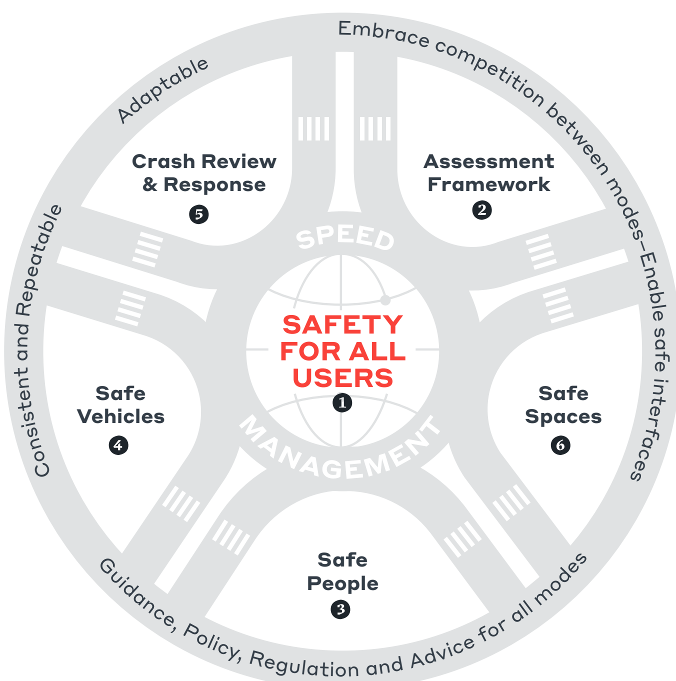
Intelligent Transport Systems *Advance Vision Zero Road Safety*

The following series explores how intelligent transport systems can become part of the Vision Zero road safety solution. Vision Zero seeks to eliminate fatalities and serious injuries within the worldwide road transportation system. The Swedish Parliament adopted Vision Zero in 1997, recognizing that death and serious injury are not acceptable consequences of mobility. Today, countries and cities around the world continue their journeys toward achieving a higher level of road safety,[1] applying the Vision Zero philosophy and evidenced-based approach to designing safe road systems.

Ongoing progress toward the goal of "zero" requires adopting an evolved view of road safety based on shared responsibility between road users and system designers, departing from traditional approaches that put the onus on individual road users to ensure their own safety. Together, road users and system designers[2] are responsible for the existence of a Safe System. Road users should adhere to regulations, but they also make mistakes; system designers have the responsibility to plan, design, implement, operate and maintain road systems that take into account human error. Shared responsibility also engenders a holistic understanding of system interdependencies and interfaces—key to designing safe road systems for all users.

Viewing each intelligent transport system (ITS) within the broad context of a transport system—considering people, processes, infrastructure, vehicles, technology and associated data—is already standard practice in some parts of the world but a relatively new concept in others. The first article in the ITS-Vision Zero series explores the ITS whole-system approach in the United Kingdom (UK), where it was established more than two decades ago. The UK approach and use cases from the United Kingdom and Australia provide guidance for application as communities of all sizes seek to implement road safety according to Vision Zero.



Articles in the six-part series

1. Intelligent Transport Systems Advance Vision Zero Road Safety
2. On the "ITS" Road Toward Vision Zero
3. Effective Intelligent Transport Systems Integrate Human Factors
4. Adopting the "ITS" Holistic View to Advance Road Safety
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6. Creating Safe Road Ecosystems

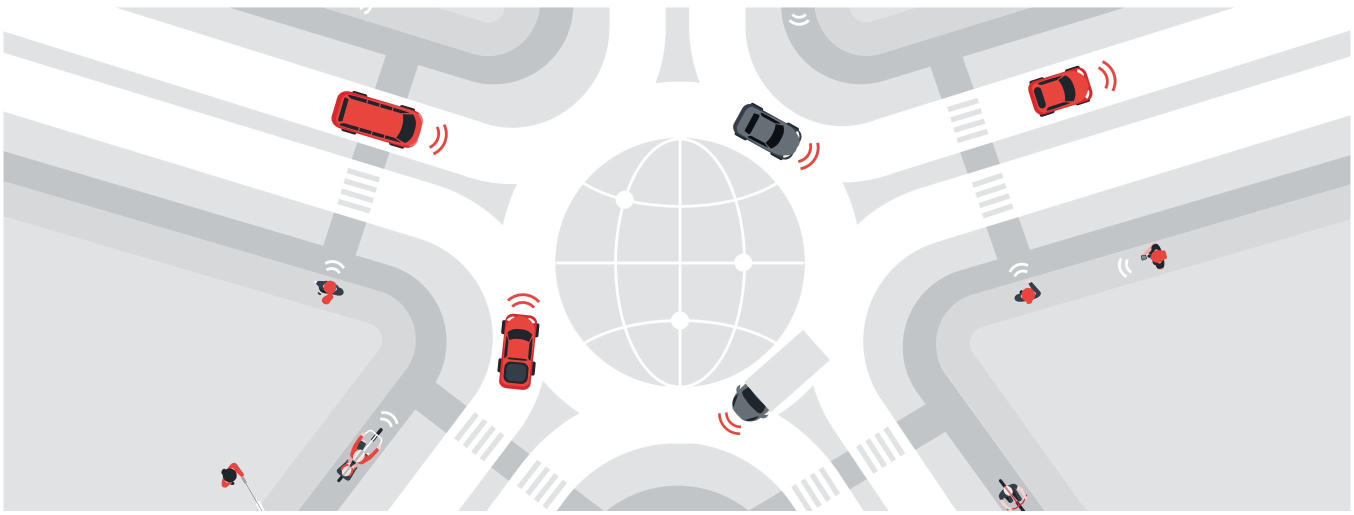
1 See the brochure: Vision Zero: setting a higher standard for road safety, WSP, pp. 11-13

2 System designers–according to the Vision Zero approach–include policymakers, politicians/government officials, infrastructure owners and operators, planners, engineers and road designers, vehicle manufacturers, trauma and hospital care providers, enforcers, plus any others who provide for the road transport system. Each contributes important knowledge and expertise to help make and keep roads safe.

1

Intelligent Transport Systems Advance Vision Zero Road Safety

Adopting whole-system approaches enables safe and sustainable mobility for all.



Society is facing significant issues: the impacts of climate change, increasing levels of congestion and the health consequences of COVID-19. All of these issues affect mobility—why, when and how people move about in their daily lives. Communities around the world must also continue to address another global public-health issue affecting both human life and mobility: Today, approximately 1.3 million people die on the world's roads each year from traffic crashes; another 20 million to 50 million people are seriously injured.[1]

Road Safety Urgency

Approximately 1.3 million people die on the world's roads each year; another 20 million to 50 million people are seriously injured.

Vulnerable Road Users
More than half of all road traffic deaths are among pedestrians, cyclists and motorcyclists.

Source: World Health Organization

1 World Health Organization

As communities increasingly seek to reshape transport systems to provide accessible, affordable and environment-friendly options, there is greater opportunity to focus on the fundamental human need for effective road safety. Transport infrastructure networks that facilitate the safe movement of people and goods will also enable communities to thrive and prosper.

How can we—all those responsible for planning, designing, operating and maintaining transport and infrastructure—use this period of upheaval to create safe and sustainable roads and mobility for everyone? The answer begins by considering how the benefits of the rapidly growing intelligent transport system (ITS) market can support a paradigm shift to the Vision Zero road-safety approach (Figure 1).

Vision Zero's main message is that death and serious injury on the world's roads are preventable.

Effective intelligent transport systems integrate people, processes, infrastructure, vehicles, technology and associated data to form safe and efficient environments for the movement of people and goods. It is when ITS is considered in this holistic manner—rather than focusing solely on the technological aspects—that it achieves the most beneficial outcomes. Without this system-based approach, potentially positive changes to individual aspects can have adverse impacts on other parts, and therefore on the overall system. Introducing a new technology, for example, may create an unintended negative effect on safety if it has not been considered holistically.

PARADIGM SHIFT

	Traditional/Prevailing	Vision Zero
Issue	Preventing all crashes	Preventing fatalities and serious injuries
Premise	Deaths are inevitable	Deaths are preventable
Focus	Perfecting human behavior	Designing a road system that takes into account human error
Responsibility	Individual road users	Shared: road users and system designers

Figure 1 — Principles of Vision Zero

Powerful Partnership

Providing infrastructure for 21st-century mobility is a multifaceted undertaking that requires contributions from diverse stakeholders. The Vision Zero approach embraces these key stakeholders—known as system designers[2]—who apply their knowledge and expertise to make and keep roads safe for all users—including pedestrians, cyclists, motorcyclists, drivers, passengers and those for whom the transport network is their workplace. The Vision Zero framework considers all users, modes and interfaces—and prioritises consideration of the safe passage of vulnerable road users who comprise more than half of all road fatalities.

Road safety approaches have tended to focus on perfecting human behaviour rather than designing a road system that accounts for human error. Vision Zero views safety in the context of the entire road system and accounts for human error.

The Vision Zero paradigm is based on shared responsibility among the road transport system users and system designers (Figure 2). Road users should follow the rules; system designers are responsible for preventing severe injury and death on urban and rural roads. If users fail to comply with these rules—due to a lack of knowledge, acceptance or ability—the system designers are required to take the necessary further steps to counteract people being killed or seriously injured.

If the road users fail, the system should not; all parts of the system need to be considered so that if one part falls short other parts will protect users.

A fundamental tool in creating a Safe System—including safe people, safe spaces and safe vehicles—is speed management, or managing the speed of vehicles according to what is appropriate for the environment. The Safe System approach ensures that the impact energy of an incident remains below the threshold likely to result in death or serious injury.

Intelligent transport systems can have a key role in enabling the achievement of a safe transport system. To be effective, it is essential that the whole system is considered, not just the technology. Aligning this holistic approach to ITS with Vision Zero proven practices has led to a reduction in fatalities and serious injuries.

Automated Speed Enforcement, *Sweden*

The installation of "life-saving cameras" in Sweden has reduced fatalities by 50% and all injuries by 20%.[3]

Shared Responsibility

System designers are ultimately responsible for the design, operation and use of the road transport system and are thereby responsible for the level of safety within the entire system.

Road users are responsible for following the rules for using the road transport system set by the system designers.

If the road users fail to obey these rules due to a lack of knowledge, acceptance or ability, or if injuries do occur, the system designers are required to take the necessary further steps to counteract people being killed or seriously injured.

Figure 2 — Responsibility for safety is shared in the Vision Zero approach. (adapted from the Swedish Transport Administration)

2 System designers–according to the Vision Zero approach–include policymakers, politicians/government officials, infrastructure owners and operators, planners, engineers and road designers, vehicle manufacturers, trauma and hospital care providers, enforcers, plus any others who provide for the road transport system. Each contributes important knowledge and expertise to help make and keep roads safe.

3 *The Handbook of Road Safety Measures*, chapter 8.2, Institute of Transport Economics (TØI)

The controlled motorway, introduced on the M25 West of London in 1995, used speed-management technology to smooth traffic flows, reduce congestion, reduce harmful emissions and create more reliable journey times. The smoothing of traffic flows and reduction in journey times considerably reduced driver stress and impatience, directly contributing to a reduction in collisions. The smoother flow of traffic also reduced noise and air pollution resulting in a benefit to public health. Controlled motorways now cover 220 kilometres (137 miles) of the English motorway network and carried 7 billion miles of traffic by the end of 2018; the overall safety benefit has been a reduction of 13 percent in fatal and weighted injury rates.[4]

The controlled motorway demonstrated that creating a controlled environment led to more compliant behaviour so that when lower speed limits were displayed, they were obeyed. Driver education was an integral part of the scheme and resulted in motorists understanding that by obeying the variable speed limits they would experience less stressful and safer journeys. The actual number of speed cameras required to achieve the outcomes was relatively low.

Prioritising speed management, a cornerstone of Vision Zero, can be facilitated using ITS technologies and processes—which include education alongside engineering and enforcement-compliance. This holistic approach brings the ability to provide different solutions; in some locations, for example, installing speed cameras will likely result in injury reduction, which, in other contexts requires further measures.

The development of smart motorways in England, starting with the Active Traffic Management (ATM) Pilot in 2006, has relied upon the alignment of ITS with the Safe System approach of shared responsibility that lies at the heart of Vision Zero. The assessment framework developed for the ATM Pilot was used to identify, assess and mitigate the impacts of the (over 100) potential hazards within the operational system, and used to frame the design. Examples of the hazards defined include events such as 'Driver drives too fast' and 'Vehicle stops in traffic lane'.

A paradigm shift in road safety to Vision Zero will continue to lead to meaningful reductions in road traffic deaths.[5] Aligning ITS with a Vision Zero mindset and methodology creates a powerful partnership—full of opportunities to transform the design, operation and management of road transport networks and achieve meaningful outcomes.

Active Traffic Management (ATM) Pilot, *England*

The ATM Pilot combined technology, people, process and infrastructure to create a new operational transport system.

The pilot demonstrated the following safety, health and environmental benefits:

26% reduction in average journey time

50% reduction in personal injury accident rate

80% of the benefit for 20% of the cost (compared to widening)

4% reduction in fuel consumption

30% reduction in noise levels

7.5% reduction in level of harmful pollutants

Variable Speed Limit Operations *Queensland, Australia*

In the first year of smart motorways, motorists experienced a nearly 50% drop in rear-end crashes with variable speed-limit signs on the Bruce Highway. The severity of crashes also reduced, with the percentage of hospitalisation crashes dropping from 43% to 20% since the implementation of variable speed-limit signs on the Bruce Highway.

4 *Smart Motorway Safety, Evidence Stocktake and Action Plan*, Department for Transport (DfT), United Kingdom, 2020

5 *Vision Zero: Setting a Higher Standard for Road Safety*, WSP, pp. 12-13

Mobility in a Changing World

While the achievement of Vision Zero is a complex effort, cities and countries are rising to meet the challenges that come with a commitment to develop safe roads and safe mobility. International organisations—including the United Nations, the World Health Organization, World Resources Institute, and the Organisation for Economic Co-operation and Development—have endorsed the Safe System approach to road safety.

Working in sync, ITS and Vision Zero can embrace change and implement appropriate practices. Both are based on strategic, evidence-based, whole-system approaches that improve road safety.

The mobility landscape is constantly evolving—responding to and preparing for demographic, economic, environmental and technological developments. Whole-system approaches consider influential dimensions—of developments individually and in combination.

Significant dimensions for consideration include:

- **Climate Emergency** – The transport sector needs to be decarbonised if the globally agreed safety threshold of a 2°C increase in average temperature is to be achieved. Fundamental changes to the transport system will be required to attain this goal—including infrastructure design and construction, shared mobility, propulsion/fuel—all of which impact the types, mix and profile of risk within the system.
- **Congestion** – Demand for mobility and use of the transport system fluctuates according to economic growth. Greater demand for mobility increases traffic volumes and congestion and therefore the risk of injury and death. No one should be excluded from safe, affordable and reliable transport; adapting the system to become more inclusive changes the risk profile and introduces new challenges and opportunities.
- **Health** – Transport can also negatively affect public health due to vehicle emissions, noise and brake dust. These undesired consequences adversely affect air quality and can create health issues. A holistic approach needs to be taken, as improved access to transport can also support improved health. New risks and opportunities continue to emerge. For example, the COVID-19 global pandemic fundamentally changed how people, commerce and places function. COVID-19 has accelerated some positive societal changes and responses as well as introducing new risk-reducing behaviours and reactions.

These and other factors will continue to affect decision-making. The key is appreciating that transport is a system with multiple dependencies and interfaces. Any change or disruption needs to be recognised and managed within the context of the system, rather than in isolation. A single change in one part of the system can have unintended consequences elsewhere—hence the need to consider the system holistically.

For example, the removal of the hard shoulder on motorways in England to increase capacity was considered in a holistic way to maintain a safe network. This shift represented a new operational regime for motorways and needed to be approached in the context of an operational system. The overall system design took account of the interfaces and dependencies between road infrastructure, people and vehicles. An evidence-based hazard analysis was used to

Bruce Highway Road Operations Improvements Project (BHROIP) *Queensland, Australia*

The BHROIP provides increased situational awareness across 1700 km of rural highway, using bespoke technology for incident detection, flood monitoring and traveller information provision to create a safe operating system.

Smart Motorway (All Lane Running, ALR) development in *England*

The Smart Motorway Programme for English motorways is based on the conversion of the hard shoulder into a traffic lane, using physical infrastructure, technology, people and processes to create a safe operating system.

The DfT Stocktake found:

- Fatal and weighted injury (FWI) rates on ALR roads were lower (0.35 per hundred million vehicle miles (hmvm) than on conventional motorways (0.38).
- Overall, the collision risk declined after ALR was introduced, which was consistent with earlier modelling.

determine the overall safety and risk profile for the new operational regime. Using the Safe System approach developed for the ATM Pilot, it was determined that safety could be improved compared to a baseline of a standard motorway. This was confirmed by post-opening monitoring studies and tested during the Department for Transport's *Smart Motorway Safety Evidence Stocktake and Action Plan*.[6]

Traffic Officer Procedures

Highways England's Traffic Officer Service helps to keep road users safe and to keep traffic moving on the strategic road network (SRN) of motorways and all-purpose trunk roads. They attend to incidents, provide rolling road blocks and many other customer-facing services that enable the safe operation of the SRN.

Traffic Officers form an essential part of the overall Safe System, linking technology and infrastructure with people and process. They work according to procedures designed to form part of that overall Safe System.

Traffic Officers have attended almost 1 million incidents since 2015.

Transport Systems from the ITS Perspective

Transport systems comprise dependent and interacting elements. At a system level, any disruption or sub-optimal performance leads to inefficiency. When the system is managed safely, it also becomes more efficient.

On an elemental level, any mobility-transport system comprises five interdependent areas:[7]

- **Physical Space**
  the infrastructure, including technology, signs, lining, etc.
- **Users**
  the people who use and access the system
- **Vehicles**
  cars, buses, trucks, motorcycles, etc.
- **Designers & Implementers**
  the people responsible for creating and building the system
- **Operators & Maintainers**
  the people who operate and maintain the system

The users of the system are diverse and complex—from drivers and passengers to pedestrians and cyclists—each with their own needs and vulnerabilities that need to be considered.

Within a transport system, competition exists between modes, users and network types. It is the interfaces and interactions within the system that most often lie at the heart of any issue. The whole system therefore needs to be designed and operated to achieve the required outcomes—with the Safe System approach guiding the process.

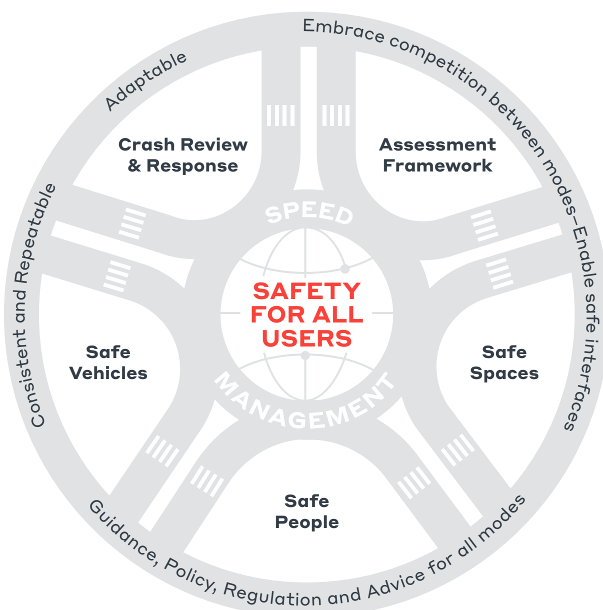


Figure 3 — Re-imagining the transport system and aligning with the Safe System approach will create sustainable outcomes.

6 *Evidence Stocktake and Action Plan*, DfT, United Kingdom, 2020

7 Noting - According to the Vision Zero approach, system designers include designers, implementers, maintainers and operators as described in the text and referred to in Figure 1 and Figure 2.

Safety at the Centre

Most serious traffic incidents are both predictable and preventable. Adding ITS, with its data-led ethos, to Vision Zero practices creates greater ability to prevent serious injuries and fatalities.

The Safe System approach manages the interactions between system components throughout the whole lifecycle of a network—taking full account of human vulnerability and resulting in a system that has been designed to be forgiving of human error. It is based on understanding and considering the needs of all users.

By placing safety at the centre of the system, those involved in designing, managing and operating the system can clearly see how their decisions and actions impact safety and their contribution towards achieving Vision Zero. An evidence-led approach, using both qualitative and quantitative data, enables system designers to get to the root causes of the failures that lead to death and serious injury. Understanding and dealing with the root causes, rather than the symptoms or presenting issues, leads to safer systems. ITS can be an enabler within the overall system that supports safe and efficient operation.

ITS solutions range from a simple, fixed-plate speed-limit sign, for example, to an all-encompassing system that links together vehicles, infrastructure and customers. The A2M2 Connected Vehicle Corridor Trial tested systems that connect motorway signalling with displays in test vehicles to demonstrate the potential benefits of providing variable speed limit and roadworks information directly into in-vehicle displays.

Figure 4 — A2M2 Connected Vehicle Corridor trial of in-vehicle 'virtual gantries'

The Future Role of ITS

It could be argued that technology has been used to manage mobility since the introduction of the first traffic signals in London in 1868. The manually operated gas-lit signal exploded less than a month after it was implemented, injuring the police officer operating it—an example of a non-holistic approach, where the introduction of one element in the system had an adverse impact on another part of that system (the human operator). The use of technology within transport has evolved significantly since those early pioneering attempts, which makes the evidence-based Safe System approach even more important as systems become increasingly complex.

It is essential that ITS is viewed as, and within, a holistic system that enables mobility, and one that considers the whole transport system and its interfaces rather than focusing on the individual devices or the technology in isolation. Just as with Vision Zero, all aspects need to work in harmony with each other for the system to operate safely and efficiently. When considered and used properly from the outset, ITS can therefore become part of the Vision Zero road safety solution.

Moving Forward Together

Transport systems are an intrinsic part of any society, enabling mobility, which in turn facilitates access to activities—education, employment, social interaction—that create vibrant and healthy communities. While increasing reliance on technology presents both opportunities and challenges for ITS, there is a timely opportunity to integrate ITS into socially acceptable solutions and practices that support Vision Zero. It is imperative that the benefits of technology and digital advances are brought into a whole-system approach to continuously reduce the number of deaths and injuries in transport.

Using leading safety indicators creates a more proactive method and culture of decision-making that embraces safety, inclusivity, health and wellbeing as fundamental components of thriving transport-mobility systems. Looking backwards at what has happened and why provides valuable evidence and understanding of how and where a system has failed; looking forward requires the desired outcome to be articulated. The Vision Zero approach combined with data-led ITS solutions enables a sustainable route towards the desired and essential outcome—no deaths or serious injuries on the world's roads.

Leading safety indicator examples:

- Reporting of near misses enables action to be taken to prevent injury: Reporting instances of scalding or near misses with hot water and kettles in offices led to the use of taps that dispense boiling water, removing the hazard.
- Reports of tyre scuffs on kerbs indicate that drivers are not cornering safely—leading potentially to a reduced speed limit, preventing more serious incidents.

WSP Author

Ian Patey

Head of Profession, Intelligent Transport
United Kingdom

ian.patey@wsp.com

WSP Author

Lucy Wickham

Senior Technical Director, Operations and Safety, Intelligent Transport
United Kingdom

lucy.wickham@wsp.com

WSP Contributor

Karin Hassner

Traffic Planner, Road Safety Expert
Sweden

karin.hassner@wsp.com

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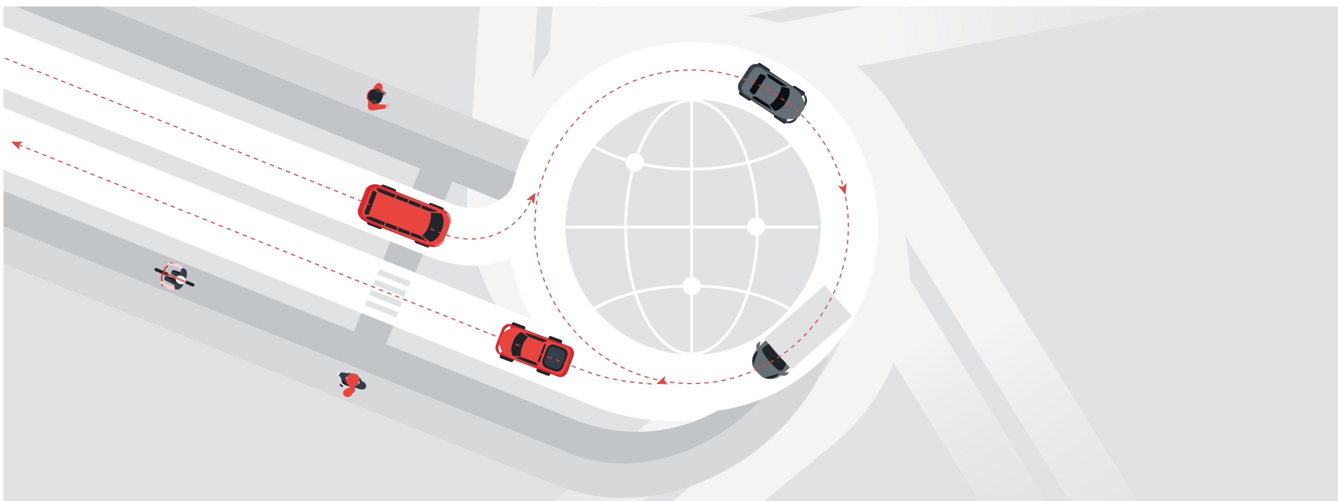
On the "ITS" Road Toward Vision Zero

Exploring the assessment framework approach developed for smart motorways in England



Vision Zero is rooted in the position that death and serious injury are not acceptable consequences of mobility. Death and serious injury are preventable within the worldwide road transportation system.

In the Safe System approach, the interaction and interdependencies that exist between people, spaces and vehicles take place within the context of an evidence-based road-safety-management system. This understanding moves our thinking toward a more collaborative environment characterised by pre-emptive safety through incident prevention.

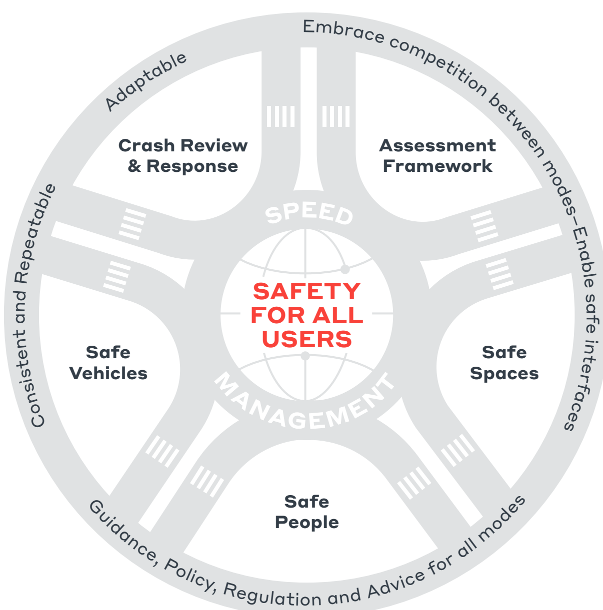


Figure 1 — The data-led intelligent transport system (ITS) whole-system approach considers diverse aspects—to develop safe transport systems for all users.

The overall management system relies on an effective assessment framework to tie together the various road-safety elements and to recognize and understand the related interfaces and interdependencies.

Effective intelligent transport systems combine people, processes, infrastructure, vehicles, technology and associated data to form safe and efficient environments for the movement of people and goods. It is when ITS is considered in this holistic manner—rather than focusing solely on the technological aspects—that it achieves the most beneficial outcomes. Without this system-based approach, potentially beneficial changes to individual aspects can have adverse impacts on other parts, and therefore on the overall system. Introducing a new technology, for example, may create an unintended negative impact on safety if it has not been considered holistically.

Embracing Holistic Thinking

Thinking holistically is then the first step in providing safe road systems. How communities currently form that holistic view and put it into practice varies around the world according to local context. In the United States, for example, this all-inclusive approach is the foundation of what is called Transportation Systems Management and Operations (TSMO). The TSMO philosophy is embraced and encouraged by agencies of all sizes and scopes, and focuses on integrating planning, funding decisions (or programming) and design with operations and maintenance to holistically manage the transportation network and optimise existing infrastructure. Within the TSMO context, optimising the existing network considers all the operational goals of an agency. Safety is usually the top goal of transportation agencies throughout the country. As part of this TSMO process, many agencies will more actively conduct a safety analysis early in the planning process, and with the input and engagement of operations personnel who might have more first-hand awareness of the needs. The analysis will allow planners to more effectively apply countermeasures that are crucial in decreasing the number of collisions, reducing congestion and maintaining the efficiency of the transportation system.

Highways England has put in place a formal and comprehensive assessment framework approach that is integral to the long-established ITS whole-system perspective. This approach enables the safety implications of any potential change or intervention within a transport network to be evaluated prior to implementation using existing qualitative and quantitative data. The predicted outcome is validated when in operation.

Improving Safety

Combining the Vision Zero paradigm—based on shared responsibility among the road-transport-system users and system designers[1] —with an ITS data-led whole-system approach creates the best range of solutions. According to Vision Zero[2], if road users fail to comply with established rules—due to a lack of knowledge, acceptance or ability—system designers must take the necessary further steps to counteract people being killed or seriously injured. In the United Kingdom, the Highways England smart motorways M42 Active Traffic Management (ATM) Pilot demonstrated that the creation of a controlled environment[3] supports Safe System design and encourages compliant human behaviour. A look at the details of the M42 ATM scheme reveals the vital role of a comprehensive, systematic and data-led assessment framework in achieving a higher standard of safety. The development of smart motorways in England, starting with the ATM Pilot in 2006, has relied upon the alignment of ITS with the Safe System approach of shared responsibility that lies at the heart of Vision Zero.

UK Smart Motorways M42 ATM Pilot Pioneers a Formal and Comprehensive Assessment Framework

A formal and comprehensive safety risk assessment framework approach was developed in England under the auspices of the smart motorways M42 ATM Pilot—in the early 2000s. This ground-breaking scheme on the motorway/freeway in the midlands region of England was designed to make better use of the carriageway space, relieve congestion and improve journey time reliability. The scheme introduced a new operational regime where the hard shoulder would be open to traffic at times of congestion. It was necessary to demonstrate that this new regime could operate safely—hence a means of demonstrating that safe operation was required.

The scheme was set in the context of a significant rail disaster in England, Great Heck 2001, which resulted from a vehicle leaving the motorway and coming to rest on a railway track

1 System designers–according to the Vision Zero approach–include policymakers, politicians/government officials, infrastructure owners and operators, planners, engineers and road designers, vehicle manufacturers, trauma and hospital care providers, enforcers, plus any others who provide for the road transport system. Each contributes important knowledge and expertise to help make and keep roads safe.

2 *Vision Zero: Setting a higher standard for road safety, WSP, pp.10-11*

3 A controlled environment is where the use of infrastructure and technology results in motorists who concentrate on the information being provided as they react and behave as necessary. The technology and infrastructure deployed on a managed motorway provides the motorists with regularly updated information/reassurance as to the status of the road, and this results in more compliant driver behaviour, leading to successful and safe scheme outcomes. Revue Routes Roads magazine, Issue No. 352-353, pp. 130-137

in the path of an oncoming train. It remains the worst rail disaster of the 21st century in the United Kingdom. The road and rail networks had each been designed for safe operation but not necessarily designed as a joined-up system. This disaster resulted in cross-industry interest, greater collaboration and a realisation that safety should be considered in a more systematic and holistic way than had been undertaken previously.

The M42 ATM scheme was one of the first of its kind on which a formal and comprehensive assessment of operational safety risk was used—to assess, analyse and determine the risk profile on the network and then to predict the risk profile on the same piece of network following implementation of the scheme with mitigations in place. This measure was undertaken to ensure that the design addressed all the significant hazards that had been identified, assessed and quantified. The mitigations comprised a suite of infrastructure interventions and process/procedural changes, many of which were not included in the standards current at that time.

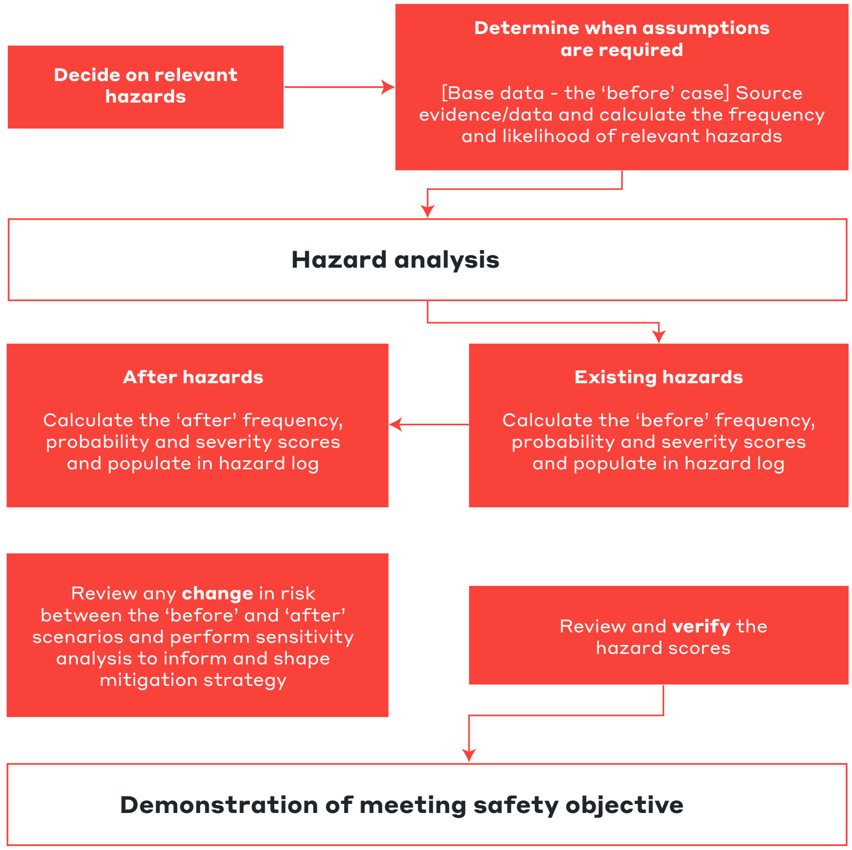


Figure 2 – Methodology used to score hazards

Understanding User Behaviour Within the System

Through the M42 ATM scheme, it was recognised that the right information needed to be provided to the user at the right place, at the right time and in the most appropriate way/format to achieve the required and desired outcomes.

Speed management, a key component of the Vision Zero model, was a critical aspect within the design of the Safe System interventions—compliance, rather than enforcement, was the driving force to create a controlled environment where users intuitively understood what to do safely. While speed cameras were deployed across the 14-km scheme length, the combination of driver education, signs and markings, and the perception that enforcement was prevalent created the controlled environment and encouraged the compliant behaviour that was necessary to achieve the required and desired scheme outcomes.

Understanding the Most Important Hazards

A comprehensive hazard log was drafted—made up of some 150 hazards. The hazards were all scored using the methodology shown in Figure 2 (on the next page).

This assessment clearly demonstrated that the majority of energy should be concentrated in mitigating the highest risks, as this would make the biggest difference. It redirected energies away from the technology and focused efforts on understanding the foundations of the risk profile that exist on the highway, which is fundamentally shaped by user behaviours (travelling too fast for the conditions, too close and not keeping in lane).

SAFETY RISK ASSESSMENT

A small number of hazards make up the majority of risk — focus on mitigating these

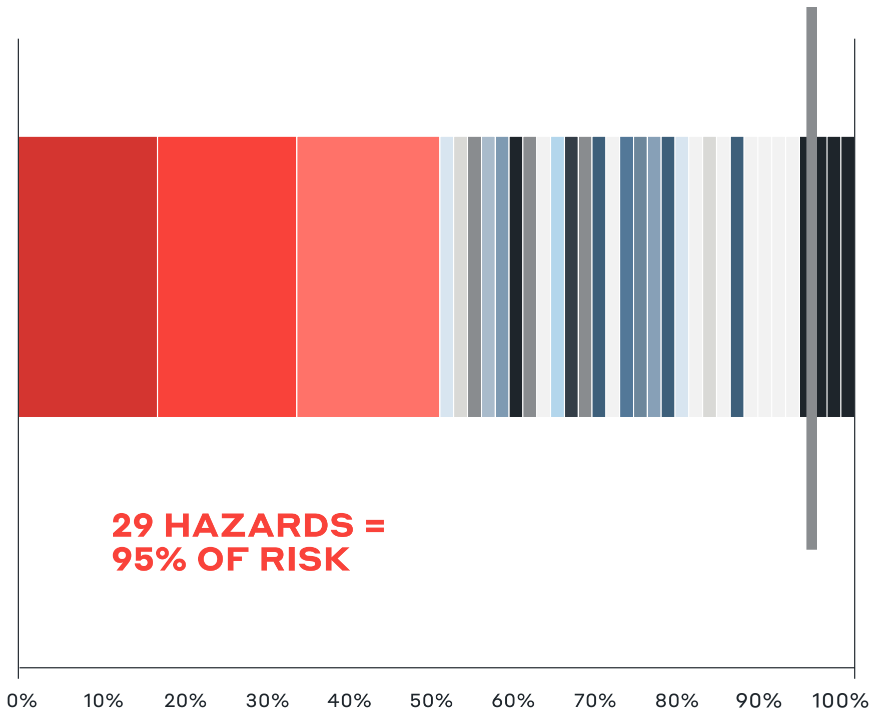


Figure 3 — Hazard Profile produced by WSP for Highways England)

WSP, with Highways England, developed a standardised evidence-based approach, the fundamentals of which are to:

- determine the safety baseline
- clearly define the safety objectives
- consider all the user populations that are affected (road workers, road users and others such as neighbouring residents)
- match the level of complexity of the safety risk assessment with the proposed intervention/project
- design appropriate mitigations
- test and check the effectiveness of the methodology, the solution and the mitigations through monitoring
- demonstrate achievement of the safety objectives

Validation by Results

The assessment framework has stood the test of time and been subject to much scrutiny—it has been evaluated on many schemes using post-opening data—giving confidence in the correlation between predicted and actual outcomes. A body of data has been built up over some 20 years—this data, both quantitative and qualitative, is regularly checked and tested (validating and verifying the assumptions behind the data and the scoring)—continuing to demonstrate a conservative approach that stands up to scrutiny.

The successful implementation of the M42 ATM Pilot led to the publication of the standard for safety risk assessment on England's strategic road network. This standard considered and drew on best practice in a variety of domains, including rail, and system safety (IEC61508). It has recently been refreshed by Highways England, and WSP were members of the drafting panel for the updated standard:GG 104 Requirements for safety risk assessment.

This multi-faceted framework is applicable to all projects and is required to be used on all activities that are undertaken by Highways England.

4 GG 104 Requirements for safety risk assessment, Highways England

Adoption for New Modes and New Mobility

WSP has used and adapted this hazard log approach for other modes and transport systems—including tunnels, connected and automated vehicles (CAVs) and, more recently, to consider e-scooters in town centres. The hazard log approach was undertaken as part of the Armidale Region Driverless initiative (ARDi) in Australia. The ARDi brought a CAV shuttle trial to rural New South Wales, with WSP providing support on elements of safety assurance, road safety and infrastructure risk and mitigations.

An effective assessment framework creates an evidenced-based understanding of road system interfaces and interdependencies, and it presents the risk profile with the associated hazards. The evaluation of potential changes prior to implementation supports proper attention to user needs, informs design updates and ensures the best use of technology applications. The framework focuses attention on areas that fundamentally advance the safety of the transport system—to prevent death and serious injury and thereby achieve a higher standard of road safety.

WSP Author

Ian Patey

Head of Profession,
Intelligent Transport
United Kingdom

ian.patey@wsp.com

WSP Author

Lucy Wickham

Senior Technical Director,
Operations and Safety,
Intelligent Transport
United Kingdom

lucy.wickham@wsp.com

WSP Contributor

Steve Kuciemba

ITS-CAV Practice Leader
United States

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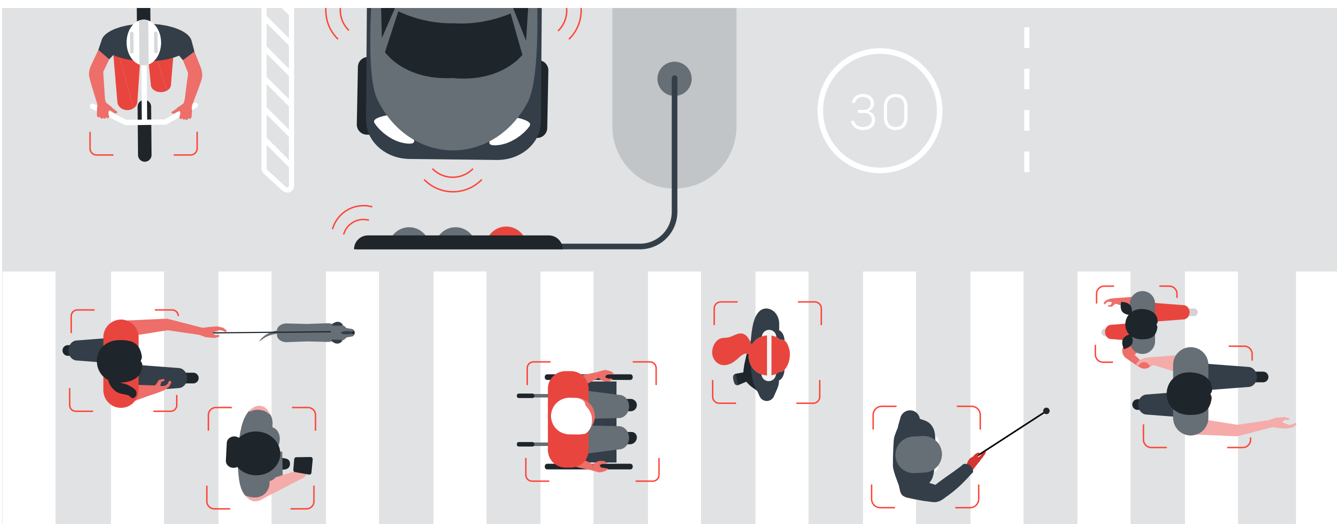
Effective Intelligent Transport Systems Integrate Human Factors

Examining how the interdisciplinary human factors specialism contributes to designing safe road systems



Road Safety Urgency

Worldwide, approximately 1.3 million people die on roads each year; another 20 million to 50 million people are seriously injured.

More than half of all road traffic deaths are among vulnerable road users—pedestrians, cyclists and motorcyclists.

The complexity of road transport systems can be understood in terms of the people who interact within them. As humans, we acquire information from the world around us; we interpret and make sense of it and then respond in our own unique ways. Within road systems, the factors that affect individuals, cognitively and emotionally, causing them to respond the way they do, are varied; and people act in unexpected and sometimes irrational ways. Transport system engineers and related system providers deal with materials and components that tend to perform in predictable, rational and repeatable ways. The human factors specialism brings an understanding of why people do what they do, offering those who design and operate road systems deeper insight to encourage user compliance and reduce human error.

Shared Responsibility

System designers are ultimately responsible for the design, operation and use of the road transport system and are thereby responsible for the level of safety within the entire system.

Road users are responsible for following the rules for using the road transport system set by the system designers.

If the road users fail to obey these rules due to a lack of knowledge, acceptance or ability, or if injuries do occur, the system designers are required to take the necessary further steps to counteract people being killed or seriously injured.

Figure 1 — Responsibility for safety is shared in the Vision Zero approach. (adapted from the Swedish Transport Administration)

Worldwide, approximately 1.3 million people die on roads each year, and another 20 million to 50 million people are seriously injured. Vision Zero is rooted in the position that death and serious injury are not acceptable consequences of mobility, and strives to achieve optimal safety for all users on roads worldwide; similarly, the intelligent transport system (ITS) whole-system approach, as established and applied in the United Kingdom (UK), uses a formal assessment framework[1] that focuses attention on those areas that fundamentally advance safety for everyone who uses the transport system.

With the Vision Zero approach, road users and system designers[2] share the responsibility for achieving safe outcomes. System designers apply their knowledge and expertise to make and keep roads safe for all users.

Road users are responsible for following the rules. If users fail to comply with road rules—due to a lack of knowledge, acceptance or ability—system designers must take the necessary further steps to counteract people being killed or seriously injured. The ITS whole-system approach aligns with the Vision Zero principle of shared responsibility—in the integration of people, processes, infrastructure, vehicles, technology, and associated data, to form safe and efficient environments.

Both of these Safe System approaches consider that people make mistakes and misjudgements; therefore, road systems must be designed so that human error does not result in fatalities or serious injuries. Death and serious injury can be prevented through a collaborative, whole-system approach to road safety that considers the interdependencies and interactions within each road network.

1 This assessment framework is explored in "On the 'ITS' Road Toward Vision Zero," article No. 2 in the WSP ITS-Vision Zero series.

2 System designers–according to the Vision Zero approach–include policymakers, politicians/government officials, infrastructure owners and operators, planners, engineers and road designers, vehicle manufacturers, trauma and hospital care providers, enforcers, plus any others who provide for the road transport system. Each contributes important knowledge and expertise to help make and keep roads safe.

Factoring in the Human

Any activity, improvement, development or change that involves a human requires empathy and understanding to create the right perspective for the right solution. It is essential that system designers have the capability to understand how the system they have designed will be used. Hence, considering and understanding human interaction must be an integral part of the design of every system.

By incorporating the human factors interdisciplinary behavioural science into the design process, system designers can shape transport systems with a deeper understanding of the factors that influence human behaviour; this insight keeps people at the centre of the design process, informs the process with an empathetic approach to comprehending the why in road-user behaviour—and offers greater potential for incident/crash prevention.

HUMAN FACTORS

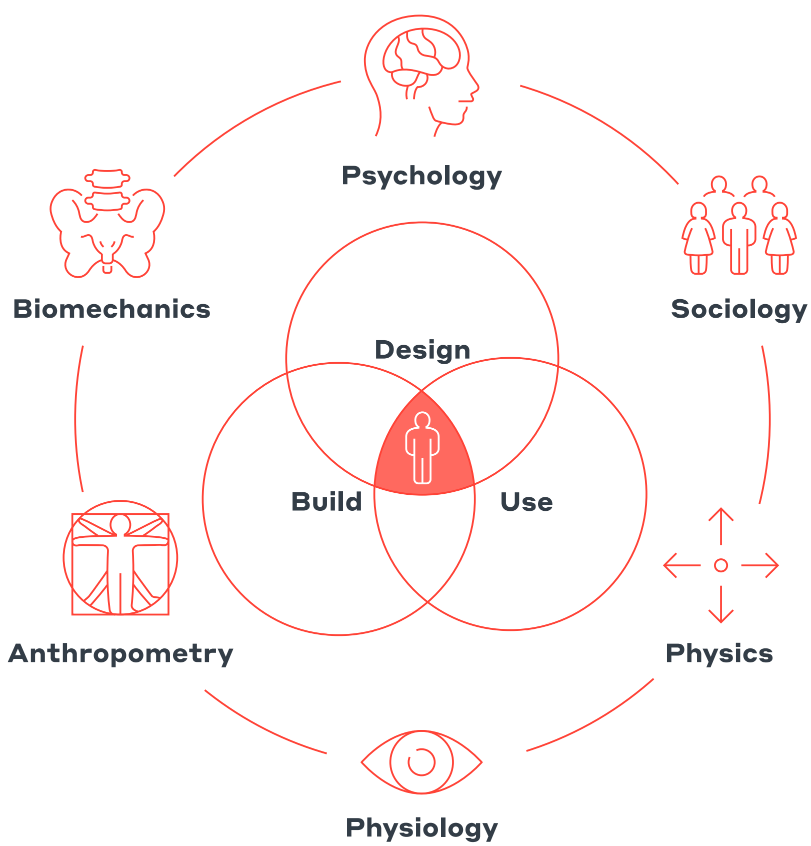


Figure 2 — Human factors is an interdisciplinary behavioural science that keeps people at the centre of the design process.

PARADIGM SHIFT

	Traditional/Prevailing	Vision Zero
Issue	Preventing all crashes	Preventing fatalities and serious injuries
Premise	Deaths are inevitable	Deaths are preventable
Focus	Perfecting human behavior	Designing a road system that takes into account human error
Responsibility	Individual road users	Shared: road users and system designers

Figure 3 – Principles of Vision Zero

**From the ITS perspective, the interdependent areas of any mobility system are physical space; users; vehicles; designers and implementers; and operators and maintainers. As noted in footnote 2, system designers, according to Vision Zero, include designers & implementers and operators & maintainers, among other contributors to the safety of road systems.*

Essential Insight for Safe System Design

The human factors approach is increasingly recognised as being fundamental in the design, implementation and operation of transport systems—including the investigation process when crashes or near misses occur. It recognises that people are a fundamental part of the overall system, contributing to its ultimate success or failure. This approach to infrastructure design challenges the traditional metrics and standards that are focused on the asset itself, rather than the users.

Bringing an understanding of the human factors that influence behaviour to the planning, design, operation and maintenance of transport systems can minimise human error and go a long way toward preventing crashes that are likely to result in death or serious injury.

Adding to the Science Behind ITS and Vision Zero

The users of the road system are diverse and complex—including drivers and passengers, road workers, pedestrians, cyclists, people using emerging micromobility options such as electric scooters, and, in some contexts, horse riders—each with their own needs and vulnerability[3] that must be taken into consideration. Competition exists between modes and users; the interfaces and interdependencies within the system—involving the physical space, vehicles and road users—often lie at the heart of any safety issue. The whole system therefore needs to be designed and operated using a human-centric perspective to achieve the required outcomes—with the evidenced-based Safe System approach guiding the process.

Behavioural science seeks to identify the factors that influence people's thinking, emotional reaction and ultimately their physical response in any given situation or environment. Fundamentally, it seeks to understand why people do what they do and to predict responses in each context. Without this intelligence, any attempt to change human behaviours and interactions—and create a Safe System—will likely fail. Developing safe transport systems therefore relies on understanding how to incorporate a proper consideration of the human factors involved.

Behavioural science will enable/assist system designers to:

- recognise that people are fallible. This means accepting that human error can, does and will occur
- understand why people do certain things – recognise the mix of societal norms and learned

3 While "vulnerability" exists in relation to all road users, Vision Zero characterizes "vulnerable" users as those most at risk in traffic, as they do not have an outside shield to protect them from the force of impact in a crash. See Vision Zero: Setting a higher standard for road safety, WSP, p. 9

behaviours and how to encourage (nudge) shifts
- understand the root causes that led to the human error
- understand how and why people respond to/modify their behaviour in response to mitigations – particularly when these may not align with what designers assumed people would do
- identify and understand the parts of the system that failed
- go back to the beginning of the development of any solution, then identify and examine all the factors that influenced the outcome.

When transport system safety specialists can adequately respond to all these considerations, they are then equipped with better evidence and understanding, enabling the delivery of effective, intelligence-led solutions. These solutions result in safer outcomes as a result of an enhanced multi-dimensional approach to understanding and improving human interactions within road systems.

Getting to the Root Cause

When presented with an issue, it is important to look beyond the surface and get to the root cause—why did this happen and what factors led to it—before starting to think about a solution. Otherwise, there is a risk of solving the wrong issue, and the problem ultimately persists. Road transport safety professionals carry out incident/crash investigations to gain a full understanding of what caused each one, and then design and target mitigations. Then they need to communicate effectively, explaining why the mitigation is necessary and how it makes a difference in order to influence behaviour and responses, and to achieve the intended outcomes.

Intelligent transport systems that are well-designed from a human-centric perspective:

- are intuitive – combining and using features such as road markings, signing, fencing, etc. that take account of how users see and understand the system/ network that they are using
- present the right information, in the right place and at the right time
- combine "push and pull" (instruction and encouragement)
- provide the right mix of education, enforcement, encouragement and engineering to achieve the required result

Once a road-transport system has been implemented, system designers then need to monitor how it used and, where necessary, take action to modify the system to accommodate actual behaviours and revised predictions—based on the available evidence—and, where practicable, devise education campaigns that encourage compliant behaviours. Intelligent monitoring of the effectiveness of mitigations

and the responses to them from a behavioural point of view is crucial, as is the willingness to learn and change mitigations and solutions as more responses and evidence is gathered/assimilated.

WSP Examples Illustrating the Integration of Human Factors

Human Factors Research, Road Tunnels, 2020—North and Mid Wales Trunk Road Agent

This research provided a detailed understanding of how road users would react in a tunnel emergency that required evacuation. The research explored whether road users in a panicked state would be able to use the existing evacuation equipment to aid their escape, and identified potential issues that require mitigation. It also provided insight into the many factors, both physical and psychological, that influence behaviours. The research concluded the biggest area of improvement required is education. The road users need to understand what to do in the event of an incident in the tunnels in order to prevent human error and promote safe evacuation. It is also important as part of the education to advise road users on how to reduce the risk of incidents in the first place, such as vehicle maintenance to prevent breakdowns/engine fires.

A2M2 Connected Vehicles Trial, 2018 - 2020—Highways England

This project provided insight on how new systems influence driver behaviour in congestion, junction management (traffic lights) and roadworks. The work involved conducting interviews in order to obtain user feedback. Connected vehicles were trialled where participants experienced messages on roadworks, road signs, speed limits, traffic light changes and lane changes. The project also qualitatively analysed the data by examining the interviews with participants and presenting these results in a report. The A2M2 project won ITS project of the year at the ITS (UK) President's dinner.

Ipswich Connected Vehicle Pilot as part of the Connected and Automated Vehicle Initiative, 2020–Queensland Department of Transport and Main Roads (TMR), Australia

The largest component of TMR's Connected and Automated Vehicle Initiative (CAVI) is the Cooperative Intelligent Transport Systems (C-ITS) Pilot. The pilot takes place on public roads in and around the City of Ipswich. This project provides insight on how new systems, utilising Cooperative Intelligent Transport Systems (C-ITS) can influence driver behaviour.

Testing will assess the value proposition of C-ITS safety use cases, including vehicle-to-infrastructure (V2I) and vehicle-to-vehicle (V2V) applications. There will be around 500 public and fleet vehicles retro-fitted with C-ITS technologies, and roadside C-ITS devices installed on arterial roads and motorways. These devices allow vehicles and infrastructure to talk to each other to share real-time information about the road and to generate safety-related warning messages for drivers.

The use cases being trialled include in-vehicle speed warning, emergency brake warning, turning warning for bicycle riders and pedestrians, roadworks warning, back-of-queue-warning, and red-light-violator warning, among other hazard warnings in the road environment. Quantitative data analysis will be employed for safety evaluation: analysing driver behavioural response to C-ITS alerts to infer crash reduction potential. The project will also employ surveys to assess user perceptions.

Bruce Highway Interchange Virtual Reality Usability Testing, 2019, Queensland, Australia

WSP led the behavioural evaluation and design of usability testing for the new Bruce Highway Interchange. This is a complex intersection design that has multiple decision points in quick succession, visibility issues and significant safety consequences if a driver makes a wrong decision. We combined virtual reality technology, behavioural science techniques and digital engineering data to simulate driver experience, understand why driver behaviours occurred and provide practical adjustments to the design—allowing the project team to save costs and improve safety outcomes for public road users.

The ever-growing human factors interdisciplinary specialism contributes to the development of effective intelligent transport systems by keeping people at the centre of the design, build and use of these systems—and thereby fostering safe and efficient interactions on roads. There is a need for the transport sector to go beyond the standards and models in place, to test and design for human behaviours and help standards evolve. Continually gaining insight from human factors studies and channelling that intelligence into projects will strengthen road safety efforts seeking to make Vision Zero a reality in communities around the world.

WSP Author

Ian Patey

Head of Profession, Intelligent Transport
United Kingdom

ian.patey@wsp.com

WSP Author

Lucy Wickham

Senior Technical Director, Operations and Safety, Intelligent Transport
United Kingdom

lucy.wickham@wsp.com

WSP Contributor

Kathy Wilson-Ellis

Human Factors Associate
United Kingdom

WSP Contributor

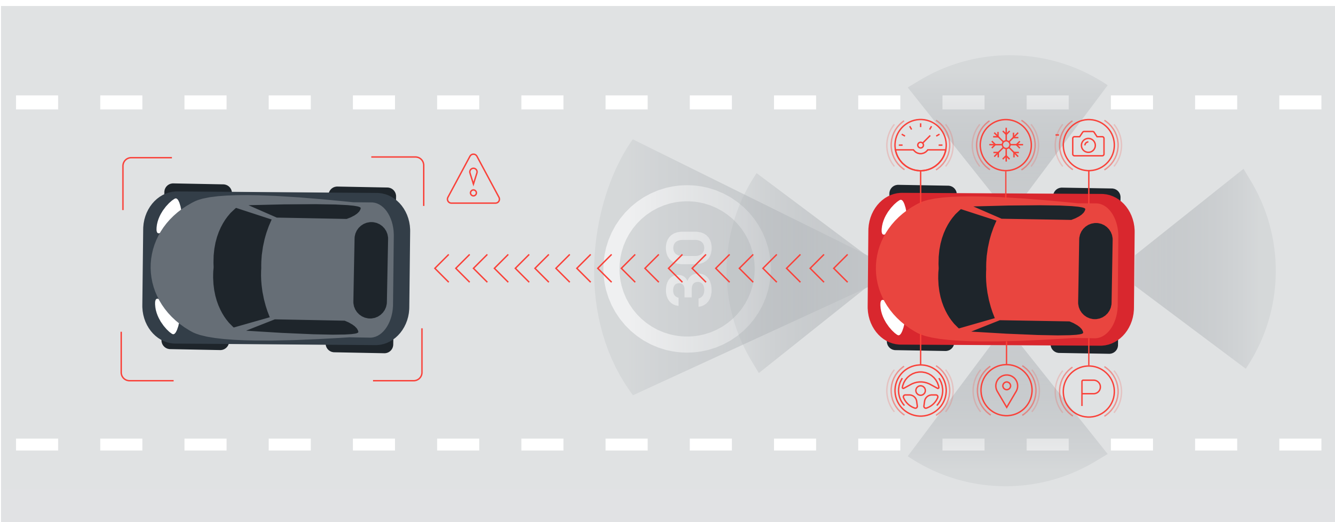
Michael Tyrpenou

Principal, Social Strategy and Design
Australia

4

Adopting the "ITS" Holistic View to Progress Road Vehicle Safety

Systems thinking drives intelligent transport systems toward the goal of Vision Zero.



Holistic consideration of intelligent transport systems is key to the delivery of modern transport systems. This view embraces the interfaces and interactions between modes and users that most often lie at the core of any safety issue—and these interactions, in great part, involve motorized vehicles.

While the physical design of vehicles is outside the scope of the intelligent transport system (ITS) field of work, there are vehicle-focused technologies, either particular to the vehicle itself or as part of the broader data-led ITS whole-system approach, that have an impact on the overall safety of the transportation ecosystem. A holistic perspective of transport systems, based on the Safe System principle of shared responsibility among the road system users and system designers[1], will facilitate vehicle-safety improvements in line with Vision Zero, which seeks to prevent death and serious injury within the worldwide road transportation system.

The ITS holistic approach integrates people, processes, infrastructure, vehicles, technology and associated data to form safe and efficient environments for the movement of people and goods.

1 System designers–according to the Vision Zero approach–include policymakers, politicians/government officials, infrastructure owners and operators, planners, engineers and road designers, vehicle manufacturers, trauma and hospital care providers, enforcers, plus any others who provide for the road transport system. Each contributes important knowledge and expertise to help make and keep roads safe.

Vehicle Safety Backdrop

Practicality, style, comfort and related distinguishing features have been and continue to be important factors in people's choice of transportation options—but those in the transportation business must always prioritize safety and continue to seek innovations in safety even if the end-user does not initially ask for them.

Advances in vehicle safety have contributed directly to the reduction of road fatalities. These advances include efforts and innovations related to seat belt use, anti-lock-braking systems, air bags, and, most recently, safety-assist systems such as backup/reversing cameras, collision-warning radar systems, and lane-departure warning systems. The United States Department of Transportation's National Highway Traffic Safety Administration (NHTSA) estimates that from 1987 to 2017, frontal air bags alone saved 50,457 lives in the United States.[2] Safety regulation and certification systems such as the New Car Assessment Program (NCAP), in both Europe and Australia, and NHTSA have created the imperative and environment for continual advances in safer vehicles, and as a result many lives have been saved.

Human error continues to be a factor in as many as 94 percent of motor vehicle crashes,[3] intensifying the ongoing challenge for system designers, including those who design road vehicles. Though fully automated vehicles are viewed as an opportunity to eliminate human error, the path toward full autonomy for all use cases is still a long way off. This necessitates a new way of thinking to proactively address the ongoing safety considerations that remain present with today's vehicles; this thinking will evolve with road-vehicle technological advances on the journey toward eventual full automation.

A New Way of Thinking

Approximately 1.3 million people die on the world's roads each year; another 20 million to 50 million people suffer serious injuries."[4] Vision Zero holds that no loss of life on the world's roads is acceptable; it considers, among a range of influential factors, how advances in vehicle safety can contribute to the overall goal of achieving zero harm around the world. This systems-thinking perspective optimizes improvement by understanding the interfaces and interrelationships, rather than considering the vehicle in isolation. As an example, the Volvo Group has committed to "strive" toward zero, guided by a holistic framework.[5] In the ITS holistic context, vehicle safety is an essential factor in preventing crashes and in reducing the risk of serious injury in case a crash does occur.

The next great leap in vehicle safety is to reduce the impact of human error as a contributing factor through the introduction of connected and automated vehicle (CAV) technology. But the technology will not reach its full potential if vehicle manufacturers approach this leap alone.

Systems thinking is a new approach in many parts of the world that reflects historical shifts in vehicle design for safety. One such shift was a move toward prioritizing crashworthiness, or the ability of a vehicle to protect its occupants—with features like crumple zones that are intended to minimize harm to occupants rather than minimize damage to the vehicle itself. These features often increased upfront cost or the cost of repairs after a crash, but this expense is more than offset by the reduction in fatalities and severity of injuries.

Similarly, integrating ITS technologies into vehicles may bring additional costs, as well as additional coordination between, and responsibilities for, vehicle manufacturers and infrastructure owners and operators (IOOs). But again, this investment will prove worthwhile when clearly linked to safer outcomes—reductions in roadway fatalities and serious injuries.

Vehicle manufacturers have accepted this premise and have opened a dialogue with IOOs, a giant step from just 25 years ago when there was almost no relationship. In the past, vehicles were designed and roads were designed, but the confluence of the two was rarely pursued. Today, we see large-scale pilot programs involving IOOs and vehicle manufacturers in partnership—we also see conferences and meetings dedicated to advancing research and sharing lessons learned—and these outcomes reflect a recognition that in order to achieve the goal of significant safety improvements, a partnership between road and vehicle must be forged.

2 United States Department of Transportation, National Highway Traffic Safety Administration (NHTSA)
3 Digital Trends, overview of NHTSA 2016 Fatal Motor Vehicle Crashes report
4 World Health Organization, Road traffic injuries, Key facts
5 The Volvo Group, Volvo Safety Vision – Zero Accidents

Figure 1 - Networked driving: vehicles communicating directly with each other and their surroundings to operate more safely - Image Source: WSP

Partnership Between Road and Vehicle

Much of this partnership will be realized through the progression to universal connectivity in support of greater automation. Connectivity is the glue that will ultimately enable a vehicle's sensor to "see" around the corner or increase its "awareness" of problems far ahead. Holistic thinking has brought us to this juncture. The world's largest automaker, Volkswagen Group,[6] is leading the charge in Europe to develop highly intelligent systems with its Car2X radio connectivity to "let vehicles communicate directly with each other and their surroundings—and thus operate more safely."[7]

In the United States (US), vehicle-to-everything (V2X) connectivity is also widely considered a key enabler that will lead toward achievement of the Vision Zero goal—zero fatalities and serious injuries in the worldwide road transportation system—provided that the system is considered holistically. The U.S. Department of Transportation (U.S. DOT) has publicly stated that V2X technologies have the potential for "significant safety and mobility benefits, both on their own and as complementary technologies when combined with in-vehicle sensors."[8]

For example, with speed being one of the major factors contributing to the initiation or severity of a crash, communicating speed limits or advisories—and possibly variable conditions based on current weather and roadway construction—from infrastructure to vehicles can more directly provide information to drivers and automated driving systems on what the recommended safe speed to operate currently is. In addition, information could be transmitted between vehicles when there is an unsafe condition, such as a large speed differential between vehicles in proximity to each other or a queue in traffic ahead, to inform other vehicles and their drivers on how to best prepare for approaching conditions.

In the United Kingdom, the A2M2 Connected Vehicle Corridor Trial[9] tested systems that connect motorway signaling with displays in test vehicles to demonstrate the potential benefits of providing variable speed limit and roadworks information directly to in-vehicle displays.

Today's collision avoidance systems are often vehicle-based and relatively independent from infrastructure, but they could be coupled with collision notification systems that communicate to infrastructure once a collision has occurred. This, along with applications such as emergency vehicle pre-emption, which adjusts signal timing along an emergency vehicle's route to support safer and faster crossing of intersections, could work to decrease response time if a crash has occurred, which can help reduce the severity of any injuries.

Look Through the Same Lens

Not all vehicle and technology companies, including some of those that are developing automated driving systems, are considering this partnership between road and vehicle as a critical step. Some technologists feel they do not need connectivity and that they can design their vehicle software or hardware systems to

6 Mark Toljagic, wheels.ca, "These are the biggest automakers in the world," August 20, 2019

7 Volkswagen, Car2X: The new era of intelligent vehicle networking

8 U.S. Department of Transportation, Vehicle-to-Everything (V2X) Communications

9 WSP designed the trial and the system architecture for the corridor; the real-world trial involved over 30 manufacturers of components, such as in-vehicle displays and sensors.

navigate traditional roadways rather than opening the dialogue on how better designed and more intelligent roadway systems could support and be supported by their vehicle systems.

Because the future of advanced or automated driving systems is fragmented across a diverse group of stakeholder organizations and companies, some are content to simply "design a better driver" through software and assume that it can operate in any design domain or environmental conditions. They have failed to see the value that connectivity can bring to the equation in terms of broadening the data input into the driving decision-making process. While these endeavours will continue to enjoy limited success within specific geofenced conditions, they will eventually reach a plateau in terms of effectiveness due to their limited ability to "see beyond the vehicle itself."

But even if everyone viewed connectivity as a principal concern, the CAV industry itself remains caught in a technology-driven conflict, as the development cycle for safety-dependent systems is much longer than the development cycle for new technologies. Many experts around the world spent a decade researching, developing, and testing a Wi-Fi based V2X communication protocol, while, during that time, the rapid evolution of cellular technology entered the conversation and the result was a lack of universal opinion on the best communication method for connecting devices. The anticipated proliferation of fifth-generation cellular (5G) will further complicate what is already an uncertain technology landscape.

Opportunities to Form a Holistic View

While the approach to vehicle communications and vehicle safety may not be universal among the stakeholders, ongoing dialogue and a holistic focus toward achieving Vision Zero can lead to infrastructure enhancements that reflect input from vehicle manufacturers—and would have a significant impact on safety.

For example, in the United States there has been a recent effort by the National Committee on Uniform Traffic Control Devices (NCUTCD) to recommend wider pavement markings to support future automated driving systems. The NCUTCD is an organization whose purpose is to assist in the development of standards, guides and warrants for traffic control devices and practices—and make recommendations to the U.S. DOT for future inclusion in their Manual on Uniform Traffic Control Devices.

The U.S. DOT and the White House Office of Science and Technology Policy also unveiled *Ensuring American Leadership in Automated Vehicle Technologies: Automated Vehicles 4.0 (AV 4.0*) at the beginning of 2020. This document builds upon previous guidance from the U.S. DOT and expands the scope to 38 relevant U.S. Government components that have direct or tangential equities in the safe development and integration of CAV technologies. A holistic viewpoint within the U.S. DOT itself, *AV 4.0* seeks to ensure a consistent government approach to AV technologies, and to specify the authorities, detail the research and coordinate the investments being made across the government. Transport Canada released in January 2019 *Safety Assessment for Automated Driving Systems in Canada*,[11] which identifies 13 outcomes that vehicles with ADS features should be able to perform, ensuring innovation can continue while policy is still being developed. In February 2019, Transport Canada released *Canada's Safety Framework for Automated and Connected Vehicles*[12] providing an overview of Canada's legislative and regulatory regimes and standards and outlining a flexible approach that uses non-regulatory tools to support the safe testing and deployment.

Another important element to consider is the human factors component,[13] which includes identifying how users will interact with any systems to ensure the desired benefits are realized without introducing other undesirable behaviors and increasing driver workload and/or distraction. This need could also open the opportunity for IOOs to work with vehicle manufacturers and technology companies to ensure any applications of in-vehicle technology are designed with safety as the highest priority.

ITS, including speed sensors and red light cameras, could also be utilized for enforcement purposes and to encourage safe road use. As noted earlier, while the physical design of vehicles, which contributes significantly to the safety of both occupants and vulnerable road users in the event of a collision, is outside the scope of ITS, various ITS technologies could be installed on vehicles to mitigate problem areas in their physical design.

Keep Equity In Sight

Vehicle manufacturers must remain vigilant in making sure safety enhancements are quickly available on the broadest cross-section of vehicles. Traditionally, new features have been implemented on high-end vehicles first and then brought to other models as consumers begin to demand them; while this method may work for luxury add-ons, it is less defensible for essential safety features.

Such progress may require a regulatory force in some cases to ensure success, similar to how all new automobiles sold in the United States, Canada, and other countries

10 *AV 4.0*, U.S. Department of Transportation

11 Safety Assessment for Automated Driving Systems in Canada, Transport Canada

12 Canada's Safety Framework for Automated and Connected Vehicles, Transport Canada

13 "Effective Intelligent Transport Systems Integrate Human Factors," article No. 3 in the WSP ITS-Vision Zero series

are now required to be equipped with backup cameras. This mandate took many years to develop and take effect, but now, two years after the mandate, it has been widely accepted. Another example would be Transport for London's Bus Safety Standard, which is preparing to require driver assist technologies on all new full-size motor coaches, such as intelligent speed assist and indirect vision systems (e.g. imminent collision detection/warning).[14]

The challenge remains that only new vehicles will benefit from changes and requirements on new vehicles, and many people already own or will purchase used vehicles. Therefore, aftermarket technologies should be designed and implemented as appropriate and, at the very least, vehicle manufacturers should consider allowing proven safety technologies to be installed on their existing vehicles without voiding warranties, especially if these technologies make it more likely for a vehicle to observe safer driving behavior and ultimately protect its occupants. In addition, during time periods in which only some vehicles benefit from certain safety functions, it will be essential to provide alternate options for unequipped vehicles. Solutions include posting information that is being sent as in-vehicle alerts on dynamic message signs and designing systems on equipped vehicles that assume other vehicles are not also equipped.

Beyond addressing equity challenges between individual vehicles, IOOs need to consider equity when approaching pilot testing of different vehicular enhancements. This includes implementing systems at different types of locations, such as signalized and unsignalized intersections, crosswalks, transit and freight corridors, and in urban and rural contexts. Another component of equity is ensuring safety across modes, with a focus on not just humans in a vehicle, but also humans traveling in the proximity of a vehicle, such as pedestrians, bicyclists, or other vulnerable road users. The safety of vulnerable road users near vehicles can be enhanced through various vehicle features such as blind spot detection and automatic emergency braking, as well as infrastructure-based pedestrian detection systems, active crosswalks, and smart lighting.

Euro NCAP has added an assessment on how well vehicle design protects the safety of vulnerable road users.[15] Including this sort of an assessment with ITS and other emerging technologies will help ensure vehicle technologies are designed to protect both vehicle occupants and other roadway users, especially the vulnerable road users who currently comprise more than half of all road fatalities.

New driver assistance features such as auto lane-keeping can help with this challenge. This measure relies on machine-readable lines, requiring targeted expenditure to make a widespread, sustainable safety impact. And a true holistic approach will be realized when these enhancements can also transcend to personal devices, wearables, and micromobility modes, such as scooters and bikes (electric and non-electric).

Moving Forward

A systematic approach requires additional responsibility for vehicle owners—to ensure that all vehicle safety features/systems are functioning correctly in relation to the system infrastructure, rather than simply making sure that the vehicle is "roadworthy" on its own. There is also a need for overall system review so that the incremental benefits and associated impact can be understood; as more vehicles include added safety features, this review can lead to an understanding of how continuous improvement impacts overall system safety.

Shared Responsibility

System designers are ultimately responsible for the design, operation and use of the road transport system and are thereby responsible for the level of safety within the entire system.

Road users are responsible for following the rules for using the road transport system set by the system designers.

If the road users fail to obey these rules due to a lack of knowledge, acceptance or ability, or if injuries do occur, the system designers are required to take the necessary further steps to counteract people being killed or seriously injured.

Figure 2 — Responsibility for safety is shared in the Vision Zero approach. (adapted from the Swedish Transport Administration)

14 *Bus Safety Standard, Executive Summary, Transport for London in conjunction with TRL*

15 *Euro NCAP, Vulnerable Road User (VRU) Protection*

Safe motorized vehicles represent a pivotal component of safe road systems. A holistic perspective will enable understanding of system interdependencies and how best to support coordinated changes to create and maintain safe interfaces between all road users and vehicles.

Designing vehicles that consider the overall system and take into account human error, and encouraging these vehicles to be operated safely—thereby sharing the responsibility for traffic safety between individual road users and infrastructure & vehicle system designers—will be essential in designing road systems that focus on safety for all users. Moving toward zero deaths and serious injuries—the goal of Vision Zero—requires this shared all-inclusive, cooperative approach among multiple stakeholders.

WSP Author

Katie McLaughlin

ITS/CAV Consultant
United States

katie.mclaughlin@wsp.com

WSP Author

Steve Kuciemba

ITS-CAV Practice Leader
United States

WSP Contributor

Scott Benjamin

Technical Director, Intelligent Transport
Australia

scott.benjamin@wsp.com

WSP Contributor

Mara Bullock

National Manager, ITS Planning Practice
Canada

mara.bullock@wsp.com

WSP Contributor

Ian Patey

Head of Profession, Intelligent Transport
United Kingdom

ian.patey@wsp.com

WSP Contributor

Fergus Tate

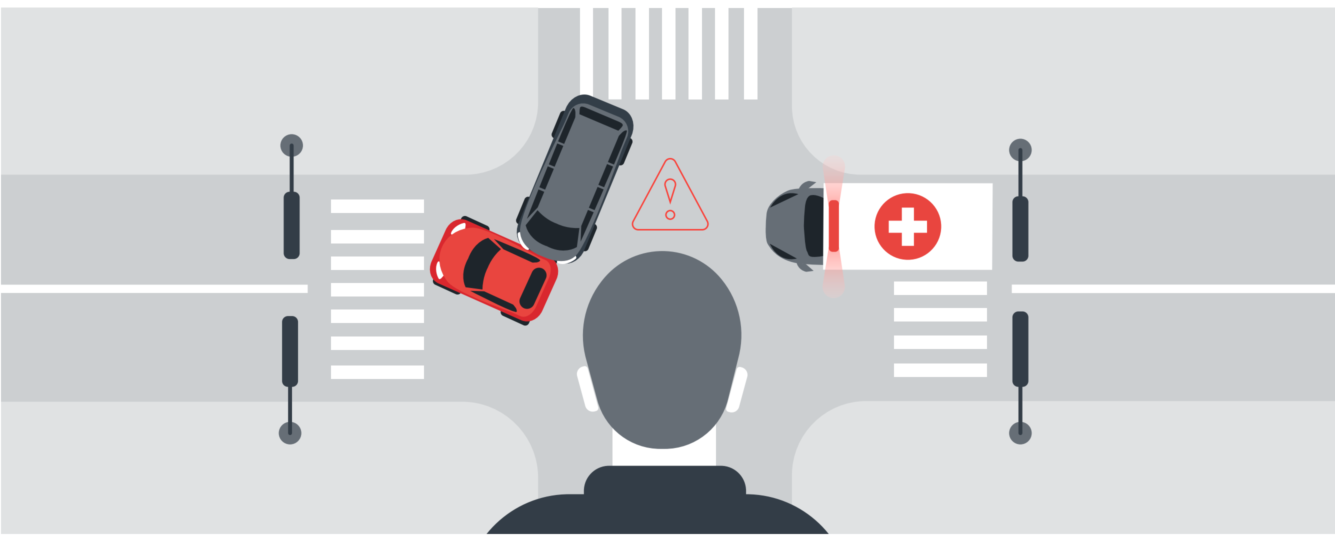
Technical Director, Transport
New Zealand

fergus.tate@wsp.com

5

Designing Out Flaws Within Road Transportation Systems

Continuous crash review and response is essential to aligning intelligent transport systems with the Safe System approach toward achieving the goal of Vision Zero—zero deaths and serious injuries within the worldwide road transport system.



Road transportation systems that work safely result from designs which safely manage the interdependencies and interfaces within them. When severe crashes occur, system designers must revisit the problematic points within the system, understand why and how they occurred, and review the system as a whole before taking corrective action with evidence-based measures. Understanding why and how severe crashes have happened is vital in preventing more deaths and serious injuries on roads—and thus integral to making zero deaths and serious injuries a reality.

With the Safe System approach, designers seek to resolve the issues everywhere within the system, not just at the locations where the crashes have occurred. This approach differs from improving “crash hot spots,” as it considers the road transport system holistically, looking at cause and effect in a system-wide context as a progression to achieve the goal of Vision Zero. Vision Zero is rooted in the position that death and serious injury are not acceptable consequences of mobility and strives to establish optimal safety for all users in road transport systems around the world.

Road Safety Urgency

Worldwide, approximately 1.3 million people die on roads each year; another 20 million to 50 million people are seriously injured.

More than half of all road traffic deaths are among vulnerable road users—pedestrians, cyclists and motorcyclists.

Overview of Crash Review and Response

When a crash occurs within a road transport system, carrying out an objective review of what happened, why and how enables the system designers[1] to make the changes that have the greatest potential to prevent similar severe crashes from occurring within the system.

Crash review must consider the interdependencies and interfaces between people, vehicles and space so that the response focuses attention on correcting the flawed aspect(s), with an eye toward amending that aspect throughout the system, not just at the location where a fatal crash occurred.

The Safe System approach can also be applied to isolated features such as intersections. Where a road network includes a series of similar intersections, all, not just those with the worst crash history, will be subject to the treatment for improvement. The approach can also be adopted for specific locations, treating all the issues at the location of a crash. Knowledge of what happens at other similar locations will inform this process.

Crash review and response comprises two key areas—the immediate response that protects and saves lives, and the analysis of why and how the crash happened in order to prevent further occurrences. The immediate response very much depends on the local situation. In the United Kingdom, for example, the emergency services are available to respond quickly, and their response is mature and effective, based on many years of experience and training. Evaluating what happened and understanding why and how relies on data and the application of objective techniques such as root-cause analysis; the actual causes are not always obvious, and, to effect positive change, it is important to treat the causes rather than the symptoms. To that end, system designers consider the road transport system holistically when undertaking crash review and response—the individual parts must work well independently and in relation to the other parts for the system to work safely.

A fundamental tool in designing safe road systems is speed management—managing the speed of vehicles according to what is appropriate for the environment. Lower speeds dramatically reduce the likelihood that a crash will occur as well as the severity of the injuries that result from crashes.[2] Speed management is a shared consideration across the elements presented in Figure 1. Post-crash care is also essential to creating safe road systems; response to crashes, from trauma care providers and other system designers, is a vital function in the "chain" of considerations/actions addressed by Vision Zero.

The speed and quality of the response can make a significant difference in the severity of injury caused by a crash—a severe injury, for example, could prove fatal without proper and timely treatment. In the United Kingdom, a crash is recorded as fatal when a death occurs within 30 days of it happening. Until severe crashes have been eradicated from the worldwide road transport system, it is important that their impact, in terms of human pain and suffering, is minimized. Analysing data about how the crash happened, where it happened, and the consequences—will enable the outcomes of the interventions to be maximised. The right response carried out swiftly will also enable training, expertise, equipment and facilities to reduce the impacts on health, the healthcare system and the overall economy.[3]

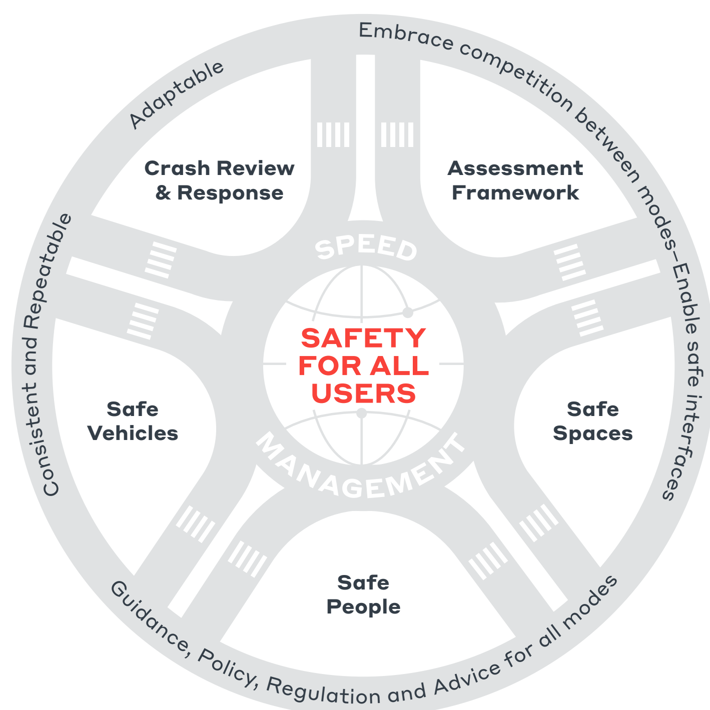


Figure 1 — Interconnected elements considered when designing and maintaining safe road systems

1 System designers–according to the Vision Zero approach–include policymakers, politicians/government officials, infrastructure owners and operators, planners, engineers and road designers, vehicle manufacturers, trauma and hospital care providers, enforcers, plus any others who provide for the road transport system. Each contributes important knowledge and expertise to help make and keep roads safe.

2 World Health Organization, Managing Speed, October 10, 2017

3 World Health Organization, Road traffic injuries

Holistic View Enables Crucial Understanding

Worldwide, approximately 1.3 million people die on roads each year, and another 20 million to 50 million people are seriously injured. Vision Zero is rooted in the position that death and serious injury are not acceptable consequences of mobility and strives to achieve optimal safety for all users in road transport systems worldwide; similarly, the intelligent transport system (ITS) whole-system approach, as established and applied in the United Kingdom, uses a formal assessment framework[4] that focuses attention on those areas which fundamentally advance safety for everyone who uses the road transport system.

With the Vision Zero approach, road users and system designers share the responsibility for achieving safe outcomes. System designers apply their knowledge and expertise to make and keep roads safe for all users. Road users are responsible for following the rules. If users fail to comply with road rules—due to a lack of knowledge, acceptance or ability—system designers must take the necessary further steps to counteract people being killed or seriously injured. The ITS whole-system approach[5] aligns with this Vision Zero principle of shared responsibility—in the integration of people, processes, infrastructure, vehicles, technology and associated data, to form safe and efficient environments.

Both approaches accept that people make mistakes; therefore, the system must be designed so that human error does not result in fatalities or serious injuries. Using post-crash data and analysis, targeted changes can be made to systems to design out the flawed aspects that lead to death and serious injury.

Using the data from severe crashes is a "lagging" methodology that is critical in the prevention of serious crashes; supplementing with a "leading" methodology, such as collating and reviewing near misses and analyzing crashes which have caused slight or no injuries, can be useful to identify where crashes may occur and also to identify why death or serious injury did not occur. Crash causation models consider the whole system, including human error, organisation failure and design failure, in order to understand the causes, and potential causes, of system failure—to design out the flaws leading to that failure. It is important that the system designers understand how to use the analysis and methodology to focus on designing out those factors that will most likely result in death or serious injury. Continuous monitoring of system operation with comparisons to expected levels of performance and outcomes allows the system operators to intervene before failure occurs—being alerted to potentially dangerous situations in time to intervene. This process can take many forms, with a monitoring and evaluation plan being one of the most common approaches.

Create a Forgiving Environment

Plan-Do-Check-Act

The Plan-Do-Check-Act process (Figure 2) provides system designers with a disciplined methodology that includes essential steps—crash review (Check) and response (Act)—to achieving Vision Zero. System designers rely on access to a rich source of data to enable them to understand the root causes of the most severe crashes and where to focus attention when changing/refining the system (Act). As this is a continuous, cyclical, process, more data is gathered after changes have been implemented (Plan and Do) so that the impact of the change can be monitored and reviewed; where necessary, further changes are made, and the system becomes progressively safer.

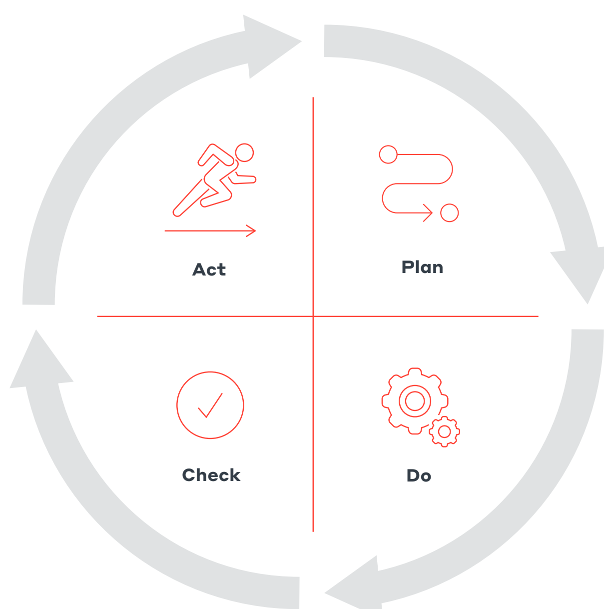


Figure 2 — the Plan-Do-Check-Act cycle used in crash review to improve performance of a system - Crash review and response forms the Check and Act parts of the cycle.

4 This assessment framework is explored in "On the 'ITS' Road Toward Vision Zero," article No. 2 in the WSP ITS-Vision Zero series.

5 The ITS whole-system approach is explored in "Intelligent Transport Systems Advance Vision Zero Road Safety," article No. 1. in the WSP ITS-Vision Zero series.

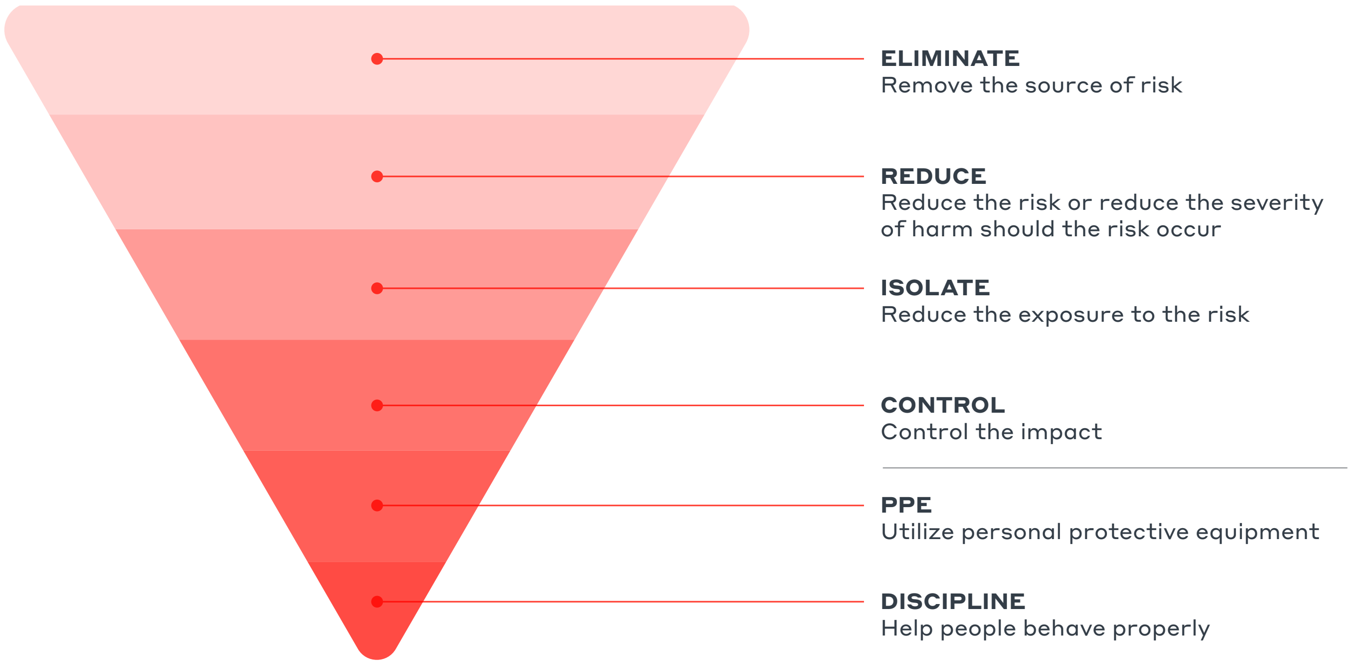


Figure 3 — ERIC-PD principles to manage risk

ERIC-PD: 'ERIC Prevents Death'

The Safe System approach seeks to understand the nature of the system failure and what contributed to it, to enable the development of a forgiving environment where the ability for the system to cause harm is ultimately eliminated; zero harm requires the application of the ERIC-PD principles to manage risk (Figure 3).

The evaluation of any crash should lead to responses that align with ERIC, aiming to eliminate the root causes and potential to create harm, wherever practicable. A systematic, evidence-based analysis of crashes will reveal why and how the crashes happened, and will enable the identification of potential mitigations likely to create maximum benefit.

System designers use various tools and techniques, including root-cause analysis and sequence of events. These tools enable the use of evidence-based interventions that support Vision Zero. Continuous review and feedback are essential to refine the system and design out the flawed aspects that lead to severe injury and death.

Broaden and Deepen Understanding

The paradigm shift to shared responsibility requires ongoing collaboration among system designers to create forgiving environments.

Providing guidance for drivers and other occupants of vehicles involved in an incident—enabling them to identify and seek the safest location while waiting for assistance—is an intrinsic part of the Safe System approach. The introduction of automated reporting systems—eCall in Europe and 911 in the United States—enables the road authorities to set signs and signals (where available) to warn oncoming vehicles of the crash or breakdown and to coordinate with emergency services more quickly and effectively.

Educating those who use the transport system—road users and stakeholders such as core responders—is also important in forming forgiving environments. Continual engagement and communication promote meaningful discussion, using the tools and media appropriate to the audience, such as desk-top exercises for emergency services. Designing elements into the system, such as road signs and markings, assist road users to drive as the system designers intended. Undertaking reviews enables system designers to understand how users respond to what they are expected to do.

The Safe System approach, as represented by Vision Zero and the

ITS holistic perspective, expects system designers to allow for road user mistakes. This means that significant attention must be given to how people use the system and the factors that influence their decision-making and behaviour. A widespread attitudinal shift to apply this evolved point of view will go a long way toward creating safe road systems.

Education works in tandem with shifts in design to advance safety and reinforces shared responsibility between users and system designers. As society changes, so do expectations, perceptions and behaviours. Ongoing learning is essential for the safe use of road systems.

A holistic view of road transport systems, one that considers how the elements of each road system work together, creates the context for effective crash review and response. The application of data and objective analysis then enables crucial understanding of why and how failure occurred, to prevent any similar future occurrence. This approach enables the causes of failure to be designed out of road systems—essential to achieving the Vision Zero goal: zero deaths and serious injuries within the worldwide road transport system.

WSP Author
Ian Patey
Head of Profession, Intelligent Transport
United Kingdom
ian.patey@wsp.com

WSP Author
Lucy Wickham
Senior Technical Director, Operations and Safety, Intelligent Transport
United Kingdom
lucy.wickham@wsp.com

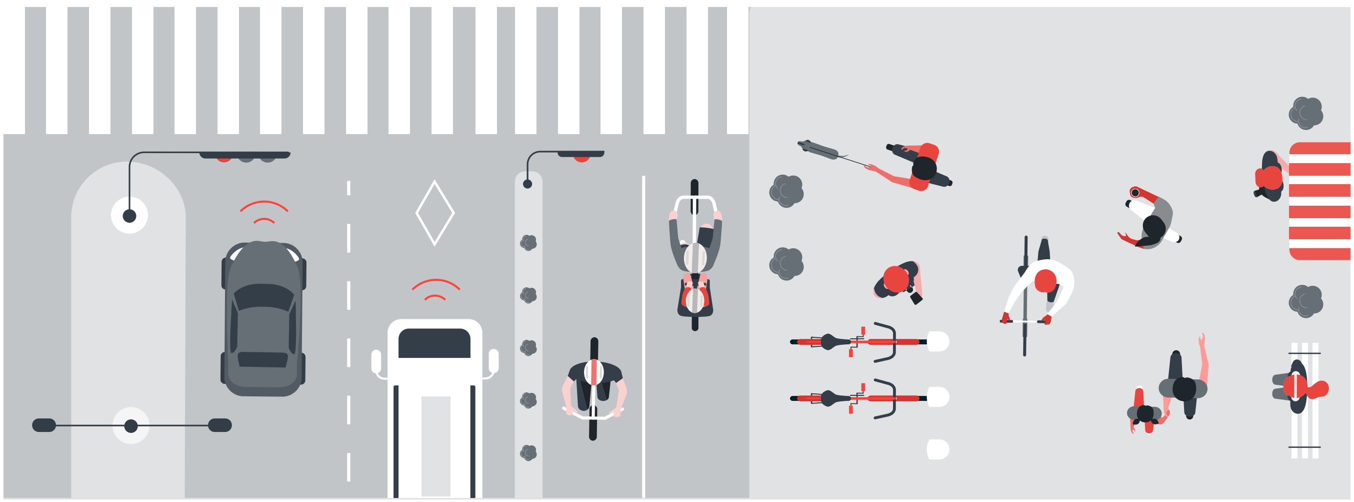
WSP Contributor
Andrew Ceifetz
Senior Technical Principal Transportation Safety, Research, and Data
United States
Andrew.Ceifetz@wsp.com

WSP Contributor
Fergus Tate
Technical Director, Transport
New Zealand
Fergus.Tate@wsp.com

6

Creating Safe Road Ecosystems

Considering how the physical space contributes to the safe design and use of road transport systems



Vision Zero is rooted in the position that death and serious injury are not acceptable consequences of mobility. Death and serious injury are preventable within the worldwide road transportation system.

Road transport systems are integral to the form and function of communities. They facilitate the movement of people and goods, thereby connecting people to places and supporting commerce. Within these systems, spaces are used for mobility and local activity. Safety should consider both of these purposes. For system designers[1] to create safe road systems, they must understand and manage the interdependencies and interactions between the people, vehicles and space (Figure 1) comprising each road ecosystem.

The users of road systems are diverse, each with their own needs and vulnerability[2] that must be taken into consideration. They include drivers and passengers, road workers, pedestrians, transit passengers, motorcyclists, cyclists, people using emerging micromobility options such as electric scooters, and, in some contexts, horse riders/horse-drawn carriages. The Safe System approach to achieving Vision Zero embraces all users and modes of transport and the places where activity occurs. Similarly, the intelligent transport system (ITS) whole-system approach considers people, processes, infrastructure, vehicles, technology and associated data to develop safe and efficient operational environments for all users.

1 System designers–according to the Vision Zero approach–include policymakers, politicians/government officials, infrastructure owners and operators, planners, engineers and road designers, vehicle manufacturers, trauma and hospital care providers, enforcers, plus any others who provide for the road transport system. Each contributes important knowledge and expertise to help make and keep roads safe.

2 While vulnerability exists in relation to all road users, Vision Zero characterizes "vulnerable" users as those most at risk in traffic, as they do not have an outside shield to protect them from the force of impact in a crash. See the brochure: Vision Zero, Setting a higher standard for road safety, WSP, p. 7

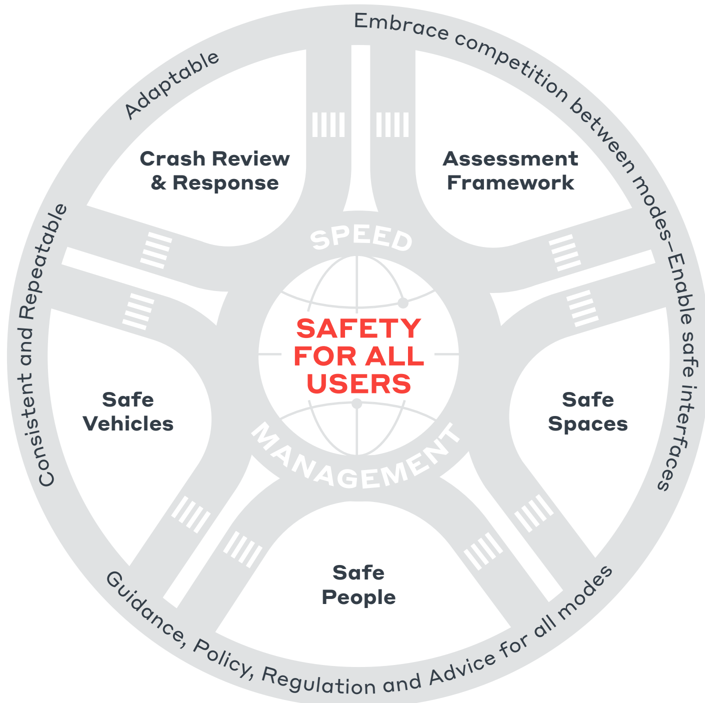


Figure 1 — Designing and Maintaining a Safe System - Interdependent Elements

To form safe ecosystems, system designers consider the physical features and operational factors and their purpose within the system toward enabling mobility and placemaking. Safely connecting the elements of space—the road itself, curbsides, roadsides, and adjacent land use—is essential to creating the context to achieve a Safe System.

Different Spaces, Same Vision

With the Vision Zero approach, road users and system designers share the responsibility for achieving safe outcomes. System designers apply their knowledge and expertise to make and keep roads safe for all users. Road users are responsible for following the rules. If users fail to comply with road rules—due to a lack of knowledge, acceptance or ability—system designers must take the necessary further steps to prevent death and serious injury.

Worldwide, approximately 1.3 million people die on roads each year, and another 20 million to 50 million people are seriously injured.[3] Vision Zero is rooted in the position that death and serious injury are not acceptable consequences of mobility, and strives to achieve optimal safety for all users on roads. Similarly, the intelligent transport system (ITS) whole-system approach, established in England over two decades ago, uses a formal assessment framework[4] that focuses attention on those areas that fundamentally advance safety for everyone using the transport system. The ITS whole-system approach aligns with the Vision Zero principle of shared responsibility.

The responsibility for providing road systems that are safe for all users rests with the system designers. System designers have the greatest influence over the design of the physical space—creating a system that works by design within which road users intuitively understand how to use roads safely. The guidance from Highways England for good road design[5] states, "Good road design places people and their safety at the heart of the design process."

Speed Management

The design techniques required to achieve safety vary according to the type of road being considered. System designers must evaluate the influential factors affecting the environment of each road and understand how to manage them within their spheres of control and influence.

For example, an inter-urban road, such as a motorway,[6] operates within a different context compared to a street.

Common to achieving safety in all road spaces is the need for speed management to maintain speeds appropriate for the environment. Excessive speed is a toxin within the system. Sometimes, speed limits are reduced due to the weather, road-side activity, traffic conditions, and/or other factors affecting a road's context.[7] Speed contributes significantly to the severity of injury resulting from a crash—for car occupants in a crash with an impact speed of 80 kilometres per hour (km/h) the likelihood of death is 20 times greater than at an impact speed of 30 km/h.[8] The consequences for pedestrians are even greater—when involved in a collision with a car

3 World Health Organization, road traffic injuries

4 This assessment framework is explored in "On the 'ITS' Road Toward Vision Zero," article No. 2 in the WSP ITS-Vision Zero series. It explains how the hazards are identified within each environment and assessed objectively to inform the design toward achieving Vision Zero.

5 Highways England, The road to good design, 2018

6 The words "motorway" and "freeway" are used interchangeably throughout the article.

7 World Health Organization, from World report on road traffic injury prevention, Road Safety, Speed, 2004

8 ibid.

travelling at 30 km/h the chances of survival are 90 percent, at 45 km/h less than 50 percent and at 80 km/h virtually zero.[9]

Effective speed management comprises a range of measures that include the design of the space and how users operate within it, setting and enforcing appropriate speed limits for the context, education of users, understanding the effects of speed in crashes and using technology to encourage behaviour change. Technology, using connectivity and additional sensors applied to infrastructure and in vehicles, such as advanced driver assistance systems, offers significant opportunity to reduce harm and create safer ecosystems through better awareness and levels of driver support.[10]

Figure 2 — A "pop-up" demonstration project as part of a public involvement campaign supporting implementation of the Armour Road Complete Street Plan (North Kansas City, Missouri, United States). Phase 1 improvements have now been constructed, and since completion no serious injury or fatal crashes have occurred.[12]

Tailored Design

One design feature of motorways/freeways to support safety is the control of access—in the United Kingdom, for example, motorway regulations prohibit some types of vehicle and user, including non-motorised users, learner drivers and motorcycles with engines smaller than 50 cubic centimetres. The combination of infrastructure design features suited to high speeds—such as grade-separated junctions—with the prohibition of slow-moving vehicles and pedestrians allows an appropriate speed limit of 110 km/h.

Designers of urban spaces, however, have little or no ability to control user access, resulting in the need for much lower speed limits and consideration of all types of user and forms of mobility—both established and emerging forms. If city roads were designed to eliminate access in a similar manner to motorways, this would severely limit the functionality of the system and the space to achieve its purpose—mobility and placemaking.

Linking land use planning and the design of roads is a critical step in achieving Vision Zero. To create safer ecosystems, system designers must identify the purpose of a road, what activities will be occurring on the road, who will be utilising the public space, and then design the road accordingly,[11] rather than applying standardised vehicle-centric designs regardless of context. Designing communities where people can live close to the amenities they need to access for work, shopping, leisure activities, and social and education purposes reduces and potentially eliminates the need for car travel.

Forgiving Ecosystems

The concept of forgiving roadside design[13] acknowledges that hazardous objects within the road space increase the risk of fatality and severe injury when a crash occurs. The standards or alignment—horizontal and vertical—for high-speed roads take speed into account and are designed to accommodate the higher operating speeds. The forgiving roadside removes potential hazards that could lead to fatality or severe injury; where it is not possible to remove a hazard, the potential for harm is reduced by design—following the ERIC-PD principles.[14] There are numerous examples of forgiving-design features:

- Shoulder width – where land is available, a wider shoulder provides a greater recovery area in the case where a vehicle leaves the road.
- Roadside barriers – protect a vehicle from striking a hazard, absorb the energy of impact, and, in many cases, allow the vehicle to come safely to its stop without significant harm to the occupants of the vehicle

9 ibid.

10 Technology, using connectivity and additional sensors, is discussed in "Adopting the 'ITS' Holistic View to Progress Road Vehicle Safety," article No. 4 in the WSP ITS-Vision Zero series.

11 sustrans, UK walking and cycling organization

12 See the brochure: Vision Zero, Setting a higher standard for road safety, WSP, p. 23

13 Forgiving roadsides design guide, Conference of European Directors of Roads, Ref: CEDR report 2013/09

14 "Designing Out Flaws Within Road Transportation Systems," article No. 5 in the WSP ITS-Vision Zero series

Figure 3 — Energy-absorbing barrier terminal (photo: courtesy of Highway

- Barrier terminals – designed to deflect a vehicle or absorb the energy of impact (Figure 3)
- Rumble strips at the edge of carriageway – to alert a driver and allow corrective action to be taken
- Passively safe sign supports – to absorb the energy from a vehicle

A self-explaining, or intuitive, road space seeks to prevent driver error; a well-designed vista or field of view enables drivers to focus their attention on the driving task and not be distracted. A forgiving design minimises the consequences of driver error. Design features can "nudge"/ encourage the right behaviours—hard barriers alongside cycle lanes increase the severity of injury in a collision, whereas a gravel edge is more forgiving.

As advanced driver assistance systems become more prevalent in the vehicle fleet, opportunities to improve road safety will increasingly arise from the co-design of road space and vehicles—for example, designing signs and road markings that can clearly be seen and interpreted by drivers and machine vision systems such as automated lane-keeping assist functions. WSP in Australia recently tested characteristics of road markings to support functions of advanced driver assistance systems, noting substantial benefits to drivers of all vehicles through setting minimum widths, reflectivity and contrast to the surrounding pavement surface.[15]

The concept of creating forgiving ecosystems must be contextualized within the complex road system. Forgiving roads design elements/ measures can improve safety for high-speed roads. However, as a forgiving road environment can lead to increased motorist speeds, incorporating forgiving design elements may be counterproductive to achieving Vision Zero in urban contexts with more roadside activity and diverse road users.

Coordinated traffic calming treatments including intentional vertical and horizontal deflection of motor vehicles, such as speed humps, chicanes, and curb extensions/ bump-outs, are effective for reducing motorists' speeds through villages, towns and suburban areas, and can result in a safer environment for all users of the transportation ecosystem in these areas.

Figure 4 — speed hump on a local street in Gothenberg. Sweden

15 "Austroroads, Connected and automated vehicles "

Figure 5 — WSP representation – a vision of a future street

Managing the Interfaces

Creating safe ecosystems requires system designers to acknowledge and embrace the competition between modes and between users, and create safe interfaces. The crash review and response process[16] enables designers to understand where and how to change the design of spaces to create a Safe System.

Managing the interfaces is a key factor in creating safe ecosystems—reducing the potential to fail by designing for conflicts at:

- Interfaces between modes
- Interfaces between modes and infrastructure – a forgiving space

Urban spaces are characterised by an increasingly complex set of interfaces—with the introduction of new modes, such as electric-scooters, electric cargo bikes and autonomous delivery pods, as well as greater provision for active modes alongside automobiles and motorcycles. The design of the physical space must take account of the potential for serious harm that these interactions introduce. Physical separation between each mode minimizes the risks associated with harmful interaction between modes—for example, cyclists and pedestrians, cyclists and motorised vehicles—but does not reduce the potential for "within-mode" harm (cyclists colliding with each other) unless there is separation between individual users travelling by a particular mode. Innovative design is required, as the physical separation of modes for movement within an urban space has the potential to compromise the infrastructure, access and activity required to support placemaking (Figure 5). Given that the potential for crashes resulting in fatalities and serious injuries reduces with lower speeds, measures that control speed create the greatest potential for achieving Vision Zero.

Applying Technology

Technology can play a significant role in managing speed—on all categories of road—to reduce the likelihood and severity of crashes. On rural roads and in urban spaces, the use of vehicle-activated signs (Figure 6) has become more prevalent. When an approaching vehicle exceeds a pre-set speed, the sign will illuminate, providing the driver with a targeted reminder of the speed limit and/or the presence of a hazard ahead.

Figure 6 — Vehicle-activated sign to encourage compliance with speed limits (photo: courtesy of Swarco)

16 "Designing Out Flaws Within Road Transportation Systems"

Figure 7 — Automatic lane closure and enforcement system, United Kingdom (photo: courtesy of Redflex)

Managed freeways and smart motorways use speed management to manage congestion and to achieve greater compliance with speed limits—to reduce crashes resulting in fatalities and serious injuries. These speed management systems rely on enforcement systems to support compliance—variable speed limits are displayed on signals either at the roadside or on gantries above the road. The enforcement equipment—radar detectors and cameras—are also located on structures. Active management of freeways and motorways can also include the use of dynamic signals to close lanes—to protect vehicles and people involved in a crash, for example, or to isolate debris on the road (Figure 7).

The design of a safe ecosystem in this context requires consideration of the mounting structures and their contribution to a forgiving and safe environment—mounting poles and gantries present obstructions, and the design of these structures must not create additional hazards. A cluttered space will not only introduce hazards that can increase the potential for, and severity of, harm but can also serve to distract the attention of drivers, increasing the risk of crashes. The design of the messaging, placement and operation of these signals must also be informed by the consideration of human factors—how drivers will understand and interact with the devices.[17]

To improve safety as communities progress toward Vision Zero, the designers of physical spaces, whether in an urban context, a rural area, suburban neighbourhood or on a freeway/motorway, must take a holistic view of roads—embracing the interdependencies and interactions between people, vehicles and space. This perspective also involves an understanding of the features, users and modes particular to each road/street space, as well as the road's purpose.

Context-specific design is integral to the ITS whole-system approach and crucial for the creation of safe road ecosystems to achieve Vision Zero, which seeks to eliminate death and serious injury from road transport systems around the world. Safe road systems underpin mobility and are essential to the development of communities where people can and want to live, work, learn, socialize and thrive.

Figure 8 — A WSP project (current road - before possible design modifications) in Hutchinson, Kansas, United States noted six transportation modes at one intersection: pedestrian, cyclist, bus/transit, car/truck, tractor and horse & buggy (horse-drawn carriage).

WSP Author

Ian Patey

Head of Profession,
Intelligent Transport
United Kingdom

ian.patey@wsp.com

WSP Author

Lucy Wickham

Senior Technical Director,
Operations and Safety,
Intelligent Transport
United Kingdom

lucy.wickham@wsp.com

WSP Contributor

Jay Aber

Senior Traffic Engineer
United States

Jay.Aber@wsp.com

WSP Contributor

Scott Benjamin

Technical Director,
Intelligent Transport
Australia

scott.benjamin@wsp.com

WSP Contributor

Robert Swears

Technical Principal, Road
Safety Engineering
New Zealand

Robert.Swears@wsp.com

WSP Contributor

Fergus Tate

Technical Director,
Transport
New Zealand

Fergus.Tate@wsp.com

WSP Contributor

Mary Haverland

Technical Executive,
Planning and Mobility
Australia

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