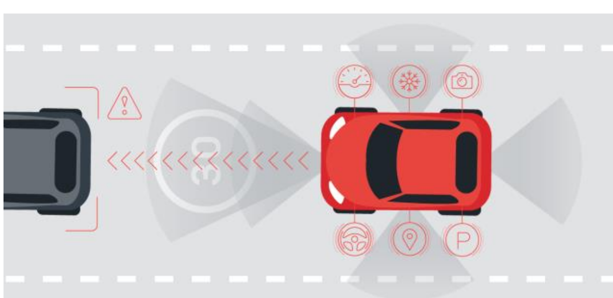
Adopting the "ITS" Holistic View to Progress Road Vehicle Safety

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 and technology, and associated data, to form safe and efficient environments for the movement of people and goods.

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

[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 others who provide for the road transport system.

[2] United States Department of Transportation, National Highway Traffic Safety Administration (NHTSA)

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 1.35 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.

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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

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]

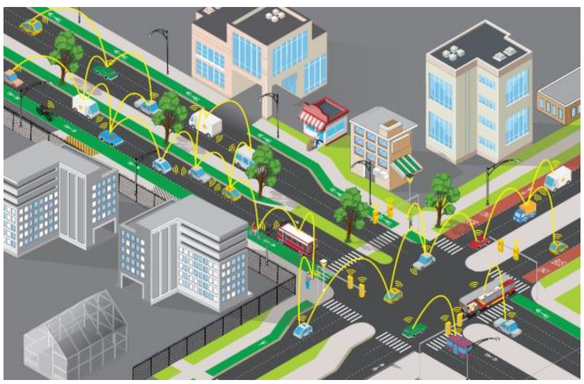

Figure 1 - Networked driving: vehicles communicating directly with each other and their surroundings to operate more safely - Image Source: WSP

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.

[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.

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 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.[10] 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

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

[11] *Safety Assessment for Automated Driving Systems in Canada,* Transport Canada

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] This 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 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.

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

[13] "Effective Intelligent Transport Systems Integrate Human Factors," wsp.com

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

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 account for 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.

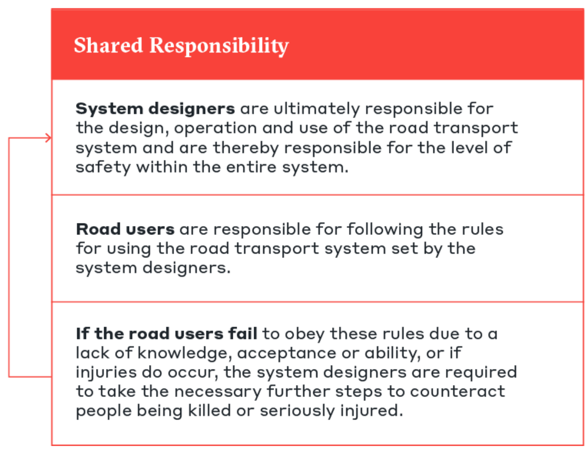

Figure 2 - Responsibility for safety is shared in the Vision Zero approach.
(adapted from the Swedish Transport Administration)

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 account for 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

[15] Euro NCAP, Vulnerable Road User (VRU) Protection

deaths and serious injuries—the goal of Vision Zero—requires this shared all-inclusive, cooperative approach among multiple stakeholders.

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