerns – the people surveyed tend to assume that the police would be more likely to detect drink driving offenses in the evening and at night rather than during the day. In turn, people's views on the likelihood that instances of speeding will be detected vary depending on what traffic environment it concerns – people assume that speeding is most likely to be detected when driving in urban areas, and least likely to be detected on rural roads. 37 percent of those surveyed expect that speeding is likely or very likely to be detected in cities, compared with just 16 percent for rural roads, despite the fact that excessive speed on rural roads plays a major role in the causes of accidents.

People's Appreciation of Traffic Rules Has Declined

Legislators are hoping that harsher punishments will reduce the number of such offenses in future, and lower the number of accidents attributable to traffic-specific driver error. A comprehensive meta-analysis of these effects was published by Norwegian researcher Rune Elvik in 2016. The author investigated the impact of higher fines on future traffic offenses and accident statistics. The results showed that, with respect to the number of offenses,

- an increase of less than 50 percent of the original fine had no effect whatsoever,
- an increase of between 50 and 100 percent of the original fine led to a 15-percent reduction in offenses, and
- an increase of more than 100 percent increased offenses by four percent.

Particularly harsh punishments are obviously considered to be unjust and unfair. They can, in turn, lead to acts of defiance and rejection – which manifests itself in allegations

Organizing Road Traffic in a Way That Protects All Types of Road User

José Miguel Trigoso
President, Portuguese Association for Road Accident Prevention (PRP)

The task of driving comprises four steps: a) observing the road environment (which includes the infrastructure, the way in which the traffic is organized, and the behavior of other road users); b) reviewing the observations made and predicting what will happen; c) deciding what to do based on the review; and d) implementing the decision that was made.

A traffic accident is the consequence of a road user's inability to meet the demands of the road environment at a certain point in time and in a certain location. This illustrates very clearly the crucial relationship between a person's attitudes and behavior and the road environment that exists at a certain point in time and in a certain location.

If we are to succeed in reducing the number and severity of accidents, we need to tackle these points in order to not only reduce the difficulties presented by the road environment, but also improve road users' abilities to respond appropriately.

To reduce the difficulties presented by the road environment, it is essential to provide infrastructure that is suitable for the type of road user it is intended to serve, encourages people to behave in the correct way (in particular, to keep to a suitable speed), and is forgiving of mistakes. We must also ensure that the road traffic is organized in a way that protects all types of road user. The priority should be on more vulnerable road users, with the highest priority assigned to pedestrians.

In terms of road users, we need to foster an attitude of road users being responsible citizens as soon as children start pre-school education, and we need to train and evaluate drivers based on the methods that have delivered the best results internationally. In doing so, we can ensure that drivers of all types of vehicles are best equipped to effectively carry out the four steps that make up the task of driving. To achieve this, drivers must keep to speeds that are appropriate for each situation and eliminate the influence of alcohol and drugs (incl. some medication), distraction (which is mainly caused by smartphones nowadays), and exhaustion (in particular due to fatigue or too much sleep).

This illustrates very clearly the crucial relationship between a person's attitudes and behavior and the road environment that exists at a certain point in time and in a certain location.

Running a red light often ends in an accident.

that cities and municipalities are “cashing in.” Incidentally, in the Elvik study, harsher punishments were associated with an average reduction in accidents of between five and ten percent; the number of fatal accidents reduced by up to twelve percent. We know from multiple studies that rules designed to reduce the driving speed have a positive impact on accident statistics as drivers had more time to react to a sudden event. Moreover, the accidents are less serious. Reducing the actual average speed of all vehicles by five percent reduces the number of traffic fatalities by 17 percent, as shown by a review from 2004. A re-run of the analysis in 2013 even reported a reduction of 20 percent. The more severe the accidents, the greater the impact of lower speeds on the accident statistics. Vice versa, higher average speeds lead to more accidents, in particular ones with fatal and serious consequences.

People’s appreciation of traffic rules has declined in recent decades. This can be seen in lower compliance with rules at stop signs and traffic lights, based on people reporting on their own behavior in surveys. Male and younger drivers in particular consider rules to be a restriction on a person’s freedom and, therefore, sometimes believe them to be an “unjustifiable imposition.” As a result, there are gender- and age-specific differences in people’s attitudes toward traffic rules. On average, female and older drivers show higher acceptance of and a more positive attitude toward compliance with the rules of the road. Older road users are more likely to follow the traffic rules and are better able to control their own behavior, whereas younger drivers are more susceptible to certain situations or circumstances, such as being in a rush, or are more easily tempted by scenarios that open the door to a certain response, such as when a traffic light changes from amber to red. Younger drivers are more likely to speed and run a red light. The situation regarding drink driving is less clear. People’s subjective expectations of a sanction being imposed can be increased if the relevant authorities actually follow up promptly, if monitoring measures are used on stretches of road, such as “section control”, or if liability is expanded to include vehicle owners.

Impact of Amended Sanctions

Amending sanctions in order to improve road safety usually only goes one way: the rules are made harsher. The hope is that future offenders will be deterred from actually committing an offense. Amending sanctions the other way, i.e., making them more lenient in the case of offenses, only happens rarely. However, the reunification of Germany provided an opportunity to investigate this phenomenon in more detail, based on the permissible drink driving limit values that applied at the time. As part of the reunification, on January 1, 1993 the permissible limit value for blood alcohol concentration (BAC) was raised from 0 to 0.08 in the former East Germany. Prior to this, driving with a BAC of up to 0.08 was treated as an administrative offense there. As a result, East Germany saw a major change to the legal regulations for drink driving, whereas they remained unchanged in West Germany over the same period.

In order to investigate the impact of a higher permissible BAC level, surveys were conducted on three separate occasions following breath tests by the police out on the road. The project was led by Mark Vollrath, a Braunschweig-based traffic psychologist. The first data collection took place at the end of 1992, i.e., immediately before the change. The second data collection from April to June 1993 aimed to identify the short-term impact, while the third phase from April to June 1994 looked at the longer-term effects. To conduct the study, approaching cars were randomly selected and stopped at multiple control points in Lower Franconia and Thuringia (n = 21,198).

The results of the study show that Thuringia, which is located in the former East Germany, saw a reduction in the frequency of drink driving between 1992 and 1994. In Thuringia, 9.5 percent of drivers stopped in 1992 were under the influence of alcohol, whereas in 1994 this figure was 8.1 percent. Therefore, the higher permissible BAC level did not increase the frequency of drink driving on the former territory of East Germany.

However, if we look at the quantity of alcohol consumed, the study showed a change in the BAC values recorded in the people tested in Thuringia, in particular young drivers: there was a shift from lower (less than 0.03) to higher (up to below 0.08) BAC values. The proportion of cases of drink drivers with a low BAC reading (up to 0.03) fell from 66.3 percent of all cases of drink driving in 1992 to 55.1 percent in 1994. At the same time, cases with a BAC reading of 0.03 to 0.08 increased from 23.2 percent to 32.8 percent. In the neighboring region of Lower Franconia, which is located in the former West Germany, the corresponding figures remained constant or even fell slightly.

Based on the results for BAC readings of over 0.08, it can be concluded that most of the people tested complied with the legal limit values. For this BAC range, no difference was identified between the former East and West Germany. The changes were therefore restricted to BAC readings of less than 0.08. Young drivers in Thuringia were an exception – overall they drove under the influence of alcohol much more often than young drivers in Lower Franconia, and they also more frequently drove under the influence of alcohol with a BAC reading of 0.08 or higher. Overall, drink-driving was viewed more negatively in Thuringia than in Lower Franconia. This could still be observed one year after the permissible limit value had changed. However, attitudes had started to move closer to those of West Germany. In West Germany there were also indications that the BAC readings of drink drivers were lower and that drink-driving was being viewed more negatively.

Stricter BAC Limit Values Reduce the Number of Traffic Fatalities

Further findings on the effects of (amended) sanctions can be obtained if we look at the international picture. In a comparison of 19 European countries where people reported on their own drink driving behavior, more than 12,000 people surveyed confirmed a positive effect of lowering the legal alcohol limit. In countries where the legal limit is 0.02, the respondents stated less often that they drove under the influence of alcohol than in countries where the legal limit is 0.05.

The positive impact of lower BAC limit values is also confirmed by the results of a Spanish study conducted in 2017, which again compared European countries. The study showed that setting strict BAC limit values reduces the number of traffic fatalities. In addition to the limit values for blood alcohol concentration, there are other factors that affect how often people drink and drive, including the amount of alcohol that a given population consumes. A clear relationship can be seen between the alcohol consumption of the population and a higher fatality rate on the roads. An increase of ten percent in alcohol consumption is associated with an increase of around five percent in the number of traffic fatalities. The impact of alcohol consumption on the number of traffic fatalities is particularly relevant for the male population. There was a significant link between reducing the availability of alcohol through price increases,

Breathalyzer tests are important and should be increased.

e.g., a higher tax rate, and the number of traffic fatalities. Increasing the price of alcoholic beverages by ten percent is associated with a reduction of seven percent in traffic fatalities.

Cultural Influences on a Person's Driving Style

Driving a vehicle is a complex task that is subject to many different factors. One of them is the cultural framework, which is shaped by economic and ecological factors, ethics principles, the legal framework, rituals of social behavior, and expectations of people's roles in social interactions. General observations that apply to the entire population also apply on a smaller scale to a small sub-set of the population, namely road traffic. For example, less prosperous European countries – as measured by gross domestic product (GDP) – record more traffic accidents than more prosperous European countries. Therefore, the higher the GDP, the lower the number of fatal traffic accidents. Furthermore, in countries with more traffic circles and a higher proportion of intersections with good visibility, traffic accidents occur less frequently than in countries that do not have this infrastructure.

Various results of inter-cultural studies published in scientific journals showed significant differences between different countries in terms of things like a more aggressive or defensive driving style, compliance with traffic rules, and general driving skills. In addition, a research project conducted by the University of Kansas (USA), Tsinghua University (China), and Nagoya University (Japan) quite specifically compared Chinese, Japanese, and American driving cultures with one another. According to the research report, China has a developing traffic culture with a growing population of drivers, and the drivers tend to strive for dominance, which can be seen in differing driving behavior such as pushing/jostling for position or forcing their way through while claiming right of way. This results in a high number of accidents. Additionally, a key reason for China's comparatively lower level of road safety is the fact that it is not only car drivers, but also cyclists and pedestrians who exhibit much more risky behavior and adapt less to the rules than road users from other cultures.

By contrast, the researchers state that Japan's driving culture is geared toward minimizing risks and, therefore, has a lower accident rate. Japanese car drivers tend to fear being involved in an accident, and are particularly worried about the costs of settling claims with those involved in an accident. This is consistent with the Japanese concept of the "dependent self", i.e., having a collective basic attitude toward life (collectivism), as opposed to the American concept of the "independent self" (individualism). In the United States, the researchers state that the car has historically and culturally been seen as a symbol of freedom. As a result, drivers tend to enforce their own decisions and driving maneuvers outside the bounds of what is permitted, which in turn leads to higher accident rates than in many other countries of the world.

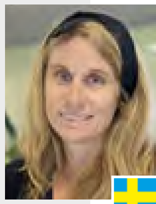
As various studies show, a person's cultural background can affect how they drive.

Importance of "Mental Programs"

A model developed by Dutch academic Geert Hofstede describes the cultural differences between individual countries with the aid of four cultural dimensions, which can be thought of as a country's personality profile. These cultural dimensions include power distance (the approach to social inequality and the relationship with authorities), individualism versus collectivism (the relationship between the individual and society), uncertainty avoidance (the approach to conflicts and uncertainty), as well as masculinity versus femininity (how gender roles are defined). A cornerstone of the Hofstede model is "mental programs", i.e., schemes which are developed and reinforced as we socialize (in our families, at kindergarten and school, at our jobs, and during our free time). National culture is always a small component of these mental programs.

Personality traits, attitudes, and dispositions in evaluation are therefore an integral part of these cultural dimensions and are shaped accordingly. Culture represents a collective program – comprising values, rituals, typical ways of behaving and making decisions, and rules – which is shared by the members of an entire population and varies from

Road Safety Is Important All Year Round



Sara Hesse
Traffic Engineer, Municipality of Karlstad (awarded the DEKRA Vision Zero Award 2023)

Traffic safety is not created overnight but depends on the conditions of the city. Karlstad is located on a delta where Lake Vänern and the river Klarälven meet, this plays an important role when building the infrastructure. Several European routes also pass through Karlstad, they are designed for heavy traffic and can be used by local traffic to relieve the smaller road network..

When the different parts of the city were built and the ideals prevailing at the time also affect the traffic system. This is relevant today as we systematically work on speed regulation. On smaller residential streets where all types of traffic mix, the speed limit is regulated to 30 km/h. These streets can have minor speed bumps. On streets with a speed limit of 40 km/h and higher, most pedestrian and bicycle paths are separated from other traffic. These streets also have pedestrian crossings or other types of safe passages for pedestrians and bicyles. This creates a safe route to school so that children can walk and cycle on their own.

Year-round traffic safety is an important issue, especially since the most common accidents involve pedestrians and cyclists injured in single-car accidents. Now it´s winter weather with 20 cm of fresh snow outside. Pedestrian and bicycle paths are prioritized when dealing with snow removal and de-icing. These paths along with the main traffic routes are plowed at 2 cm of snow. Some of them are also salted to maintain an even higher quality.

Helping the car user maintain a low speed and stop at pedestrian crossings is an ongoing effort. Even though much has been done, there are always requests for more. The challenge ahead is to get all road users, on foot or otherwise, to follow traffic rules and show consideration for each other.

population group to population group. Country-specific indices are required to compare cultures with one another. They are either provided in aggregated form, such as gross domestic product or the number of traffic accidents, or individual values are converted into a country index using mathematical operations.

Comparing the traffic-related parameters of different cultures reveals some surprising results. In countries with a high level of uncertainty avoidance (e.g., Greece, Guatemala, Germany), higher maximum speeds are permitted on the freeways. In 14 Western European countries in particular, there are significant correlations between the maximum permitted speed on freeways and the uncertainty avoidance index. In countries with a higher level of uncertainty avoidance, cars are allowed to drive faster. Moreover, uncertainty avoidance correlates highly positively with the number of newly registered vehicles and very negatively with the registration figures for used cars.

In other words, in countries with a high level of uncertainty avoidance, people have a higher desire to play it safe. In 14 European countries, there is a negative relation between traffic accidents and individualism. As a result, a high level of individualism means proportionally fewer traffic fatalities. In individualistic countries, traffic is safer because these countries tend to be more prosperous, meaning the number of vehicles in perfect working order is likely to be higher, as is the quality of the traffic infrastructure. Additionally, drivers in individualistic countries have a more realistic assessment of what is happening on the road in the context of their own objectives, and a stronger mental connection to their own standards and attitudes, which again makes traffic safer.

In feminine cultures, the engine's power output is not relevant. However, it is very important in cultures with a high masculinity index as the engine's power output represents the important emotional role that a vehicle plays as a status symbol. In more feminine cultures, people often do not even know how powerful their car engine is. Feminine cultures also deal more generously and leniently with lawbreakers. Punishments are generally relatively mild and rehabilitation programs are well developed. The sentences for "joyrides", the consumption of soft narcotics, and the acceptance of bribes are milder and more lenient.

However, when considering these results, we cannot overlook the fact that Geert Hofstede's publication originates from 2001 and the data processed was collected in the 1990s. Even if, based on the theory, we assume that cultural dimensions only change very slowly, it may be that the other country parameters have changed in the meantime – which would affect the correlations stated in the report. As a result, these results are predominantly of historic interest.

An inter-cultural study conducted by three teams led by the researchers Nordfjearn, Simsekoglu, and Rundmo from 2014 examined

Unfortunately, it is not uncommon for drivers to behave aggressively on the road.

country-specific differences in risk perception out on the road, attitudes to road safety, and driving behavior. Random samples from Norway, Russia, India, Ghana, Tanzania, Uganda, Türkiye, and Iran were compared. Following statistical calculations, the countries were sub-divided into four cultural sub-groups or clusters: Norway (1), Russia and India (2), Sub-Saharan Africa (3), and countries in the Middle East (4). The Norwegian sample (n = 247) reported high values in terms of individualism (IDV), low values in power distance (PDI) and masculinity (MAS), and moderate values in uncertainty avoidance (UAI). India and Russia (n = 441) reported low IDV values and high PDI, UAI, and MAS values. Accordingly, a statistically highly significant relationship between attitudes to road safety and people's driving behavior was identified in Norway, whereas this was not statistically significant in the other subgroups. These results correlate with the findings from previous studies and show that people in individualistic cultures tend to act according to their own attitudes toward certain behaviors.

Study on How People Perceive the Atmosphere on the Road

Another problem area when it comes to safety is the personal conduct of each individual road user. Whether it's racing, pushing/jostling for position, verbal abuse, or physical altercations: the thrust of public media reports in numerous countries is that things seem to be getting rougher and more reckless on our roads. These reports focus on prominent negative events or spectacular accidents, thereby influencing how road users perceive the atmosphere on the road. Our interaction on the road counts as a social interaction and is linked to positive attributes such as "cooperative" or "considerate" as well as negative ones such as "aggressive" and "selfish."

By combining these attributes, we can calculate the index for the atmosphere on the road, as was done for the first time in Germany as part of a 2020 study by the German Federal Highway Research Institute. This index comprised a rating for seven pairs of opposite attributes regarding how road users interact (strained/harmonious, aggressive/friendly, selfish/helpful, unfair/fair, demanding/flexible, rude/polite, reckless/considerate; each on a scale from -3 to +3) and an overall assessment. The overall assessment ascertained people's perception of the atmosphere on the road as part of a global assessment of how people deal with one another. For this purpose, the individual scale values were added up so that the overall scale ran from -21 to +21. To conduct the study, a sample of German speakers that was representative of the population (n = 2,446, 16 to 102 years of age, median age = 49.97 years, 52.5 percent male) was surveyed.

The results for Germany show that the atmosphere on the road was not rated particularly positively or particularly negatively at the time. The index value for all of Germany was -2.4, i.e., almost zero with a very slight negative trend. As a result, it was not possible to confirm the oft-reported public opinion that there is a poor atmosphere on the road. However, there were clear differences between different groups of people. Overall, people aged 25 to 39 and 40 to 64 had a much more negative view of the atmosphere on the road (index of -3.47 and -3.86 respectively) compared with people aged 16 to 24 (-1.21) and people aged 65 and over (index for people aged 65 to 74: -1.29). Participants aged 75 and over had the most positive opinion about the atmosphere on the road (2.27). Looking at the participants' education level, a significantly lower road atmosphere index was recorded for people with a higher level of education (-3.69) than for those with a lower level of education (-1.66). Furthermore, full-time workers (-3.78) had a more negative view of the atmosphere on the road than people who were undertaking an apprenticeship, in training, in school, or completing studies (-0.90) or retired people (0.08). Other much more negative ratings about the atmosphere on the road were submitted by people who drove a lot (-5.6) versus those who only drove a little (-1.34), and by people who are very perceptive of aggression from other road users [-5.54; compared with people who are moderately (-2.42) or less perceptive of aggressive behavior (0.46)].

In addition, people who live in urban areas had a more negative view of the atmosphere on the road than people from rural areas. However, the recorded road atmosphere index did not differentiate between men and women or different federal states, or based on whether the participants had a driving license for a car, or between people who used a particular mode of transport frequently/daily and less frequently/not at all. The responses regarding the perceived change in the atmosphere on the road over the last three years showed that, for Germany as a whole, only 7.6 percent of participants perceived an improvement in the atmosphere on the road. 40.8 percent of people surveyed did not believe this to be the case, and 51.7 percent reported that it had worsened.

Further analyses established a link between a perceived worse atmosphere on the road and participation in road traffic as a car driver. According to these analyses, people who drove a lot stated more frequently that they believed there was a worse atmosphere on the road than those who drove only a little.

Escalation in Aggressive Behaviors

Dense traffic, overloaded roads, and traffic jams caused by more and more people traveling all tempt people to drive at speeds that are inappropriate for the situation, push/jostle for position, and carry out risky overtaking maneuvers. However, this is not a general or automatic observation, rather it can only be seen in people who have a correspondingly high "inner potential for aggression." The perceived irritation resulting from a traffic event can also encourage an aggressive response. The irritation is perceived particularly strongly when

a. there is a big difference between the speed the driver wants to travel at and the speed they can actually travel at given the circumstances,

b. vehicles in front do not get out of the way despite there being a large enough space for them to do so in the slower lane

c. vehicles approach at high speed from behind, "sit on the rear bumper", and try to push past.

These types of situations set the scene for escalations, which increase the likelihood of traffic offenses and risky driving maneuvers. Factors such as heat and physical exhaustion after a long and tiring day at work shorten people's fuses before they turn aggressive. The same applies to the feeling of anonymity, i.e., the notion that we will not be identified in our own vehicle and thus will not be punished for aggressive behavior, as well as restricted information about what is currently going on with other road users. This, in turn, leads to us forming stereotypes of other road users, such as "the racer" or "the sneaky one."

For example, even just the type of vehicle (for instance a fast sports car) can be enough to activate certain stereotypes in our mind, which results in us assuming the other driver is deliberately obstructing or provoking us, and we will tend to ignore situational factors as possible causes. Additionally, if someone is driving so slowly that they are holding us up, then we barely ever stop to think that the person behind the wheel is perhaps unfamiliar with the road/car, or could be distracted, or is simply having a bad day. Instead, we view this behavior as malicious intent toward us.

Street Racing as a New Risk Phenomenon

If we now move away from the level of individual drivers and starting looking more at the social context of the traffic environment, it becomes clear that there are new types of risk phenomena which are creating more potential hazards. Nobody can escape traffic in our public spaces nowadays and everyone is a road user to differing degrees (as the responsible party, an observer who is not involved, or even a victim on the receiving end of another party's undesirable conduct). As a result, people's perception of the atmosphere on the road or the level of safety also change.

One aspect of car driving that really taps into our emotions is often driving at an inappropriate speed, and this is reported in the public media with terms such as the "thrill of speed" or "racing." In the media, the term "racer" has become synonymous with spectacular or extreme cases of speeding. It denotes car races where the drivers drive recklessly at very high speeds, ignore the traffic rules, and try to max out their car's speed. Drivers might participate in illegal street races, which are

Just seeing a fast sports car can activate certain stereotypes in our mind

competitions where one or more drivers compete for victory, but individual racers might also compete against themselves and “race alone against the clock.”

Misusing the vehicle for these types of competitions and to get this kind of “kick” is an international phenomenon with striking data on reported and unreported cases. According to the German Ministry of the Interior, in 2022 the police recorded a total of 605 cases of illegal private motor vehicle races involving 739 participants in Bavaria alone. Compared with the previous year (when 555 illegal races were recorded), this represents an increase of nine percent. The participants were almost always male, younger than 30 years old, and in possession of high-performance vehicles.

Different “Types” of Racer

In the limited amount of reference literature available on this topic, participants in street races are predominantly identified as young men aged 16 to 24. Participants in street races are also more likely to take part in other risky driving behavior. This includes driving under the influence of alcohol or drugs, and other risky behavior within the last 30 days, such as texting/phoning while behind the wheel, driving too close to the vehicle in front, aggressively winding their way through traffic, or running red lights. As a result, this cohort can generally be considered to be more willing to take risks. This can also be seen in other areas of life, as participants in street races are more likely to report that they smoke tobacco, have alcohol problems, consume cannabis, and participate in anti-social or criminal behavior.

A DEKRA study conducted in cooperation with the Chair of Traffic and Transportation Psychology at Dresden University of Technology (TU Dresden) and the Berlin district attorney’s office investigated the reasons why people participate in prohibited motor vehicle races. This study identified three “types” of racer based on their various motives: racers motivated by performance, reactive racers, and dissocial racers. Racers motivated by performance want to assert themselves in competition against others, show off their driving skills, or test what their vehicle can do. The focus is on the actual act of driving fast. They want to compete against others and define their self-worth and identity through the use of powerful vehicles in spectacular driving scenarios. This search for the “ultimate kick” can be seen as a way of countering their generally lower activation level, which they want to compensate by seeking out intense experiences.

Reactive racers are often individual racers. Their extreme speeding is a result of strong exposure to a stimulus, such as psychoactive substances or intense emotional states. For this second type of racer, it is likely not a low activation level, but a lack of restraint following the consumption of substances and/or an emotional state that plays a key role. It is known that this type of irregular emotional control is associated with a higher propensity to commit traffic offenses, as well as substance misuse.

Dissocial racers have a significant history in terms of traffic and criminal law violations and a fundamental, wide-ranging lack of respect for the rules. They frequently have run-ins with the police or investigative authorities, carry weapons with them in the vehicle, and are insulting and threatening toward the police. This type of racer finds it very difficult to adapt in several areas of life.

It is not uncommon for illegal car races to end in tragedy.

"Rubbernecks" Create Risky Situations

Another risk phenomenon that particularly affects serious traffic accidents on freeways is "rubbernecks", who make the arrival of the emergency services more difficult if not impossible. "Rubberneck" is a derogatory term for someone who watches an accident situation as an onlooker without providing immediate assistance. They often take photos of or film injured people and crashed cars, which frequently hinders the police, rescue services, or fire service in their duties. Most of them do not realize that by doing so, they are not only obstructing the emergency services and other road users, but also endangering them and themselves at the same time.

Even if no systematic research on these dynamics has been conducted so far, we can assume that a stronger need for social recognition appears to be the overriding driving force behind people falling foul of the

Posers like to drive vehicles equipped with flashy-looking features and drive around noisily in a way that sets them apart, as this enables them to show off.

Illegal Street Races: Major International Differences

During an international literature review in 2017, a Canadian interdisciplinary research team identified that the estimated prevalence of participation in street races varied greatly between different samples. This can be attributed to the composition of the sample, the year it was taken, the reference point in time (e.g., the last 30 days or during the past year), the definition of the term "racer", the impacts of legislative changes, the pressure of prosecution, and the socio-demographic and ethnological framework. The international situation is as follows:

New Zealand: In a sample of young men aged 18 to 21, the prevalence of respondents who had ever participated in a street race was 18.8 percent. The prevalence was 3.2 percent for women and 11.1 percent overall for the sample.

Italy: In a study of young people from small and medium-sized cities in the northwest of Italy, 38 percent of men aged 14 to 17 and 13 percent of women stated that they had taken part in a race with another vehicle at least once in the last two months.

Australia: 58 percent of a group of men aged 16 to 24 from Queensland stated that they had taken part in drag races on public roads in the past year. These types of races were relatively widespread among those surveyed – 10.2 percent of all respondents stated that they had done it during the past month, 17.1 percent during the past year. Almost 50 percent stated that they had never taken part in the activity to date.

USA: In a national representative survey of car drivers in the USA aged 16 and older, 3 percent stated that they had raced against another driver during the past month. A total of 4,010 people were surveyed. Another study examined data from the "NEXT Generation Health Study" (n = 2,395), an annual survey of a cohort of respondents that is representative of the country (average age = 18.17). Here, 13.3 percent of the sample of young people in the US stated that they had taken part in a street race in the last twelve months. 8.4 percent stated that they had taken part in a street race as a passenger.

Canada: Between 2009 and 2014, researchers examined data collected from telephone interviews (n = 11,263) as part of a periodic cross-sectional survey of adults aged 18 and over from Ontario who had driven a car during the past year (CAMH Monitor). The main objective of this "health monitor" is to describe trends concerning smoking, alcohol consumption, drugs consumption, mental and physical health, people being unfit to drive, and other risk behaviors and obtain assessments for various political measures. The results show a prevalence of 0.9 percent in people reporting that they had taken part in street races. These types of races were confirmed more often by those who also stated that they drove after consuming alcohol (no = 0.7 percent, yes = 4.8 percent), drove after consuming cannabis (no = 0.7 percent, yes = 10.7 percent), and had been involved in an accident in the past year (no = 0.7 percent, yes = 4.6 percent).

Instead of helping, sensation-seeking onlookers are content to take videos on their cell phones.

In 2021, the "Johanniter-Unfall-Hilfe" voluntary humanitarian and aid organization in Germany showcased a large QR code ("Gaffen tötet" or "Rubbernecking kills") on an ambulance for the first time, aiming to stop voyeurism at crash sites and save lives.

law as a rubberneck. It is about the desire to get the defining image of an accident and style themselves as the hero of the day on social media, setting themselves apart from the gray monotony of everyday life. The fact that technical recording devices are always available means every observer is a potential reporter. There appears to be a need for people to have their social contacts participate directly in the experience – which is easily done given the widespread use of smartphones.

However, just because someone is watching an incident, that does not automatically mean they are "rubbernecking." Researchers stress that there is a difference between bystanders/observers on the one hand and disrupters/people who endanger others on the other. A distinction needs to be drawn between different types of observation. This ranges from a passerby who just looks to see what is happening and simply carries on their way, to a "passive" rubberneck who "merely" stops and may then cause problems by obstructing access for the rescue services, to someone who actively and possibly aggressively wants to enforce what they believe is their entitlement to watch what is going on. Intensively watching something can include the aspect of obliviousness, which develops its own dynamics and the person may blank out anything that does not relate to the incident.

As a result, rubbernecking is a behavior that goes far beyond purely instinctive observation that is based on curiosity. Instead, it relates to a desire to follow the "fascinating" incident more closely. This means that the rubberneck's mind is focused heavily on what is happening and largely ignores anything that does not relate to it.

Even if "rubbernecks" sometimes present themselves in a negative light by acting violently toward the emergency services or deliberately and intentionally failing to clear the way for rescue teams, fundamentally these types of actions are something quite different. Whereas with rubbernecks the focus is on sensationalism or wanting to capture the defining image of an accident, attacks on emergency services or refusing to clear the way for rescue teams represents a direct or indirect act of aggression. Although attacks on police officers have occurred in the past, albeit not to the same extent as today, physical attacks on rescue teams or fire fighters is a new social phenomenon that has not been researched enough to date. This doesn't just happen in the context of road traffic, but it is seen very frequently there. Not only is aggressive behavior directed at the emergency services, the perpetrators also consider it acceptable that the emergency and rescue services cannot tend to the victims. This type of behavior not only shows a high level of aggression, it also indicates a loss of empathy for the victims and a tendency to reject figures of authority, such as the fire service, police, or rescue services.

Negative Impact of Social Media

This type of behavior develops a certain dynamic due to the different ways we are able to communicate on social media, which in turn opens up new ways for how someone portrays themselves. "Likes" given for a win in an illegal street race, or a bystander's admiring glances at a "cool" tuned vehicle as someone is posing in their car, symbolize a new "currency" when it comes to recognition, appreciation, and a person's status within a social community. These "likes" can be interpreted as positive feedback. By activating the driver's reward center, particularly by releasing dopamine, a neurotransmitter, in the core of the lower forebrain, they generate a pleasant state of euphoria for the driver – feelings of happiness, in simple terms.

As studies show, if a photo is popular because it has been liked lots of times, this has a significant impact on how the photo is perceived. The participants liked a photo more if it had received more likes from people of the same age – even if it depicted risky behavior such as smoking marijuana or drinking alcohol. This effect was particularly pronounced with photos that the participants had provided themselves. The study also showed that looking at photos with lots of likes as opposed to few likes is associated with stronger activity in neuronal regions that are linked to the way in which we process rewards as well as social cognition, imitation, and attention. In addition, when young people looked at photos depicting a risky subject (as opposed to a neutral subject), the network responsible for cognitive control was activated less. Therefore, our moral yardstick becomes less influential and the reflexive control of emotional impulses by the control mechanisms in our frontal lobe is gradually lost. As a result, undesirable behavior caused by a lack of impulse control is not kept in check to a sufficient extent. Posts that receive a lot of likes also encourage others to imitate what they see.

The Facts at a Glance

- **Road safety can be significantly improved by creating clearly understandable and easily recognizable infrastructure alongside training and road safety education measures, and through the use of instructions and prohibitions along with the associated monitoring and sanctions.**
- **Driving along a narrow, winding mountain pass or searching for your destination in an unfamiliar city require controlled cognitive processes and a high level of attention.**
- **Feedback-based learning processes have proven effective, especially for novice drivers.**
- **Road safety campaigns, ideally without a "fear appeal", are an effective way to reduce traffic accidents.**
- **People's appreciation of traffic rules has declined in recent decades.**

Having the Right Framework Is Key

Automated driving systems, connectivity between vehicles, and the communication between the vehicles themselves and between vehicles and centralized and decentralized systems have now become essential for identifying critical driving and traffic situations at an early stage, warning of hazards, and if required also actively intervening in what is happening on the road. In addition to ensuring the systems work properly, it is also crucial to ensure they interact correctly with the road infrastructure. Furthermore, as vehicles become more and more automated, having the highest possible level of trust in their effectiveness and reliability is also key.

With its Vehicle General Safety Regulation, the EU has set important markers for the future of road safety. It stipulates that new vehicles coming onto the market and newly registered vehicles must be equipped with systems such as intelligent speed assistance systems, emergency lane keeping assistants, and automated emergency braking systems that recognize pedestrians and cyclists, as well as fatigue warning systems, reversing warning systems, or turning assistance systems. All of them have the potential to identify hazardous situations in good time, prevent accidents, and save lives.

For these assistance systems to be effective, the vehicles must be equipped with cameras and sensors. However, despite now being very advanced, the systems themselves also impose certain requirements on the infrastructure. If we look at lane keeping assistants and traffic sign recognition systems by way of example, they require there to be road markings that are clearly visible in all light and weather conditions, as well as the corresponding signs. The environment also needs to be as sensor-friendly as possible – i.e., sufficient lighting for the camera systems, minimal interference for the radar sensors, and a low likelihood that environmental factors might cause the sensors to misinterpret the data they acquire.

Furthermore, accurate and up-to-date GPS and map data is required to support the systems handling navigation, speed warnings, and traffic flow monitoring, for example. For this reason, high-resolution map data containing detailed information on things like the course of the road, bends, traffic signs, speed limits, obstacles, and

Essential Data for Developing and Validating Automated Driving Functions

Dipl.-Ing. Henrik Liers
CEO, Traffic Accident Research
Institute at TU Dresden GmbH

The introduction of automated driving is often linked to hopes of a more efficient, inclusive, and safer way of traveling. However, it requires the task of driving to be transferred from human drivers to the vehicle. This is a paradigm shift which is posing major challenges, particularly for companies in the automotive industry, but also for technical services, type approval authorities, and experts.

Vehicle manufacturers must ensure that automated driving functions operate in compliance with the rules in their respective domain. This includes being able to manage different traffic situations and weather and environmental conditions, for example. Additionally, when type approval authorities homologate a vehicle model equipped with Level 3+ functions, they need benchmarks against which they can assess these vehicles. The aim is for automated vehicles to drive at least as well as – and ideally significantly better – than human drivers.

To solve both of these challenges, we need suitable data for developing, validating, and testing driving functions. It is impossible to test all conceivable situations and scenarios out on the road as the time and money required would be immense. As a result, virtual, simulation-based testing and development methods are becoming vitally important. These, in turn, require a suitable set of scenarios that cover the immense spectrum of normal, critical, and accident situations. The latter are considered to be "corner cases" and represent the most critical scenarios that must be managed without fail. This requires the use of accident databases.

In Germany, the data obtained as part of the German In-Depth Accident Study (GIDAS) plays a key role in this respect. It is a unique collaborative project between the German Federal Highway Research Institute (BASt) and the German Research Association for Automotive Technology ("Forschungsvereinigung Automobiltechnik", FAT), which involves recording and reconstructing around 2,000 traffic accidents every year on site together with injured parties. As a provider of a GIDAS data collection team, we are committed to making real accident data available for use in a set of scenarios for automated driving.

The partially automated processes we use for this are always based on the reconstructed accident that is put together for every GIDAS accident case. The trajectories, speeds, and maneuvers of all the road users involved are then extracted from this reconstruction. Relevant objects such as trees, walls, or parked cars and roadway elements including markings and lanes are also taken from the scaled CAD sketch. All relevant data from the real accident is then transferred into a virtual scenario.

The format itself also plays a decisive role because this type of scenario data is used by companies that operate globally. To ensure maximum compatibility and interoperability, e.g., using the data in different simulation tools, the data is saved in open formats. These de-facto standard formats – predominantly OpenDRIVE and OpenSCENARIO – fall under the umbrella term "OpenX" and lay the foundation for a uniform, harmonized procedure when developing and assessing driver assistance systems. By transferring real accident data into OpenX simulation files and making them available, we are playing a key role in ensuring that automated driving functions are developed and tested efficiently using a data-driven process in a way that conserves resources.

other relevant aspects of the environment is also important, so that – one day – vehicles will be able to accurately determine their location and plan routes in fully automated mode. This data must be updated at regular intervals in order to take into account changes to the road infrastructure. For fully automated driving, clear road markings and traffic signs are both essential so that the vehicles can interpret the road and react accordingly.

Standards for Vehicle Communication

One important aspect in this context is reliable signal coverage, as most applications relating to connected cars are, after all, heavily dependent on fully functioning communications. For non-safety-related applications, a drop in signal coverage is not critical, as the user can easily determine whether there is connectivity or not. But when it comes to safety-relevant services or applications like eCall, warning displays should be triggered to inform the user about any communication outages. Furthermore, the system should be able to independently regain control of the relevant function once the signal is stable again.

In order for connected vehicle technologies and highly automated driving to succeed, standards for vehicle communication ultimately also need to be ensured. Examples include the availability of 5G networks, which provide another significant step up in performance compared to their predecessors. Whereas 4G only enables data transfer rates of up to 100 megabits per second, the 5G standard allows up to ten gigabits per second, with a maximum latency time of one millisecond. This level of ultra-short delay is essential if vehicles are to permanently exchange data in real time with one another and with the infrastructure, e.g., traffic light or traffic control systems. "Car-to-X" communication informs the driver in a split second about hazardous situations along the route, even if these hazards are not even visible yet. In these cases, a highly or fully automated vehicle would even brake or change lanes independently in order to avoid the hazard area with sufficient clearance, without the need for the person at the wheel to intervene.

We need to take a holistic approach to cyber security

Implementing a Cyber Security Management System

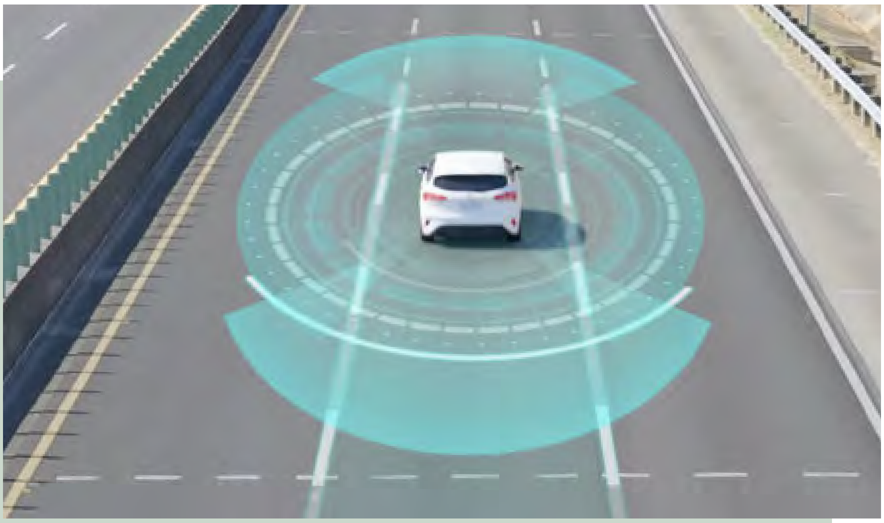
It is clear that the ever-increasing use of automated systems in vehicles also means an increased risk of electronic tampering from outside. For this reason, we need to tackle the issue as early as possible in order to close the entry points that could be exploited for cyber-attacks and prevent attacks from outside. These entry points have arisen due to the increased connectivity of vehicles with manufacturer systems, and in some cases also with each other and with the traffic technology in cities and on freeways. As a result, since July 2022 manufacturers have had to ensure that any new vehicle types are safe against connectivity and data transfer manipulation. From July 2024, this regulation applies to all new vehicles in the EU. The basis for this is the set of regulations formulated in 2020 by the UNECE World Forum for Harmonization of Vehicle Regulations (WP.29), which stipulates that manufacturers must run a certified management system for cyber security (UN-R 155) and software updates (UN-R 156) throughout the entire development period and life cycle of a vehicle.

These management systems must be audited every three years, and proof of this must be provided by the manufacturers. The German Federal Motor Transport Authority already appointed DEKRA as a service provider or "Technical Service" for this back in August 2021. In addition to reviewing whether the deployed security measures are appropriate, the process also involves auditing the company's processes and the entire supply chain. As part of "penetration tests", DEKRA's experts scrutinize various aspects, such as how susceptible the systems are to attacks from outside, the extent to which the vehicle detects tampering, and how it deals with it and what it reports back. This type of holistic cyber security assessment is not without good reason – checking security-critical components also plays a key role in ensuring the overall safety and security of the vehicle system.

Human Subject Research Study on People's Trust in Automation

As already mentioned, highly and fully automated driving requires a high degree of connectivity between the various information systems involved. By expanding the mobile broadband network along freeways and highways, the aim is to lay the foundation for high-performance, permanent, real-time networking of sensor data supplied by vehicles, the road infrastructure, and the digital communication between vehicles. In future, the aim is that smart solutions which enable automated and cooperative hazard avoidance in real time will provide a digital kind of "swarm intelligence" for the road, helping to eliminate safety deficits.

But what happens if the chain of information is susceptible to faults and no valid data can be transferred because the system is not reliable enough? To find the answer to this question, a collaborative project between DEKRA and the Chair of Engineering Psychology at Dresden University of Technology (TU Dresden) was conducted on the DEKRA Lausitzring test facility in Klettwitz. The study focused on the impact of takeover requests – where an automated vehicle requests that the driver takes over control of the vehicle – in situations where inaccurate information was displayed. The study looked in particular at how incorrect takeover requests affected the



The sensors installed in modern vehicles capture data about the environment, including other vehicles, pedestrians, traffic signs, and road markings.

resulting “biological costs” of the driver – which were recorded via heart beat patterns, which indicated heart rate variability, or the driver’s visual fixations, for example. The driver’s subjective trust in the automated systems was also examined under various test conditions. 49 people from a previous online survey (n = 88) were recruited for the 40-minute test drive. They were initially not told about the actual background to the study. The participants were aged between 18 and 56 and had held their driving license for an average of nine years.

The test vehicle was modified in order to test the highly automated driving function. The participants believed that the vehicle was driving by itself, but in fact a trained DEKRA safety driver was in manual control of the vehicle and initiated critical takeover scenarios. During the test drives, the participants initially drove several laps without any particular events occurring. They were then confronted with either an unexpected, inaccurate takeover request, or a takeover request that the driver considered plausible and was therefore realistic. Both test conditions were simulated by corresponding information shown on the cockpit display. After driving for another few minutes without any disruptions, all participants were also confronted with a silent error, whereby the vehicle started slowly drifting into the opposite carriageway without any prior system warning in the cockpit display. During the journey, the participants turned their attention to a secondary task of their choosing, such as answering e-mails or reading an article. The purpose of this was to simulate a journey in a highly automated vehicle (SAE Level 3) as realistically as possible.

After analyzing the eye tracking data, no statistically significant group differences were identified between the effects of being confronted with an unexpected, unjustified takeover request and a takeover request that the driver considered plausible. However, after the driver had been confronted with the first takeover situation, they did start to monitor what was happening on the road more closely, i.e., it caused them to turn away from their secondary task. This could be seen from the fact that they spent a higher proportion of the time looking at the areas inside the vehicle that relate to controlling the vehicle, and looking at the road environment. Specifically, this increased from 35 to around 44 percent of the total time in the ten-minute block that was analyzed in each case. Being confronted with the silent error caused a further significant increase in the time spent monitoring the driving, to 54 percent of the time that the participants spent on average looking at the areas related to driving. In other words, being confronted with a takeover request makes driving less convenient as the drivers spend less time focused on a secondary task

Using Artificial Intelligence to Improve Traffic Management and Road Safety in Cities

Enrique Miralles Olivar
Technical Director,
Spanish Road Association (AEC)

Nowadays, urban mobility is facing major challenges with respect to environmental sustainability, road safety, the efficiency of the public transport network, the development of new mobility aids, the flow of traffic, etc. The public and private organizations responsible for managing how we move about are increasingly relying on technological aids that help us to make decisions faster and more efficiently. Against this backdrop, the potential of artificial intelligence (AI) has become clear, as one of its strengths is analyzing and processing huge amounts of data in real time.

Imagine a situation where traffic lights dynamically change their cycles depending on the traffic density, average speed, and weather conditions. AI wouldn’t just predict traffic jams, it would also optimize the flow of traffic and thereby reduce both travel times and carbon emissions.

Smart detection and reaction systems also have the potential to revolutionize road safety. Sensors that are built into the roads, connected vehicles, and monitoring cameras would all feed data to algorithms designed to detect risky driving patterns. If a potentially dangerous situation were detected, the AI could intervene and warn the drivers, change traffic signals, or even activate emergency braking systems.

However, we need to approach this transformation with caution and consider the ethical and social implications. Technological progress almost always comes before there are ad-hoc rules in place for fully exploiting its potential and safeguarding the rights and safety of all citizens. We find ourselves at a turning point shaped by a new technology whose limits are still unknown. It is, therefore, our duty to lay the foundation for ensuring it is developed properly. To ensure that AI is used effectively as part of traffic management applications, we need to have sound public policies that support the recording and exchange of data and ensure transparency, data protection, and safety for citizens.

and they turn their attention to the traditional task of monitoring the road ahead.

Differences in the Ability to Take Over Control of the Vehicle

The results gained from the drivers' own reports of how their level of trust in the automated systems changed were less clear. There was no evidence of a larger decline in trust in the group that had been confronted with an unjustified takeover request compared against the group that had been confronted with a plausible warning. However, looking at the overall sample, it was possible to observe a decline in trust in the system's reliability, for example.

The steadiness of the participants' heart beat, or, in other words, the heart rate variability differed only marginally between the two takeover scenarios. The second safety-critical situation – the failure to notice the vehicle starting to drift into the opposite carriageway – did not significantly change the participants' heart rate variability. In most cases, the drivers only noticed this dangerous change to the vehicle's trajectory very late, or not at all, because they were focused on a secondary task that was not related to driving. Based on this observation, it seems plausible that the demands placed on the participants were also not influenced to any significant extent as they did not recognize the dangerous situation as such.

Diversifying Transportation Infrastructure

Mark Chung
Executive Vice President Roadway Practice,
National Safety Council (NSC)

In the United States, the urgent shift towards "Complete Streets" — roadways designed for all users, not just automobiles — aligns perfectly with the opportunities presented by the historic Bipartisan Infrastructure Law (BIL). This landmark legislation is not just a funding mechanism but a catalyst for the essential and overdue transformation of American urban planning and transportation engineering.

The BIL, with its substantial investment in infrastructure, offers a unique and timely opportunity to address the alarming safety challenges on U.S. roads. The rising crisis of pedestrian and cyclist fatalities in America (National Highway Traffic Safety Administration, 2021) can be directly addressed with the resources and policy support provided by the law. For instance, a tangible application of the BIL could be the development of extensive, protected pedestrian and cycling paths in major U.S. cities. For instance, envision New York City or Chicago using funds to expand their bike lane networks, making them safer and more accessible. This effort aligns with the law's focus on diversifying transportation infrastructure and echoes successful models from cities like Amsterdam or Copenhagen. By investing in dedicated and protected bike lanes, and pedestrian-only zones, these cities can enhance safety, reduce automobile dependency, and promote healthier, more sustainable urban living.

The economic imperatives of the U.S. are significantly bolstered by this law. American cities, which have traditionally lagged behind their European counterparts in economic benefits derived from multi-use roadways, now have the means to catch up. The funding and policy frameworks in the BIL provide a much-needed impetus for cities to rapidly adapt and harness the economic advantages of pedestrian-friendly and cycling-inclusive urban designs.

Regarding public health and environmental sustainability, the law's focus on diversifying transportation infrastructure aligns precisely with the U.S.'s urgent need to reduce its automobile dependency. The legislation's provisions for alternative transportation not only promise to mitigate pollution but also position the U.S. at the forefront of combating public health issues, including roadway fatalities and injuries, related to transportation.

Furthermore, the BIL is particularly consequential in addressing the acute issue of social equity in U.S. transportation. With its emphasis on comprehensive and equitable transportation development, the law presents an unprecedented opportunity to bridge the gaps in accessibility and connectivity, especially in underserved communities. This is a critical step towards ensuring all Americans have equitable access to essential services and opportunities.

In conclusion, the United States is at a pivotal moment where the implementation of roadway designs for all users is both urgently necessary and eminently feasible, thanks to the BIL. This law is not just a funding source but a blueprint for action, providing the resources and policy support needed for the U.S. to overhaul its urban landscapes swiftly and decisively. The time for gradual change is over; the U.S. must now harness this historic opportunity to transform its cities for the safety, economic well-being, and environmental sustainability of all its citizens.

The aim is that one day, highly automated driving functions will also enable drivers to focus their attention on secondary tasks.

Accordingly, the drivers' ability to take over control of the vehicle when a silent error occurred was poor. None of the participants were able to take over control promptly and safely. Only six participants did successfully take over control, but they did so a little too late as parts of the vehicle were already on the opposite carriageway. However, the drivers were able to prevent the entire vehicle moving into it. 40 participants either took over control of the vehicle too late or did not respond at all to the vehicle drifting into the opposite carriageway. In contrast, the drivers' ability to take over control was much improved in the previous situation where they were confronted with a plausible takeover request. The participants were ready to take over control and had their hands on the wheel after 5.1 seconds on average. However, four people did not make any attempt to manually take over control of the vehicle.

All in all, these results give us food for thought across the board, and they highlight that there are still many hurdles to overcome on the path to highly and fully automated driving, not just when it comes to vehicle technology. If we are to ensure vehicle safety given the increasing role played by software, sensors, and control units, we must also consider that in the medium term, we will need event-driven, on-demand vehicle inspections. This is also because vehicle manufacturers are increasingly set to provide firmware and software updates wirelessly "over the air" rather than via a cable in the workshop.

The Facts at a Glance

- **Driver assistance systems require a variety of sensors to record the environment around them, including cameras, radar, lidar, and ultrasonic sensors. They capture data about the vehicle's surroundings, including other vehicles, pedestrians, traffic signs, and road markings.**
- **Accurate and up-to-date GPS and map data is required to support the systems handling navigation, speed warnings, and traffic flow monitoring.**
- **In order for connected vehicle technology and highly or fully automated driving to succeed, reliable communication infrastructure as well as standards for vehicle communication are essential.**
- **If the technology makes too many mistakes, people's trust in the driver assistance system concerned diminishes.**
- **In the future, technical vehicle inspections are set to become more and more data-driven and will also need to be event-based.**

Setting the course for a Uniform, Safe Flow of Traffic

The design of the traffic environment is a cornerstone of our ability to manage a wide range of situations out on the road. This all revolves around ensuring that the "hardware" (i.e., the road design) meshes neatly with the "software" (i.e., the drivers), thereby making it easier for them to travel quickly, conveniently, and above all safely. Furthermore, we always need to consider the needs of other road users such as cyclists, pedestrians, motorcyclists, and people with physical and other impairments.

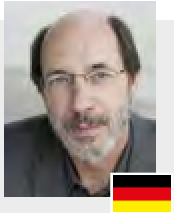
Alongside vehicle systems for ensuring passive, active, and integral safety, as well as adherence to traffic regulations/correct conduct and alertness among road users, the infrastructure also plays a key role in road safety. There are a whole range of measures that offer potential for improvement in this area – such as making danger areas safer, maintenance of road equipment and ensuring that road surfaces are safe for traffic, speed monitoring at accident hot spots, road structures to protect against collisions with trees, installing suitable traffic barriers, and many more.

As a basic principle, the design of the road/traffic area should not cause drivers to act in a way that endangers safety. However, the fact is that a lack of or inadequate infrastructure or a sub-optimal road condition are often also contributory factors to driver errors out on the road. The following design guidelines illustrate how a uniform, safe flow of traffic can be facilitated:

- Ensure drivers have adequate visual orientation. Essentially, this can be done in two ways: the inhibition principle vs the guiding principle. The inhibition principle is based on drivers being prevented from behaving in a way that is inappropriate for the situation. It highlights the situation that the driver needs to consider (e.g., a sharp bend) in the form of a traffic sign, regardless of the driver's subjective expectations, and requires them to refrain from certain behaviors. The guiding principle fosters an understanding of the importance of behaving appropriately and in

Traffic Psychology and Road Infrastructure Design

Prof. Dr. Wolfgang Fastenmeier
President, German Society for
Traffic Psychology (DGVP)



People's behavior on the road as part of the "driver-vehicle-road environment" system cannot be understood without considering the impact of our physical environment – especially road design – on the road users. In doing so, we must also consider the particular conditions that drivers and non-motorized road users are both subject to.

When it comes to motorized traffic, one of the key questions is how central factors that influence people's behavior on the road can be taken into account when planning and designing roads.
Examples of important factors for our traffic and driving behavior include conditions of perception, expectations, attitudes (to risk), the demands and stresses placed on us, and our cognitive capacity and limits.

When we plan and design traffic routes, we must follow guidelines which should primarily be derived from our knowledge of

- the underlying driving tasks and the sub-tasks involved,
- the resulting mental and psychomotor capabilities that we use to complete each driving task,
- the associated possibilities and limits of a human's ability to process information, and
- the motivation of the road users and how this can be incorporated accordingly in the plans and designs.

A complex process of registering and processing information is required to carry out these driving tasks. The road environment (road structures, traffic flows, buildings/development, plants, usage, signals, navigational lines, signage, etc.) provides information to the drivers and to road users more generally. They then interpret and evaluate this based on their prior experience of identical or similar situations and convert it into expectations about traffic flows, whether or not certain groups of road user are likely to be present and how they will behave, and whether or not certain driving maneuvers are permitted and feasible in terms of driving dynamics. Behavior- and experience-related design criteria therefore need to take into account that road users aren't just guided by how well developed the road environment is, they are also guided by their subjective idea of the overall traffic situation and the possibilities it offers in order to satisfy different driving motives and needs – including those of the other road users.

This, in turn, leads to what is probably the most important general design principle, known as "expectation congruence": that the situations that road users anticipate as a result of the road design should, to the greatest possible extent, match the situation that has been objectively signaled to them. If these expectations are not met, i.e., when the road user's subjective assessment differs from the objective situation, there is a higher probability of mistakes, traffic conflicts, and accidents. Therefore, the road design must ensure that the desired behavior corresponds to the way in which drivers experience the road and traffic situation, i.e., that the drivers' anticipated situation, the things they want and are entitled to do, and the objective conditions all match up as far as possible.

Road design and transport infrastructure require a clear perspective, including with respect to non-motorized types of road user. Pedestrians and cyclists are overrepresented in accidents, particularly among very young and older age groups. Since they are mostly involved in collisions with motor vehicles, and the severity of the consequences primarily depends on what speed these vehicles were traveling, infrastructure and road design must focus on promoting safe communication between drivers and other road users, ensure that travel by non-motorized means is simple, and ensure that these types of road user are protected against collisions and injuries.

We need interfaces between the technical systems and our human system that take into account road users' habits of perception, capabilities, and needs and ensure a smooth, accurate exchange of information between these two systems. This will enable us to prevent road users making mistakes and being subject to inappropriate levels of strain.

the desired way. This approach provides general information (e.g., about the course of a bend) in the form of prohibition and hazard signs using road markings and guidance structures that are used specifically for that particular situation.

- The challenge when it comes to road design is to find the right balance in terms of the demands placed on drivers, i.e., not making things too easy or too difficult for them, and avoiding negative key stimuli that could cause them to misjudge the stretch of road. The use of elements that indicate where the road is going, as well as traffic signs, street lighting, road markings, signaling systems, etc. all help to create a realistic idea of what to expect.
- Broken longitudinal markings (= boundary lines) improve the driver's perception of speed because the markings act as additional points of reference. This means the driver's subjective assessment of how

Smart traffic systems can make road traffic safer, more efficient, and more eco-friendly

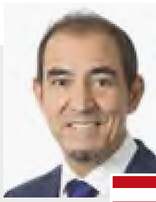
long it will take them to hit another object, i.e., the likelihood of a collision, is more accurate.

- Since our visual system can detect light green to yellow color tones quickly, these colors should be used on signs where there is insufficient contrast. This is because the light-sensitive receptors (cones) in the human eye are predominantly responsible for our vision during the day. The cones' spectral responsitivity is largest within a wavelength of 530 to 590 nanometers, which corresponds to light green to yellow.
- Acoustic reference stimuli play an important role in how drivers perceive speed. A driver's perception of speed is significantly reduced if the acoustic stimuli are dampened – they will underestimate the speed in such cases. Rumble strips – which alert the driver to the fact that they are unintentionally drifting out of lane or coming off the road – act as alarm and warning signals for our tactile and auditory receptors.
- Drivers should be provided with accurate, clear, understandable, and quickly recognizable information about how to manage their drive on the stretch of road. Distorted or concealed areas/information, optical illusions, and areas of obstructed vision (stretches of road that the driver cannot see at close range) must all be avoided.
- Since drivers tend to underestimate their driving speed when they are traveling at high speed for a prolonged period of time, there should be visible transitions from open stretches of road to intersections.
- To prevent drivers performing prohibited maneuvers to compensate for other road users, differentiated overtaking possibilities based on the category of road – e.g., federal vs rural roads – should be considered. In addition to protected overtaking opportunities that are announced in good time (e.g., overtaking lanes that alternate between the carriageways in each direction), the need to overtake should gradually be reduced, starting with higher-category roads and then moving on to lower-category roads.
- Variable message signs are designed to respond to the current traffic situation and can dynamically display a range of information. By presenting this information in a transparent manner, they help drivers to build up a more realistic idea of the situation on the road, including assessing upcoming traffic flows. Variable message signs can be used to warn car drivers of traffic jams, accidents, construction work, or speed restrictions, or provide general information about traffic conditions, for example. In the broadest sense, this helps drivers to accept restrictions that they encounter on their journey and provides a buffer before they become willing to flout the rules of the road.
- Smart traffic systems are even more innovative. They respond to changes in the traffic environment and even interconnect infrastructure systems (such as variable message signs

There are no fewer than 42 traffic lights controlling the traffic at the Grovehill intersection in Beverley (East Yorkshire, England), but they tend to cause a lot of confusion.

or dynamic light signaling systems) with vehicle systems. By exchanging information and having all participating systems cooperate with one another, they aim to make road traffic safer, more efficient, and more eco-friendly. One use case for intelligent traffic systems is the concept of adaptive lighting, which enables the street lighting to be reduced on less busy roads, while ensuring full lighting on busy sections. A more advanced innovation could enable street lamps to detect hazardous situations via radar sensors and subsequently warn the vehicles affected by "flashing" the street lamps. Another example is variable speed displays that change depending on the traffic density, weather, road condition, or air pollution control. This variable speed management is based on traffic telematics, which is when the latest data about what is happening on the road is promptly deployed in different ways as part of an automatic or manual traffic control concept. Different systems are used for this purpose. Section traffic management systems display amended speed limits based on the prevailing road, traffic, and weather conditions and, if necessary, provide warnings using additional symbols to denote things like fog or traffic jams. Network traffic management systems control how the traffic is routed. Variable direction signs direct long-distance traffic to the destination along less congested routes.

Best Practice in Infrastructure Benefits Everyone



Christian Schimanofsky
Director, Austrian Road Safety Board (KFV)

According to road traffic accident statistics, more than 43,000 people are involved in an accident on the road every year in Austria, of which around 3,400 are pedestrians and around 9,250 are cyclists (average from 2018 to 2022). It is difficult to estimate how many accidents could have been prevented entirely by better infrastructure, or where better infrastructure would at least have reduced the severity of the injuries. There is no doubt that infrastructure design plays a crucial role in reducing the severity of accidents and increasing safety for everyone, in particular vulnerable road users. The creation of "pedestrian priority zones" and the provision of higher-quality infrastructure for cyclists are two examples of effective infrastructure measures that have been implemented in Austria based on rules that have been continually refined and enhanced.

The KFV has closely examined twelve pedestrian priority zones throughout Austria and conducted comprehensive analyses of what is happening on the road and safety. The results showed that these zones are an excellent traffic-calming measure in bustling road environments. In the pedestrian priority zones that were examined, much lower speeds were measured than in 30 km/h zones. The speeds that vehicles were traveling at mostly fell within the range of the maximum permitted speed of 20 or 30 km/h. Conflicts between pedestrians and car drivers only occurred in around one percent of the more than 7,300 pedestrian crossing movements analyzed.

Surveys show that road users rate the subjective level of safety as very high. When installed in suitable traffic areas, pedestrian priority zones have a positive impact on road safety. However, in order for them to work effectively, it is crucial that the road design is well thought through. The choice of navigational lines, furniture, and zoning in the road environment as well as fields of view are decisive factors in this respect.

Additionally, cycling accident statistics in Austria are high and have been rising for years, demonstrating that the cycling infrastructure also needs to be adapted to suit the changed framework (more bike traffic, new methods of travel such as electric scooters or cargo bikes, higher speeds as a result of e-mobility). The revision of the Austrian guideline for cycling is addressing these changed requirements, thereby laying an important foundation for making cycling safer. The key changes include ensuring cyclists and motor vehicles are clearly segregated when cars are traveling at relatively high speeds, providing wider cycling infrastructure (e.g., bicycle lanes and multipurpose lanes next to parked cars should measure two meters instead of 1.5 meters), and making adjustments for electric bikes and cargo bikes.

A very complex traffic circle in Bremen where six busy roads and different modes of transport including streetcars meet one another. Situations like these can quickly overwhelm road users.

Section Control to Ensure Compliance With Speed Restrictions

When it comes to speed, section control – also known as "average-speed checks", "point-to-point checks", or "time-over-distance checks" – is a relatively new technology for ensuring compliance with speed restrictions. With this technology, the driver's average speed is measured over a given stretch of road, which is usually between two and five kilometers long but can also be much longer. The vehicle is recorded when it enters and when it exits the section being monitored. Its average speed is then accurately calculated based on how long it took to travel between these two points. This average-speed check operates 24 hours a day, seven days a week, meaning the likelihood of speeding offenses being prosecuted is almost 100 percent. During the 1990s and 2000s, this type of section control was most notably trialled and implemented in Europe, such as in the Netherlands, the United Kingdom, Austria, and Italy, as well as in New Zealand and Australia.

On stretches of road with section control, the number of speeding offenses can be reduced to just a few percentage points or even less than one percent, which indicates a high level of compliance with the speed restrictions. A study in the Netherlands showed that in areas with section control, less than 0.5 percent of all traffic breached existing speed limits. It therefore comes as no surprise that section control leads to a reduction in all accidents, with reviews putting this effect at 30 percent. According to the meta-analysis, there was even a substantiated 56 percent reduction in serious and fatal accidents. An Italian evaluation study confirmed the effect of section control on safety; however, it does become less effective over time. After the system had started operating, there was a 39.4 percent reduction in accidents in the first half-year, and an 18.7 percent reduction in the fifth half-year, compared against the time before the system was introduced.

Given that the evaluation results are fundamentally positive, experts have repeatedly suggested that section control should be combined with existing automated and manual speed monitoring measures so as to encourage drivers to comply with speed restrictions over longer sections of the road network. In this context, we also cannot ignore the tendency for drivers to speed before and after the stretch of road with section control in order to "compensate" for the fact that they are "held back" when passing through the section control. The provision of average-speed monitoring systems should generally be focused on stretches of road that have had high accidents rates in the past or documented problems with excessive speed.

Traffic Circles Have a Long History

Traffic circles have also proven to be a highly efficient measure all across the globe for reducing the speeds on our roads, in both built-up and non-built-up areas. The concept of routing traffic using a ring or circle has existed for almost 150 years. They were originally intended more as a way of quite literally putting monuments or statues "center stage" and having people navigate toward them from all directions, and as a way of satisfying military requirements. However, as the traffic on our roads increased and cities continued to grow, at the end of the 19th century they started to become a means of controlling traffic. Nobody knows exactly when or where the first modern traffic circle came to be installed. According to Swiss traffic researcher Pedro de Aragao, the Frenchman Eugène Hénard first described a traffic circle that could only be used in one direction back in 1877. However, the American William P. Eno was also working on this concept at around the same time, and recommended that one be installed in New York City.

Several years then passed before traffic was actually able to drive round the New York Columbus Circle (1905) and the Arc de Triomphe in Paris (1907). The concept was implemented at Brautwiesenplatz in the German town of Görlitz back in 1899. Numerous traffic circles of many different sizes then followed in large parts of Europe and the USA. However, they could not keep up with the increasing amount of traffic, meaning many countries stopped building them or only built them very rarely. It took until 1966 for them to have their real breakthrough. Researchers in Great Britain realized that a traffic circle only becomes fully effective if the traffic already on it has right of way. This "yield-at-entry" rule was first implemented in Great Britain and subsequently also in France. It was accompanied by changes to the geometric design of the entry and exit points in order to make the traffic circles even more effective. This system then came to be known as the "modern traffic circle." Other countries had great difficulties in introducing this rule because in places where people drove on the right, for example, it meant that the traffic coming from the left had right of way, which went against the traditional "right before left" rule.

Various Advantages

However, legislators in these hesitant countries then gradually also realized how effective modern traffic circles were, and they went on to incorporate them accordingly in their national regulations. In the early 1990s, the previously hesitant countries eventually ended up increasing the construction of traffic circles and including them in road traffic legislation. The trend started a little later in the USA, and even today there remain differences between states in the use of traffic circles.

In any case, the advantages of traffic circles are manifold. The risk of accidents is lower because the vehicles approach them at a lower speed and, once on them, drive round them at a lower speed than a traditional intersection. The same applies to the severity of accidents, because vehicles do not cross one another at right angles, but tend to approach one another tangentially. Traffic circles also offer sustainability and environmental benefits as they eliminate unnecessary waiting times at a red light when there is no traffic coming the other way. There is no need for expensive traffic light systems which incur high maintenance and power costs. Moreover, traffic circles usually cope better with high traffic volumes than signal-controlled intersections. The disadvantages of traffic circles include the fact that they often need more space, and the longer routes for cyclists and pedestrians. There are also often problems when long vehicles try to maneuver round a smaller traffic circle. In principle, appropriately sized traffic circles make sense in many places. In some cases, traffic circles have also been built in underground traffic systems, such as Norwegian tunnels.

Differences in Terms of Signage and Right of Way

One very critical aspect is, however, the fact that every country has its own regulations for using traffic circles. These relate in particular to the use of turn signals and the rules for pedestrians and cyclists when crossing the entry and exit points. For example, in some countries it is prohibited to use your turn signal at the entry point, in other countries this is permitted but not required, and other countries require the driver to indicate in which direction they want to exit the traffic circle before they reach the entry point. The rules for exiting a traffic circle also differ, but drivers usually need to use their turn signals. The correct use of turn signals is, in fact, very important for a traffic circle to function correctly. If drivers fail to use their turn signal in a country where they are required to when exiting a traffic circle, this does not increase the risk of accidents but it does hold up arriving traffic unnecessarily and thus reduces the traffic capacity.

Traffic circles need to be clearly identifiable at an early stage, particularly at night

Further differences arise in the signage installed at traffic circles and in the rules for who has right of way. Additional "Yield" signs are sometimes required to ensure that the traffic already on the traffic circle has right of way over arriving vehicles. In some countries pedestrians have a general right of way when crossing the entry and exit points, in other countries they only have right of way over vehicles that are exiting the traffic circle, and in other countries it is vehicles that have a general right of way.

To further reduce the speed on traffic circles and make them more clearly identifiable, the central island often has a hill with plants. It is also not uncommon for the central space to be used for artwork. Traffic circle islands are ideal for public art installations, but such installations may also result in drivers becoming distracted if the artwork is particularly striking. Furthermore, if very solid, sharp-edged, or pole-type structures are used, there could be serious consequences if a vehicle were to collide with them. Motorcycle users are particularly at risk in this regard. As a result, in order to maximize road safety, the center of traffic islands must always be designed with due consideration for the approach speeds, lines of sight, traffic density, modal split, and the potential for drivers to be distracted.

We Need to Promote Multimodality

Mar Cogollos
Director, Association for the Study of
Spinal Medullary Lesions (AESLEME)

Due to new mobility models, particularly in urban areas, we now have an entirely different situation than just five years ago when the car was considered "king of the road." The development of new mobility models that aim to make our mobility cleaner and more sustainable – as provided for in the guidelines of the Agenda for Sustainable Development (SDG) and the Spanish strategies for road safety and climate change, as well as the Spanish law on sustainable mobility – has gone hand in hand with a significant increase in the group of at-risk road users (motorcyclists and cyclists, people with mobility aids, and pedestrians, in particular children and older people).

At AESLEME, we have come to the sad realization that pedestrians – which we all are – are the biggest losers in all of this. And when these pedestrians are older people or people with restricted mobility, the "general inaccessibility" of our cities then makes it more difficult for them to travel safely, e.g., the failure to drop a curb, a hole in the ground or an uneven paving slab, a staircase, or one of the many obstacles on our sidewalks (terraces, street lamps, motorbikes, scooters).

Imagine that these people are our parents, grandparents, or people with a disability – can we put ourselves in their shoes? We need to promote multimodality and be able to combine public transport with healthy, eco-friendly walking and cycling. Above all, we need to follow the rules and learn to live alongside one another, because if we do not recognize the risks, we will end up making wrong decisions that could cost us our lives or lead to serious injury.

The model of a society where everyone is in a hurry must be countered with a model of a society that pushes for safe and sustainable eco-mobility that protects the most vulnerable people. Creating a culture of public road safety requires commitment at an institutional level and a social pact, as it affects us all. We are all responsible for making it a reality.

Universal Traffic Signs and Consistent Traffic Rules Would Be Advantageous

Whether in built-up or non-built-up areas, traffic signs play a key role in traffic management systems. Given the increasing amount of international and inter-regional traffic, there is a need for solutions for universal traffic signs so as to reduce the potential risks for drivers. For this reason, a Chinese study from 2019 aimed to determine the key factors that could affect how road users performed when they were asked to guess the meaning of different traffic signs. To this end, the research team surveyed 201 Chinese students aged between 19 and 23 who had never driven a car in Germany and had no daily driving experience. 39 percent of the participants had already taken Chinese driving lessons. 39 Chinese traffic signs and 15 German traffic signs were used for the study.

The results showed that the highest rate of correct answers – almost 63 percent – was recorded for warning signs. The average rate for correctly guessing all the signs used was around 57 percent. The German danger warning sign 102 (meaning a crossing or intersection where drivers have to yield to the right) and the advisory/information sign 307 (end of a road with right of way) had the lowest success rate, with only 0.33 percent on average guessing each of them correctly. Key factors that influence whether or not people can identify the meaning of a traffic sign are the semantic gap – i.e., the difference between what a sign shows and what it should depict – and their familiarity with it – i.e., how often the person has encountered the traffic sign in the past. This applies to all types of traffic sign, such as those informing drivers about the right of way, the use of the road, or speed, to name but a few.

In this context, further standardization of the traffic rules would undoubtedly also be advantageous. Just as a reminder: the Convention on Road Traffic and the Convention on Road Signs and Signals were signed in Vienna back in November 1968, thereby establishing an international framework for road traffic. In the years that followed, they were then transposed into national legislation in most countries around the world. However, despite having taken these major steps, considerable differences in national traffic legislation and regulations remain to this day, which make it much more difficult to drive internationally. Things always become dangerous if identical traffic signs instruct drivers to do different things in different countries.

Another aspect that is not particularly driver-friendly, but can at least be considered non-critical, is the fact that every country has its own limits for the maximum permitted speed depending on the type of vehicle and road category. The same applies for the limits for the maximum blood alcohol concentration level. On the other hand, the fact that there are major differences in the rules for crossing the road at pedestrian crossings, including within Europe, does pose problems. Although the corresponding information signs are almost identical throughout Europe, the rules governing how drivers should respond differ. For this reason, people at a zebra crossing should never simply assume that approaching vehicles will stop; instead they should wait until they actually brake. In Germany or the United Kingdom, for example, the rule is that vehicles must stop when it is clear to see that pedestrians want to step onto the crossing. In Italy, however, pedestrians do not have right of way until they are already on the zebra crossing.

Different Levels of Knowledge About Traffic Signs on Cycling Infrastructure

When it comes to traffic signs, DEKRA explicitly focused on cyclists in a survey conducted by opinion pollsters forsa in February 2024. The survey investigated their knowledge of traffic signs relating to cycling infrastructure in Germany. 1,013 cyclists were selected according to a systematic random process and shown five different traffic signs. For each sign, they had to state the extent to which different statements about traffic rules for cyclists were correct or incorrect. 14 percent of the respondents used a bicycle more or less daily, 30 percent usually traveled by bicycle once or several times each week, 34 percent used a bicycle less than once a month, and 96 percent had a driving license for a car. The key results were as follows:

With respect to the "Bicycle path" traffic sign, more than 60 percent of those surveyed know the applicable rules. 71 percent know that this traffic sign means they must use the bicycle path and are not allowed to cycle on the road. However, 25 percent are unaware of this. A fifth (20 percent) of those surveyed wrongly assume a speed restriction of 30 km/h on the bicycle path, and a further 14 percent do not know whether or not it applies. By contrast, 66 percent know that the bicycle path sign does not stipulate any such restriction. A comparatively small proportion (6 percent) of those surveyed assume that they have right of way on the bicycle path at crossings and intersections, regardless of who is coming from the right. 89 percent know that this is not the case.

With respect to the traffic rules for bicycle boulevards, greater differences were identified in the cyclists' knowledge. For example, some rules are known to two thirds of those surveyed, whereas others are known to only a third. Two out of every three cyclists (67 percent) know that cars are not allowed to drive on a bicycle boulevard – unless there are additional signs permitting this. However, 29 percent believe that this rule does not apply. A little over half of the cyclists (58 percent) know that multiple cyclists on a bicycle boulevard are always allowed to cycle next to one another. However, only 32 percent know that they are restricted to a maximum speed of 30 km/h when cycling on a bicycle boulevard.

Almost all of the cyclists (97 percent) know that they have to watch out for pedestrians after passing the "Shared footpath and bicycle path" sign. However, a smaller proportion of them know that the sign indicates they must use the bicycle path and are not allowed to cycle on the road. Half (53 percent) of those surveyed know this, whereas 40 percent think that they are also allowed to use the road.

Suspended from a 70-meter pylon using 24 cables, the "Hovenring" cycle path traffic circle located between the Dutch cities of Eindhoven and Veldhoven provides around 5,000 cyclists a day with a safe means of crossing a busy intersection.

The rules governing how to behave should be easy to understand

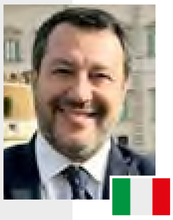

With respect to footpaths that have an additional sign depicting a bicycle with the suffix "frei" (meaning "permitted"), two rules are known to virtually all cyclists and one aspect is known only to a minority. Virtually all of those surveyed know that this sign means that cyclists must watch out for pedestrians (97 percent) and that they are allowed to use the footpath as cyclists alongside pedestrians (92 percent). However, only one in every three of those surveyed (33 percent) is aware that cyclists are only allowed to cycle at walking speed in such cases. 55 percent believe that such a speed restriction does not apply here.


With respect to the "Segregated footpath and bicycle path" traffic sign, we again see that different proportions of the cyclists know about different aspects. For example, nine out of ten (90 percent) of those surveyed know that this sign means they must cycle within the designated markings. However, a much smaller proportion of the cyclists – 57 percent – know that this sign means they must use the bicycle path and are not allowed to cycle on the road. 37 percent of those surveyed think that they are equally entitled to cycle on the road instead of the bicycle path. Around one in ten of those surveyed believes that they must only cycle at walking speed on segregated footpaths and bicycle paths, and that multiple cyclists are always allowed to cycle next to one another. However, eight in ten of those surveyed know that these are not rules associated with this sign.

The results of the survey are consistent with the assessment made by the German Road Safety Volunteer Organization (Deutsche Verkehrswacht) a few years ago, at least to a certain extent: namely that people have insufficient knowledge of the rules that apply to cycling. This is by no means something that is restricted solely to cyclists; car drivers and pedestrians are also a substantial part of it. The rules are often interpreted and applied incorrectly. Decision-makers are also not always certain of the legal options, meaning the rules on correct conduct are frequently considered irrelevant. According to the Road Safety Volunteer Organization, the parties concerned have virtually no awareness of the impact that the rules have on safety. Take, for example, the rules for non-exclusive bicycle lanes that form part of the road: are cyclists obligated to use them? Are motor vehicles allowed to use them? How do they noticeably differ from exclusive, designated bicycle lanes that are explicitly for cyclists?

"Consideration makes for wider paths" - this legal graffiti on a pedestrian and cycle path near Wuppertal, Germany, calls for greater mutual respect.

Major Investments in Roads and Freeways



Matteo Salvini
Italian Minister of
Infrastructure and Mobility

In Italy, around 200 billion euros needs to be invested in roads, freeways, and railways over the next ten years. The "Strategic Infrastructure Plan 2023–2032" includes more than 1,350 construction sites for roads and freeways in the years 2023–2024, with 3.5 billion euros earmarked for maintenance and another 4.5 billion euros earmarked in the planning contract of Italian infrastructure company Anas, two billion euros of which is intended for the construction of new roads.

In addition, the resolution by the Italian Ministry of Infrastructure and Mobility on improvements to road safety in inland areas (national strategy for inland areas) provided a total sum of 50 million euros, split into 20 million euros for 2023 and 30 million euros for 2024, to fund measures relating to special maintenance programs for the 43 inland areas identified as part of the SNAI strategy in the 2021–2027 cycle.

The roads have been inadequately maintained in recent years, meaning that investments amounting to several hundred billion are planned for roads and freeways. The Ministry of Infrastructure and Mobility will be a linchpin and the main player in this revolutionary measure.

With respect to road safety, it is also important to note the draft legislation to amend the Italian Road Traffic Act. The text imposes restrictions on driving under the influence of alcohol or after the consumption of drugs, with harsher punishments for repeat offenders in future. Harsher future punishments are also in store for people who speed and people who use electronic devices while driving, while the use of radar speed traps and electric scooters is to be restricted. The Italian parliament will introduce these amendments in 2024.

In addition, the relevant experts only rarely know all the ins and outs of the criteria for applying the rules, as well as the intended benefits of certain types of cycling infrastructure. The Road Safety Volunteer Organization cites a bicycle path that is merely advisory as one example: how can it be identified? Where does it make sense? When is one permitted? Due to both of these factors, the different types of cycling infrastructure are being used in an unstructured, non-systematic way. Fundamentally, the Road Safety Volunteer Organization recommends that the rules governing how all types of road user should behave should be easy to understand. Uniform, understandable rules must apply for a small number of clearly identifiable cycling solutions.

Protective Structures for Motorcyclists

When considering ways to increase road safety for riders of two-wheeled vehicles, we soon start to focus our attention on riders of motorcyclists. Traffic barriers are an important element of the road infrastructure in this regard. The background to this is as follows: studies conducted by various accident researchers indicate that in Germany, for example, around 80 percent of motorcyclists who lose their lives do so due to obstacles encountered in non-built-up areas – and around half of this number are killed in accidents involving traffic barriers. The problem is that by default, countless numbers of traffic barriers are built with their primary goal in mind: that the rail should be at the same height as the hood of a car. While this enables them to offer maximum protection for car drivers, the remaining space between the barrier and the ground represents a huge risk for motorcyclists. If motorcyclists were to crash, there is a danger that they could slide under the traffic barrier or hit one of its supporting posts. In such situations, severe or even fatal injuries are not unusual.

However, traffic barriers can also be designed to offer optimum protection for motorcyclists who crash into them. In many locations, a combination of a large top surface, such as that offered by a box shape, and a secondary rail under the main rail to prevent people from crashing into the posts has proven effective in both crash tests and real-life accidents. The secondary rails used in this design can also be retrofitted to many existing systems. For example, the "Euskirchen Plus" system further developed by DEKRA several years ago on behalf of the German Federal Highway Research Institute (BASt), offers motorcyclists involved in collisions a relatively high level of protection. This system was proven to provide an improved

Traffic barriers with a secondary rail can save the lives of motorcyclists.

protective effect for motorcyclists both when riding upright and when sliding across the road on their side.

Alongside adding secondary rail systems to protective structures, replacing the rigid direction signs mounted on steel tubing that are often found at corners with flexible systems is also an important measure for reducing the consequences of injuries following a crash. To this end, the Ministry of Transport for the German state of Baden-Württemberg has joined forces with a local road equipment company to develop a plastic curve marker sign. The system, which was first presented in 2014, comprises a sign with an area of 50 x 50 centimeters that is placed on a plastic mount that has the same shape as the old direction post and is attached to it using screws. The added value this innovation provides in terms of road safety was demonstrated in impressive form in a crash test conducted by DEKRA in 2017. In the crash test, a motorbike traveling at 60 km/h was crashed into the old standard curve marker sign model, “metal plate on a steel post,” then a second motorbike traveling at the same speed was crashed into the new, plastic curve marker system. The load values measured in the dummy upon impact with the steel post far exceeded the biomechanical limits, while those recorded upon impact with the plastic system were well below the limits. A motorcyclist would thus not have survived the crash into the steel post. However, a motorcyclist wearing appropriate protective clothing would have survived the crash into the new curve marker sign with only minor injuries. Plastic curve marker signs also offer the advantage that road users evidently find them even easier to spot.

Risk of Skidding Due to Differences in Level at the Side of the Road

Roadside guide posts are always important safety installations when it comes to identifying the course of the road. They are mounted at the side of the road and fitted with reflectors so that road users can see well in advance where the road is going. The major plus-points over road studs are that they remain visible and thus effective even if there is a covering of snow, are damaged less often, and do not require any modifications to the road surface. They also enable road users to assess distances better.

If a vehicle drifts out of lane toward the side of the road, the condition of the shoulder and side strip is often decisive in determining the extent to which the driver can still maneuver the vehicle. The shoulder is the area between the boundary line and the actual edge of the road, whereas the side strip is the area next to this that does not have a top road surface. If there is no shoulder, the vehicle’s wheels will immediately leave the road if they cross the boundary line. This changes the amount of grip available to them, and there may also be a difference in level between the road surface and the side strip, as the latter is often lower. As a result, it is much more difficult to steer the vehicle back onto the road. There is, therefore, a high risk that inexperienced drivers will turn the wheels too hard to overcome the difference in level – as soon as the wheels reach the road again, the vehicle is then abruptly swung toward the oncoming traffic, and there is also a very high risk of skidding. To combat this, where sufficient space is available an appropriately wide shoulder that is designed for the speed and course of the road should be provided. The adjacent side strip should be brought to the same level as the road and paved such that it remains at this level even after prolonged rainfall and after trucks have driven over it.

When we travel on rural roads, we repeatedly encounter bends where we were unaware beforehand that they are as sharp as they are, bends that become sharper and sharper, and series of bends where some are less sharp and others are very sharp. In the vast majority of cases, rebuilding these stretches of road is not an option, at least in the short and medium term. This means that other safety measures are required. One particularly effective solution in such cases is to install a series of individual direction signs featuring red and white stripes to indicate the direction of the bend. The sharpness of the bend is shown by the spacing of the signs. The positive effect of this solution can be significantly enhanced further if a traffic barrier with a secondary rail is additionally installed at the outside of the bend. High-contrast road markings are key, particularly when driving through bends. The aforementioned safety measures can be enhanced by installing information signs to warn drivers of the bend(s) in good time. Furthermore, it is essential to ensure the side strip at the side of bends remains intact.

The condition of the shoulder is decisive in determining the extent to which a driver can still maneuver the vehicle

Intensifying Construction and Maintenance Work

Optimizing our road infrastructure involves reconciling various crucial aspects, including the condition of the road surface, the predictability of the road's layout, the ability to see the road clearly, the design of the sides of the road, road markings, the design of intersections and junctions, the creation of opportunities for evasive maneuvers and overtaking, and – when it comes to bridges – the general condition of the structure. Of course, it is not possible to rebuild every dilapidated road or refurbish it from scratch. However, if all construction and maintenance work were to be planned, prioritized, and carried out with a view to ensuring the highest possible degree of safety, we could expect significant improvements in safety.

A problem that particularly affects bridges is material fatigue. This is caused by the age of the structures, some of which are disproportionately old, as well as traffic volumes, which have been rising sharply for years. The collapse of the Morandi bridge, part of the Italian freeway A 10 in Genoa, in August 2018 is a shocking example of what can happen in this respect. A major factor affecting bridges is the massive increase in the amount of heavy-goods traffic. For these reasons, as we strive to improve our road infrastructure, we cannot overlook the importance of the necessary structural inspections, both now and in the future. In Germany, for example, they are governed by the DIN 1076 standard. Regular inspections by experts help to detect and remedy structural defects at an early stage, making them another important building block in our efforts to improve road safety.

In addition, no discussion of road planning measures would be complete without highlighting the importance of regular maintenance of the road surface. A road surface that has as good grip and is as even as possible plays a key role, particularly in the safety of motorcyclists. Insufficient friction coefficients lead to longer braking distances and increase the risk of a motorcyclist losing control when cornering or during evasive maneuvers, which in turn increases the risk of skidding. Grit on corners is also very dangerous for motorcyclists – especially in the first month after winter, or when tractors, cars, and trucks "collect" the grit by the side of the road and carry it onto the road itself. There is always a risk of this occurring and motorcyclists encountering this, even in areas that use modern road sweepers. In addition to this, unevenness can increase the probability of water collecting, which leads to a higher risk of hydroplaning and black ice. This must be taken into account during repairs. In particular, the bitumen mass that is still often used to mend

In many countries there is an urgent need to refurbish dilapidated bridges – but also a high backlog of investment.

pot holes and cracks in many countries can quickly become dangerous for motorcyclists, as it causes the road surface to become extremely slippery when wet. As such, repairs should always be carried out using materials with a similar friction coefficient to the rest of the road surface, otherwise the exit ramp could end up resembling an ice-skating rink.

Consistent Pursuit of the "Shared Space" Approach

When we consider how to provide infrastructure that maximizes road safety in inner-city areas, we cannot forget the fact that around half the population travels as a pedestrian, cyclist, or user of public transport. When designing these types of "urban mixed traffic spaces" shared by motorized and non-motorized road users, it is possible to apply similar principles to those that govern the ergonomic design of a vehicle cockpit. Accordingly, the information provided out on the road should be clear and comprehensible, designed to be low-risk so as to encourage safe behavior, and provide self-explanatory, speed-reducing measures at crossings.

The design principles of "self-explaining roads" as well as conflict-defusing solutions that reduce identifiable disadvantages for non-motorized traffic, could so to speak also be applied for non-motorized road users in smaller-scale inner-city traffic environments. Against this backdrop, the concept of "shared space" has become increasingly widespread over the past few decades. A hallmark of this type of traffic environment is that signs and demarcations are largely non-existent as all road users follow implicit rules. In contrast to other traffic-calming measures, the concept does not rely on restrictive rules, but rather on voluntary changes in behavior based on mutual respect and everyone looking out for everyone else. Individual road environment designs that are typical of the area bring together and balance the needs of pedestrians, cyclists, cars, and other spatial functions. The use of "shared space" developed the fastest in the Netherlands, Denmark, Germany, Sweden, and the United Kingdom.

More Truck Parking Spaces are Required

A lack of parking spaces on freeways, for example in Germany, poses a further risk to road safety that should not be underestimated. Although the federal government and states have been building new truck parking spaces for years, the increase in freight traffic has meant they have, so far, been unable to make up the shortfall. According to experts, another 40,000 or so parking spaces for trucks are required on German freeways alone.

Among other challenges, one major problem here is the requirements governing the permitted time at the wheel and mandatory rest times. Truck drivers must always comply with these rules, otherwise they run the risk of severe penalties. Due to the lack of parking spaces, truck drivers therefore often park their vehicles at the entrance and exit roads of gas stations and rest areas or in breakdown lanes to ensure they do not breach the rules on time at the wheel. This poses a high risk of accidents, because the trucks are often inadequately protected and do not stand out at night, making them almost impossible for other road users to spot.

To remedy this situation, the company Bosch Sicherheitssysteme, for example, has developed a "360 degree solution" to improve digitalization and safety at truck stops and rest areas with its "Secure Truck Parking" platform. By means of a booking platform and an app, it enables freight forwarders and truck drivers to see available parking spaces along their route in real time and book them online, thereby eliminating the time-consuming and stressful search for a parking space as they approach the end of their permitted time at the wheel. More than 300 parking lots with around 15,000 parking spaces throughout Europe are already listed.

Legislators could also take up this issue. To date, the penalties for exceeding the permitted time at the wheel have been much harsher than those for illegal parking. Making them consistent could dissuade some truck drivers from parking their vehicles at critical spots. However, this would only shift the problem elsewhere because the truck drivers would then have to continue driving until they found a free parking space. Overtired truck drivers also pose a higher risk of accidents.

Crowded truck parking lots are a common sight, not only, as seen here, on freeways in Germany.

Many cities now have "shared spaces."

This type of road environment design is underpinned by recent findings gained from the fields of behavioral and environmental psychology and, in particular, the assumptions of risk compensation theory. As previously mentioned, it aims to minimize the demarcation between vehicles and pedestrians. The concept is based on a perceived level of "uncertainty", which encourages road users to behave with greater care and attention. This builds on theories such as "risk homeostasis", which was developed by Gerald J. S. Wilde in 1982. It states that at any given moment, road users perceive a subjective level of risk and constantly compare this with the maximum level of risk they are willing to accept. If the two differ from each other, they will adjust their behavior/apply greater care and attention in order to eliminate the discrepancy.

As a result, "shared spaces" are streets and places which have been designed to make things more convenient for pedestrians and give them more freedom of movement. They do this by reducing the focus on vehicles and ensuring that everyone who uses the environment is able to make equal use of the available space. Design elements such as seating, central bicycle parking spots, simple drainage details, and monuments can help foster interaction and human activity. "Shared spaces" use tactile surfaces on the ground, contrasting colors, street furniture, traffic circles, consistent and harmonious color schemes for asphalt and paving, unobtrusive curb designs, and careful lighting that accentuates the overall space. Pedestrians and cyclists cross simple "courtesy crossings" with respect to traffic circles and interact with slow-moving traffic based on unspoken rules. "Shared spaces" are particularly effective when vehicles drive at speeds of less than 32 km/h and there is little traffic (fewer than 100 vehicles per hour), which breaks down the hierarchy between vehicles and pedestrians and promotes equality.

Whereas extensive literature is available on road design and the behavior of pedestrians and car drivers in general, academic research on "shared spaces" is remarkably scarce. A review from 2014 by Simon Moody and Steven Melia showed that most findings merely exist in the form of consultants' reports, conference contributions, student degree theses, or manuscripts for organizations, which either support or reject aspects of "shared spaces." Those in favor largely described the benefits of existing systems, whereas opponents of the concept posed the question of whether the reduction in accidents observed at some, though not all, locations was sometimes the result of pedestrians being intimidated and fearful due to the lack of separation between traffic flows.

Making Mobility Accessible to All

When it comes to infrastructure, we ultimately also need to focus more on the needs of people with physical and other impairments than is currently the case in many places. These people are often reliant on local public transport to travel from A to B. However, they need outside help even just to get to the bus or train because there are barriers which impede their mobility or have not been adapted with their needs in mind.

The barriers in public transport for people in wheelchairs or with other physical impairments are particularly apparent. For example, it can be a challenge for them to simply make their way to the next stop because it is too far away, there are loose paving slabs or raised curbs in the way, or an electric scooter is parked in the middle of the footpath and is blocking access. At bus stops, there is often too big a gap between the edge of the curb and the bus entrance. The solution of a fold-out ramp in the bus is available to remedy this, but this means that people with impairments are reliant on outside help again. Still, in Germany, for example, numerous bus stops have now been refurbished and have a

Wheelchair users still face many barriers in road traffic.

higher curb at the entrance and exit points that the bus can get relatively close to. This negates the need to fold out a ramp, making it easier for these passengers to travel.

Another problem is that traffic lights often change too quickly, meaning older people and those with reduced mobility cannot cross the road in time. Additionally, public transport information such as timetables and route instructions is often inaccessible to people with sensory impairments. As a result, it would be a good idea to design such public mobility spaces in line with the “two senses principle” – a fundamental principle for the design of mobility systems and public buildings which is anchored in the DIN 18040 accessibility standard. The principle states that information should be conveyed and perceivable via at least two of the three senses of hearing, sight, and touch.

Micromobility is Developing Dynamically

Mirosław Suchoń
Chair, Infrastructure Committee in the Polish parliament

Road safety is one of the key challenges of modern society, and road infrastructure plays an important role in improving road safety. Poland’s national road network consists of 19,460 kilometers of roads. This includes 5,115.6 kilometers of expressways, of which 1,849.2 kilometers are highways and 3,266.4 kilometers are expressways. Since 2016, Poland’s expressway network has increased by 62%, including highways by 14% and expressways by as much as 113%.

Standardization of signage, intelligent traffic signals, or special design solutions (such as traffic circles, bicycle lanes, illuminating pedestrian crossings, or other traffic calming infrastructure elements) make it possible to effectively reduce the number of accidents. Investments in the development of road infrastructure are also aimed at improving the accessibility and flexibility of the transportation network. This, in turn, can contribute to minimizing traffic congestion and reducing the risk of collisions, resulting, among other things, from the shift of transit traffic from city centers to their outskirts. Expanding the network of highways and expressways improves traffic flow and, by reducing travel time and driver stress, has a positive impact on road safety.

Micro-mobility is developing dynamically in Polish cities. For example, in Warsaw, according to data from the City Hall, an 11% increase in bicycle traffic has been recorded compared to 2022. This is why in Warsaw the number of bicycle routes is being expanded and includes more than 771 km. Warsaw’s city bicycle rental system has been in operation since 2012. It is equipped with ca. 3,300 bicycles, including 300 with electric drive. More and more residents of Poland’s capital are using e-scooters. According to the report prepared by Łukasz Nawaro of the University of Warsaw in cooperation with a team from the Office of Strategy and Analysis of the Warsaw City Hall, the average e-scooter trip lasts 8 minutes, and the number of users is estimated at around 100,000.

Therefore, the adaptation of roads to different modes of transport and modern mobility concepts is becoming essential in the context of dynamic social and ecological changes. At the same time, the development of modern technologies, such as autonomous cars and advanced traffic management systems, pose further challenges for continued investments in the Polish road infrastructure.

In 2022, Luxembourg City provided an excellent example of good accessibility practice, for which it was awarded the "Access City Award 2022" by the European Commission. In line with the motto "Design for All", Luxembourg has focused on making it easier for people to access the city, in particular those with physical or other impairments. To this end, a Department for Integration is also working closely with organizations championing the rights of people with disabilities. Low floor buses with ramps are used throughout the city, and there are visual and audio announcements in buses and at bus stops. Users can also have display texts spoken aloud.

The right to mobility for people with disabilities is also expressly set out in Article 20 of the UN Convention on the Rights of Persons with Disabilities. However, it is clear that barrier-free access in places such as the public transport network would also benefit families with prams, travelers with luggage, or older passengers with a rollator, plus many other users.

The Facts at a Glance

- **Road design should not cause road users to act in a way that endangers safety.**
- **One of the challenges when it comes to road design is to avoid negative key stimuli that could cause people to misjudge the course of the road.**
- **Experts suggest that section control should be combined with existing automated and manual speed monitoring measures so as to encourage drivers to comply with speed restrictions over longer sections of the road network.**
- **Because vehicles approach traffic circles at a lower speed and, once on them, drive round them at a lower speed than a traditional intersection, the risk of accidents is lower.**
- **Universal traffic signs and consistent traffic rules would be advantageous.**
- **As shown by a survey conducted on behalf of DEKRA, cyclists have very different levels of knowledge about traffic signs relating to cycling infrastructure.**
- **Sufficient funds and investments are required to keep road infrastructure in good condition (maintenance, expansion, and new build of roads and bridges).**
- **Numerous cities in Europe have been designing selected road environments according to the "shared space" principle for many years.**
- **When it comes to infrastructure measures, we also need to focus more on the needs of people with physical or other impairments.**

Do Not Neglect Infrastructure!

Vehicle technology and the human factor are two key components of road safety. However, as explained in detail in the previous chapters, efficient infrastructure that works well is also incredibly important. This doesn't just mean the road itself, but also the communication technology required for automated and connected driving.

Fundamentally, many of the infrastructure measures in this report – which aim to eliminate factors that cause accidents and reduce the risks in dangerous locations – must be accompanied by traffic control interventions, most notably speed restrictions and bans on overtaking. The aim must always be to provide "self-explaining roads" with "forgiving" roadside areas. In other words, road users should be able to intuitively identify what driving behavior and speed are required based on the road design alone. It should be possible to identify dangerous spots. Stretches of road that appear to be safe, actually are safe. At the same time, the road should offer sufficient safety margins so that drivers can quickly regain control of their vehicle after a mistake, if possible resulting in no accident or an accident with less serious consequences.

However, when it comes to infrastructural measures, we also cannot overlook aspects such as speed monitoring at accident hot spots, the emergency response to road accidents, and the need to standardize the traffic rules as far as possible. Similarly, it is essential to invest regularly in the construction and maintenance of roads, bridges, and tunnels – for all types of road user. When it comes to people's lives, the relevant authorities and road construction organizations should not blindly make cuts.

Given the increasing use of connectivity and digitalization both within and outside vehicles, the available communication technologies such as 5G are also set to play an increasingly important role in infrastructure. If vehicles are to communicate among themselves and with traffic light or traffic management systems, the connectivity required for this must be guaranteed at all times. This will ensure that vulnerable road users such as pedestrians and users of two-wheeled vehicles also benefit from networked mobility.

Finally, however – as has been stated in previous DEKRA Road Safety Reports – there is one clear requirement we should never forget: if we want to prevent as many dangerous situations as possible on the roads before they even occur, it remains absolutely essential for all road users to behave responsibly, be realistic when judging their own abilities, and demonstrate a high level of acceptance for the rules and regulations. No matter how good our road and communication infrastructure or vehicle technology becomes, nothing will alter that fact.

DEKRA's Demands

The Human Factor

- **Stricter blood alcohol concentration limits can demonstrably reduce the number of traffic fatalities. This should also influence the debate about limit values for cannabis. There should be absolutely zero tolerance for novice drivers, dangerous goods transport, and passenger transport in particular.**

- **Extreme, reckless racers pose a particularly high risk to road safety, and their fitness to drive should, therefore, be examined in each individual case.**

- **The increasing number of accidents involving pedestrians and cyclists is mostly not recorded by the police, meaning it is not included in traffic accident statistics. To obtain a realistic picture of the situation here, there is an urgent need to incorporate other data sources such as hospitals and the medical profession, subject to data protection regulations.**

- **When we transform urban spaces and routes to make them nicer places to spend time in and make them more attractive for active travel methods, in particular walking and cycling, we must ensure that they remain accessible for supplies/deliveries and waste disposal as well as the rescue services, fire service, and police in the event of an emergency.**

- **There should be a greater focus on road safety education and monitoring in order to increase people's acceptance of, compliance with, and general awareness of traffic rules, in particular new ones. Accompanying image campaigns can also make a valuable contribution to this.**

Infrastructure and Statutory Regulations

- The design of roads and roadsides must consistently be geared toward maximizing safety.
- On rural roads in particular, speed restrictions must be consistent with the accident risk on individual roads or sections and with how built out the road environment is. The organizations responsible for this locally require the necessary regulatory leeway.
- On stretches with a high number of accidents, we must increasingly expand sections of road to include a third lane that alternates between the carriageways in each direction so as to provide safe overtaking possibilities.
- On critical stretches of road, bans on overtaking must increasingly be introduced and enforced.
- On rural roads, the roadside must be kept clear of obstacles such as trees, poles, etc. wherever possible. Where this cannot be done, suitable protective structures must be installed.
- Sufficient funds for investments are required to keep road infrastructure in good condition (new build, expansion, and maintenance).
- Measures to improve safety for a certain group of road users or make things more attractive for them, must not come at the expense of the safety of other groups.
- Bicycle paths and footpaths must be kept clear of obstacles as far as possible.
- It is essential that there are sufficient protected crossings for pedestrians and cyclists.
- Traffic circles can increase the flow of traffic as well as safety in many locations. It is crucial to design them safely.
- When maintaining and looking after our road infrastructure, including during the winter, pedestrian and cycling infrastructure must be considered as important as the roads.
- If the speed limit is higher than 30 km/h in built-up areas, cyclists should generally be segregated from motor vehicles.
- The world of mobility is changing at an ever-faster pace, and this requires a fast response in terms of infrastructure design. Planning timeframes must be shortened and cumbersome over-regulation must be reduced.

Technology

- Wherever possible, signposts, curve marker signs, etc. should be made of materials that minimize the risk of injury in the event of a collision, particularly for vulnerable road users.
- The establishment and expansion of smart infrastructure (Car-to-Infrastructure communication) must be accelerated in order to make the most of automated driving systems.
- In order for connected vehicle technologies and highly automated driving to succeed, reliable communication infrastructure and standards for vehicle communication also need to be ensured.
- The increasing connectivity of vehicles with manufacturer systems, and in some cases also with each other and with the traffic technology, has created entry points for cyber attacks. To close them and prevent attacks from outside, it is essential to take a holistic approach to cyber security.

Any Questions?

Your Contacts at DEKRA

Vehicle Inspections
Florian von Glasner
Tel.: +49 711 78 61-23 28
florian.von.glasner@dekra.com

DEKRA SE
Handwerkstrasse 15
70565 Stuttgart, Germany

Accident Research
Markus Egelhaaf
Tel.: +49 711 78 61-26 10
markus.egelhaaf@dekra.com

Andreas Schäuble
Tel.: +49 711 78 61-25 39
andreas.schaeuble@dekra.com

Luis Ancona
Tel.: +49 711 78 61-23 55
luis.ancona@dekra.com

DEKRA Automobil GmbH
Handwerkstrasse 15
70565 Stuttgart, Germany

Analytical Expertise on Accidents
Michael Krieg
Tel.: +49 711 78 61-23 19
michael.krieg@dekra.com

DEKRA Automobil GmbH
Handwerkstrasse 15
70565 Stuttgart, Germany

Basic Principles/Processes
André Skupin
Tel.: +49 357 54 73 44-257
andre.skupin@dekra.com

Hans-Peter David
Tel.: +49 357 54 73 44-0
hans-peter.david@dekra.com

DEKRA Automobil GmbH
Senftenberger Strasse 30
01998 Klettwitz, Germany

Traffic Psychology
Dr. Thomas Wagner
Tel.: +49 357 54 73 44-230
thomas.wagner@dekra.com

DEKRA e. V. Dresden
Senftenberger Strasse 30
01998 Klettwitz, Germany

Corporate Communications
Wolfgang Sigloch
Tel.: +49 711 78 61-23 86
wolfgang.sigloch@dekra.com

DEKRA e. V.
Handwerkstrasse 15
70565 Stuttgart, Germany

Our Services for More Safety

DEKRA ensures the safety and performance of all kinds of vehicles in road traffic. The company offers comprehensive inspection services for cars and motorbikes through to trucks and buses.

DEKRA inspects and certifies products to ensure they operate safely and comply with the relevant standards and regulations for access to global markets.

DEKRA offers comprehensive safety inspections and assessments all over the world for buildings, infrastructure, and industrial facilities.

DEKRA offers compliance, performance improvement, and supply chain services relating to safety and sustainability standards.

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Bibliography

Afukaar, F. K., Antwi, P. & Ofosu-Amaah, S. (2003). Pattern of road traffic injuries in Ghana: Implications for control. Injury Control and Safety Promotion, 10(1–2), 69-76.

Atchley, P., Shi, J. & Yamamoto, T. (2014). Cultural foundations of safety culture: A comparison of traffic safety culture in China, Japan and the United States. Transportation Research Part F, 26, 317-325.

Avenoso, A. (2011). Eine wissenschaftsbasierte Annäherung an Straßenverkehrssicherheitspolitik: Europäischer Verkehrssicherheitsrat-ETSC. Schriftenreihe Fahreignung. Bonn: Kirschbaum Verlag.

Bergmann, H. (2009). Angeschnallt und los! Die Gurtdebatte der 1970er und 1980er Jahre in der BRD. Technikgeschichte, 76(2), 105-130.

Berkman, L. F., Glass, T., Brissette, I. & Seeman, T. E. (2000). From social integration to health: Durkheim in the new millennium p. Social Science & Medicine, 51, 843-857.

Byrne, P. A., Ma, T., Mann, R. E. & Elzohairy, Y. (2016). Evaluation of the general deterrence capacity of recently implemented (2009-2010) low and Zero BAC requirements for drivers in Ontario. Accident Analysis and Prevention, 88, 56-67.

Castillo-Manzano, J. I., Castro-Nuño, M., Fageda, X. & López-Valpuesta, L. (2017). An assessment of the effects of alcohol consumption and prevention policies on traffic fatality rates in the enlarged EU. Time for zero alcohol tolerance? Transportation Research Part F: Traffic Psychology and Behaviour, 50, 38-49.

Conner, M. & Norman, P. (2015). Predicting and Changing Health Behaviour: Research and Practice with Social Cognition Models. McGraw-Hill Education (UK).

DaCoTA. (2012). Speed Enforcement. Deliverable 4.8t of the EC FP7 project DaCoTA.

Damon, N. (1958). The Action Program for Highway Safety. Annals of the American Academy of Political and Social Science, 320 (1), p. 15-26.

Elias, W. (2018). The role of fines and rewards in the self-regulation of young drivers. European Transport Research Review, 10(6).

ETSC, 2013. Back on Track to Reach the EU 2020 Road Safety Target? 7th Road SafetyPIN-Report, Accessed date.

Farah, H., Musicant, O., Shimshoni, Y., Toledo, T., Grimberg, E., Omer, H. & Lotan, T. (2014). Can providing feedback on driving behavior and training on parental vigilant care affect male teen drivers and their parents? Accident Analysis & Prevention, 69, 62-70.

Faus, M., Alonso, F., Fernández, C. & Useche, S. A. (2021). Are Traffic Announcements Really Effective? A Systematic Review of Evaluations of Crash-Prevention Communication Campaigns. Safety, 7(4).

Firth, K. (2011). Removing traffic engineering control – the awkward truth. Transport Engineering and Control, 2, 73-79.

Gargoum, S. A. & El-Basyouny, K. (2018). Intervention analysis of the safety effects of a legislation targeting excessive speeding in Canada. International journal of injury control and safety promotion, 25(2), 212-221.

Gasch, U. & Weber, L. (2017). Gaffen 4.0 – Schneller auf YouTube als im Rettungswagen! Kriminalpsychologische Annäherung an den hässlichen Bruder der Neugier. Kriminalpsychologie, 10, 571-577.

Gerlach, J., Boenke, D., Leven, J. & Methorst, R. (2008). Sinn und Unsinn von Shared Space – Zur Versachlichung einer populären Gestaltungstheorie – Teil 1. Straßenverkehrstechnik, 2, 61-65.

Grayson, G. B., Maycock, G., Groeger, J. A., Hammond, S. M. & Field, D. T. (2003). Risk, hazard perception and perceived control (TRL Report 560). Crowthorne, Berkshire: TRL Limited.

Gstalter, H. (2021). Man muss nur die Verkehrsstrafen erhöhen, dann wird alles gut. In W. Fastenmeier, U. Ewert, J. Kubitzki & H. Gstalter (Ed.). Die kleine Psychologie des Straßenverkehrs. Bern: Hogrefe, p. 83-92.

Haghpanahan, H., Lewsey, J., Mackay, D. F., McIntosh, E., Pell, J., Jones, A., Fitzgerald, N. & Robinson, M. (2019). An evaluation of the effects of lowering blood alcohol concentration limits for drivers on the rates of road traffic accidents and alcohol consumption: a natural experiment. Lancet, 393(10169), 321-329.

Hamilton-Baillie, B. (2008). Shared Space: Reconciling people, places and traffic. Built Environment, 34, 161-181.

Hofstede, G. (1984). Culture's Consequences: International Differences in Work-Related Values (vol. 5). Sage Publications.

Hofstede, G. (2001). Cultures Consequences—Comparing Values, Behaviors, Institutions, and Organizations Across Nations (2nd edition). Sage Publications.

Holte, H. (2021). Verkehrsklima 2020. Kontinuierliche Erfassung des Verkehrsklimas: Baseline Messung (German Federal Highway Research Institute Reports, Book M316). Bergisch Gladbach. Fachverlag NW in Carl Ed. Schünemann KG.

Holte, H. (2022). Der automobile Mensch – wie er fühlt, denkt und handelt. Can be accessed at https://blog.hardy-holte.de/.

Høye, A. (2014). Speed cameras, section control, and kangaroo jumps – a meta-analysis. Accident Analysis & Prevention, Vol. 73, 200-208.

Høye, A. (2018). Bicycle helmets – To wear or not to wear? A meta-analysis of the effects of bicycle helmets on injuries. Accident Analysis & Prevention, Vol. 117, 85-97.

Huang, Y.-H., Zhang, W., Roetting, M. & Melton, D. (2006). Experiences from dual-country drivers: Driving safely in China and the US. Safety Science, 44(9), 785-795.

Jäncke, L. (2015). Ist das Gehirn vernünftig? Erkenntnisse eines Neuropsychologen. Bern: Verlag Hans Huber.

Kaparias, I., Bell, M.G.H., Miri, A., Chan, C. & Mount, B. (2012). Analysing the perceptions of pedestrians and drivers to shared space. Transportation Research Part F: Traffic Psychology and Behaviour, 15(3), 297-310.

Kar, I. N., Guillaume, C., Sita, K. R., Gershon, P. & Simons-Morton, B. G. (2018). U.S. Adolescent Street Racing and Other Risky Driving Behaviors. The Journal of adolescent health, 62(5), 626-629.

Karndacharuk, A., Wilson, D. J. & Dunn, R. (2014). A Review of the Evolution of Shared (Street) Space Concepts in Urban Environments, Transport Reviews, 34(2), 190-220.

Karutz, H. (2022). Zuschauendes Verhalten an Unglücksorten – nicht immer ist es „Schaulust", nicht immer sind es „Gaffer". Bundesgesundheitsblatt, Gesundheitsforschung, Gesundheitsschutz, 65(10), 1043-1050.

Kashima, Y., Siegal, M., Tanaka, K. & Kashima, E. S. (1992). Do people believe behaviours are consistent with attitudes? Towards a cultural psychology of attribution processes. British Journal of Social Psychology, 31(2), 111-124.

Lewis, I., Watson, B. & Ho, B. (2021). Slow down! Get off that phone! The impact of a high school road safety education program in influencing whether a young person speaks up to a risky driver. Transportation Research Part F: Traffic Psychology and Behaviour, 78, 353-368.

Linkov, V. & Zámečník, P. (2020). Cultural Differences-Induced Mistakes in Driving Behaviour: An Opportunity to Improve Traffic Policy and Infrastructure. In E. Vanderheiden & C.-H. Mayer (Ed.), Mistakes, Errors and Failures across Cultures: Navigating Potentials (p. 605-619). Springer International Publishing.

Liu, J., Wen, H., Zhu, D., & Kumfer, W. (2019). Investigation of the Contributory Factors to the Guessability of Traffic Signs. International Journal of Environmental Research and Public Health, 16(162), 1-21.

Lund, I. O., & Rundmo, T. (2009). Cross-cultural comparisons of traffic safety, risk perception, attitudes and behaviour. Safety Science, 47(4), 547-553.

McDougall, S. J. P., Curry, M. B. & Bruijn, O. de. (2010). The Effects of Visual Information on Users' Mental Models: An Evaluation of Pathfinder Analysis as a Measure of Icon Usability. International Journal of Cognitive Ergonomics, 5(1), 59-84.

Meesmann, U., Martensen, H. & Dupont, E. (2015). Impact of alcohol checks and social norm on driving under the influence of alcohol (DUI). Accident Analysis and Prevention, 80, 251-261.

Melinder, K. (2007). Socio-cultural characteristics of high versus low risk societies regarding road traffic safety. Safety Science, 45, 397414.

Meyer, L., Wagner, T. & Winkelmann, A. (2021). "Too fast and not furious" – Verbotene Kraftfahrzeugrennen nach § 315d StGB. Zeitschrift für Verkehrssicherheit (Road Safety Magazine), 67(3), 158-169. Montella, A., Persaud, B., D'Apuzzo, M. & Imbriani, L. L. (2012). Safety Evaluation of Automated Section Speed Enforcement System. Transportation Research Record, 2281(1), 16-25.

Moody, S. & Melia, S. (2014). Shared Space – research, policy and problems. Proceedings of the Institution of Civil Engineers – Transport, 167(6), 384-392.

Ng, A. W. Y. & Chan, A. H. S. (2007). The guessability of traffic signs: Effects of prospective-user factors and sign design features. Accident Analysis & Prevention, 39, 1245-1257.

Nordfjærn, T. & Şimşekoğlu, Ö. (2014). Empathy, conformity, and cultural factors related to aberrant driving behaviour in a sample of Urban Turkish drivers. Safety Science, 68, 55-64.

Nordfjærn, T., Şimşekoğlu, Ö. & Rundmo, T. (2014). Culture related to road traffic safety: A comparison of eight countries using two conceptualizations of culture. Accident Analysis & Prevention, 62, 319-328.

Nordfjærn, T. & Zavareh, M. F. (2016). Individualism, collectivism and pedestrian safety: A comparative study of young adults from Iran and Pakistan. Safety Science, 87, 8-17.

Özkan, T., Lajunen, T., Chliaoutakis, J. El., Parker, D. & Summala, H. (2006). Cross-cultural differences in driving behaviours: A comparison of six countries. Transportation Research Part F: Traffic Psychology and Behaviour, 9(3), 227-242.

Özkan, T., Lajunen, T., Chliaoutakis, J. El., Parker, D. & Summala, H. (2006). Cross-cultural differences in driving skills: A comparison of six countries. Accident Analysis and Prevention, 38, 1011-1018.

Peterson, C. M., Gaugler, J. E., Nelson, T. F. & Pereira, M. A. (2021). "Slowed for several months": A mixed methods comparison of minor, moderate, and extreme speeders. Transportation Research Interdisciplinary Perspectives, 12(2), 100511.

Peterson, C. M., Nelson, T. F. & Pereira, M. A. (2021). Driver speeding typologies by roadway behaviours and beliefs: A latent class analysis with a multistate sample of U.S. adults. Transportation Research Part F: Traffic Psychology and Behaviour, 81, 373-383.

Phillips, R. O., Ulleberg, P. & Vaa, T. (2011). Meta-analysis of the effect of road safety campaigns on accidents. Accident; analysis and prevention, 43(3), 1204-1218.

Rößger, L., Schade, J., Schlag, B. & Gehlert, T. (2011). Verkehrsregelakzeptanz und Enforcement. Research report by the Gesamtverband der Deutschen Versicherungswirtschaft e.V. (Association for accident research on behalf of insurance companies in Germany, Part of the German Insurance Association)

Rundmo, T. (1999). Perceived risk, health and consumer behaviour. Journal of Risk Research, 2(3), 187-200.

Schade, J., Rößger, L., Eggs, J., Follmer, R. & Schlag, B. (2019). Entwicklung und Überprüfung eines Instruments zur kontinuierlichen Erfassung des Verkehrsklimas.: Report on research project FE 82.0639/2015 (German Federal Highway Research Institute Reports, Book M289). Bergisch Gladbach. Fachverlag NW in Carl Ed. Schünemann KG.

Schlag, B., Anke, J., Lippold, C., Wittig, J. & Walther, A. (2019). Wahrnehmungspsychologische Aspekte (Human Factors) und deren Einfluss auf die Gestaltung von Landstraßen. German Federal Highway Research Institute, "Verkehrstechnik" series, book V 317. Report on research project: FE 02.0366/2013/FGB. Bergisch Gladbach: German Federal Highway Research Institute.

Schneider, W. & Shiffrin, R.M. (1977). Controlled and automatic human information processing I: Detection, search and attention, Psychological Review 84, 1-66.

Sherman, L. E., Payton, A. A., Hernandez, L. M., Greenfield, P. M. & Dapretto, M. (2016). The Power of the Like in Adolescence: Effects of Peer Influence on Neural and Behavioral Responses to Social Media. Psychological science, 27(7), 1027-1035.

Sjöberg, L. (2000). Factors in Risk Perception. Risk Analysis: An International Journal, 20(1), 1-12.

Soole, D. W., Watson, B. C. & Fleiter, J. J. (2013). Effects of average speed enforcement on speed compliance and crashes: A review of the literature. Accident Analysis & Prevention, 54, 46-56.

Stefanidis, K. B., Davey, B., Truelove, V., Schiemer, C. & Freeman, J. (2022). Does exposure to social media content influence attitudes towards, and engagement in, road rule violations? A systematic review. PloS one, 17(9), e0275335.

Stevenson, M., Harris, A., Wijnands, J. S. & Mortimer, D. (2021). The effect of telematic based feedback and financial incentives on driving behaviour: A randomised trial. Accident; analysis and prevention, 159, 106278.

Stöcker, A.-K. & Schütz, A. (2019). Das Konzept von „Beibehalten vs. Verändern" – Effekte unterschiedlicher Formen von Feedback. Report Psychologie, 44(10), 14-19.

Sümer, N., Özkan, T. & Lajunen, T. (2006). Asymmetric relationship between driving and safety skills. Accident Analysis & Prevention, 38(4), 703-711.

Velichkovsky, B., Rothert, A., Kopf, M., Dornhöfer, S. & Joos, M. (2002). Towards an express-diagnostics for level of processing and hazard perception. Transportation Research Part F: Traffic Psychology and Behaviour, 5(2), 145-156.

Vingilis, E., Yildirim-Yenier, Z., Vingilis-Jaremko, L., Wickens, C., Seeley, J., Fleiter, J. & Grushka, D. H. (2017). Literature review on risky driving videos on YouTube: Unknown effects and areas for concern? Traffic injury prevention, 18(6), 606-615.

Vollrath, M., Krüger, H.-P. & Löbmann, R. (2005). Driving under the influence of alcohol in Germany and the effect of relaxing the BAC law. Transportation Research Part E: Logistics and Transportation Review, 41(5), 377-393.

Wang, W., Cheng, Q., Li, C., André, D. & Jiang, X. (2019). A cross-cultural analysis of driving behavior under critical situations: A driving simulator study. Transportation Research Part F, 62, 483-493.

Warner, H. W., Özkan, T., Lajunen, T. & Tzamaloukas, G. Sp. (2013). Cross-cultural comparison of driving skills among students in four different countries. Safety Science, 57, 69-74.

Wickens, C. D., Hollands, J. G., Banbury, S. & Parasuraman, R. (2013). Engineering Psychology and Human Performance. (4th edition). Boston: Pearson.

Wickens, C. M., Smart, R. G., Vingilis, E., Ialomiteanu, A. R., Stoduto, G. & Mann, R. E. (2017). Street racing among the Ontario adult population: Prevalence and association with collision risk. Accident Analysis and Prevention, 103, 85-91.

Winkelbauer, M. & Soteropoulos, A. (2016). Wirksamkeit von Section Control. Zeitschrift für Verkehrsrecht (Traffic Law Magazine), 333-340.

Wundersitz, L. N., Hutchinson, T. P. & Wooley, J. E. (2010). Best practice in road safety mass media campaigns: A literature review (Report No. CASR074). Centre for Automotive Safety Research.

DEKRA
Handwerkstrasse 15
70565 Stuttgart
Germany
Tel. +49 711 7861 0
Fax +49 711 7861 2240
www.dekra.com

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