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Are crash causation studies the best way to understand system failures – Who can we blame?

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ABSTRACT

The search for common and serious single causes of road crashes naturally leads to a concentration on the road user. This is supported by a legal framework in the search for the main cause and the suspect for this cause.

In prevention, we have for decades been more inclined to look for systematic improvements of all elements of the road transport system, and we direct the recommendations for actions towards system designers, organizations, products and services.

In this paper the discussion about causation and prevention is broadened in the light of Vision Zero and its approach to prevention of serious and fatal injuries. We also discuss the Swedish judicial system and why the prevention approach has not been legislated or even generally accepted. Occupational health and safety legislation and road rules are compared, as well as how sustainability practices and reporting are tools to apply prevention where organizations have a natural sphere of influence that could mitigate deaths and serious injuries within value chains.

It is recommended that we stop using the term causation as it is only directing actions in one direction. There is a risk that the focus on causation, in particular single causes, will deviate actions away from robust prevention countermeasures such as increased seat belt use, relevant speed limits, and well functioning roundabouts and median barriers. Furthermore, there is also a risk that important preventative actions from organizations are overlooked.

1. Background

The early days of traffic safety in the road transport system were concentrated on the driver of motor vehicles (Norton, 2015, Tingvall, 2015, Tingvall and Lie, 2017). Road rules, education, licensing, enforcement and information were all directed towards the individual driver. The fundamental safety paradigm built on the driver as the sole perpetrator of road crashes and road rules were formulated in a way that all crashes could be attributed to a violation of rules by an individual human. Behind this idea lies a paradigm that searches for the perfect driver/road user.

The Vienna convention (UNECE) is an illustration and example of how safety regulation has looked upon the driver's responsibilities. The Vienna Convention on road traffic from 1968 is a milestone in harmonizing road rules across the world. The convention has today been ratified by 86 countries (UN, United Nations Treaty Collection). This UN convention is a basis for rules and regulation around the world, with the road user responsibilities placed in sharp focus. In the first of the general rules, Article 7 clearly puts the road user behavior in focus. Article 13, further elaborates on the driver's responsibility in the field of appropriate speeds. It can be seen that driving according to this rule would be more or less impossible, but the possibility to blame a driver for a crash is almost unlimited. There are articles in the Vienna Convention addressing the infrastructure provider and the vehicles, but not in any significant way to be used by the legal system to provide a basis for sharing responsibility between the road user and system providers.

Article 7: General rules.

1. Road-users shall avoid any behaviour likely to endanger or obstruct traffic, to endanger persons, or to cause damage to public or private property.
2. It is recommended that domestic legislation should provide that road-users shall not obstruct traffic or risk making it dangerous by throwing, depositing or leaving any object or substance on the road

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or by creating any other obstruction on the road. If road-users have been unable to avoid creating an obstruction or danger in that way, they shall take the necessary steps to remove it as soon as possible and, if they cannot remove it immediately, to warn other road-users of its presence.

3. Drivers shall show extra care in relation to the most vulnerable road-users, such as pedestrians and cyclists and in particular children, elderly persons and the disabled.
4. Drivers shall take care that their vehicles do not inconvenience road-users or the occupants of properties bordering on the road, for example, by causing noise or raising dust or smoke where they can avoid doing so.
5. The wearing of safety belts is compulsory for drivers and passengers of motor vehicles, occupying seats equipped with such belts, save where exceptions are granted by domestic legislation.

Article 13 Speed and distance between vehicles.

1. Every driver of a vehicle shall in all circumstances have his vehicle under control so as to be able to exercise due and proper care and to be at all times in a position to perform all manoeuvers required of him. He shall, when adjusting the speed of his vehicle, pay constant regard to the circumstances, in particular the lie of the land, the state of the road, the condition and load of his vehicle, the weather conditions and the density of traffic, so as to be able to stop his vehicle within his range of forward vision and short of any foreseeable obstruction. He shall slow down and if necessary stop whenever circumstances so require, and particularly when visibility is not good.

There have been alternative approaches to road safety through history. One important line of thought was elaborated by W Haddon Jr. when gearing the traffic safety strategies more towards prevention of death and injuries (Haddon, 1980). His definition and use of the terms"active" and"passive" safety, meaning the level of action the road user needs to take to prevent death or injuries clearly points at a new direction for road safety policies.

While prevention and a more holistic view on safety became wider spread, the paradigm around the road user as the main cause of crashes still seems to prevail. And, with that, the concept around crash causation. This goes hand in hand with police investigations primarily aiming at finding someone to blame for the crash.

2. Vision Zero

Starting from the field of prevention, Vision Zero was introduced in the 1990s. It is built around a set of fundamental approaches to road safety (Johansson, 2009, Swedish government bill, 1997, Tingvall, 1995). In Vision Zero, the ultimate goal is the elimination of severe and fatal injuries. The Vision Zero further states that road deaths and severe injuries are considered unacceptable and preventable. To many, this shift was against common practice. The basis was to shift from defining crashes as the main problem to identifying the most problematic outcome as the main target for prevention. In many ways, the shift of emphasis from all crashes to the most severe ones made traffic safety improvements more focused towards the goal, the elimination of severe and fatal injuries. The Swedish Parliament decided on the government bill in 1997.

The parliamentary Vision Zero decision in Sweden in 1997 also contained the principles of responsibility for safety in the road transport system. While the idea of how to share the responsibility for safety was not new (Koornstra, 1992), this was a parliament explicitly deciding on how to deal with the responsibility for prevention of deaths and serious injuries caused by crashes in the road transport system. In the government bill that the parliament adopted, it is stated that it is the providers of the system that have the ultimate responsibility for safety while the road users are responsible for following road rules (The text is cited below). In the third, most important paragraph, it is stated that if the road users fail to follow rules and regulations, the responsibility for improving the safety falls back on the providers of the system (Swedish government bill, 1997; Tingvall, 2022).

- The system designers have ultimate responsibility for the design, upkeep, and use of the road transport system and thus are responsible for the level of safety for the entire system.
- As before, the road users are still responsible for showing consideration, judgment, and responsibility in traffic and for complying with the traffic regulations.
- If the road users do not adequately assume their share of the responsibility, for example, due to a lack of knowledge or skill, or if personal injuries occur or risk occurring for other reasons, the system designers must take additional further measures to prevent people being killed or seriously injured. (Vision Zero principles, Swedish government bill1996/97:137).

In the Vision Zero approach, system designers play an important role. They are the actors influencing the design and use of the road transport system. They hold a shared responsibility for the safety of the system as a whole. This responsibility has not been formalized but still is an important element when seeking design and use improvements.

Further, a cornerstone of the Vision Zero is formed by the design principles, to design and adapt the road transport system to the fallible and fragile human. This was seen by some road safety practitioners as a stark contrast to the common approach to improve the road user performance by training, educating and enforcing. However, for many road and vehicle designers it was not very radical. Vehicle safety systems and guard rails etc. have been common practice since long.

When designing for the fallible human there is an obvious need to differentiate between errors and mistakes at one side and violations on another. Deliberate and significant violations based on the road users decision must be tackled with special methods including technical means and enforcement.

The human body is not well designed for the energy levels/speeds and potential crash forces we see in everyday traffic. Over time, we have been accustomed to mobility/speeds far exceeding our human tolerance. Within the Vision Zero, a model for safe travel in a vehicle was developed (Tingvall et al., 2000). The model, shown in Fig. 1, illustrates how

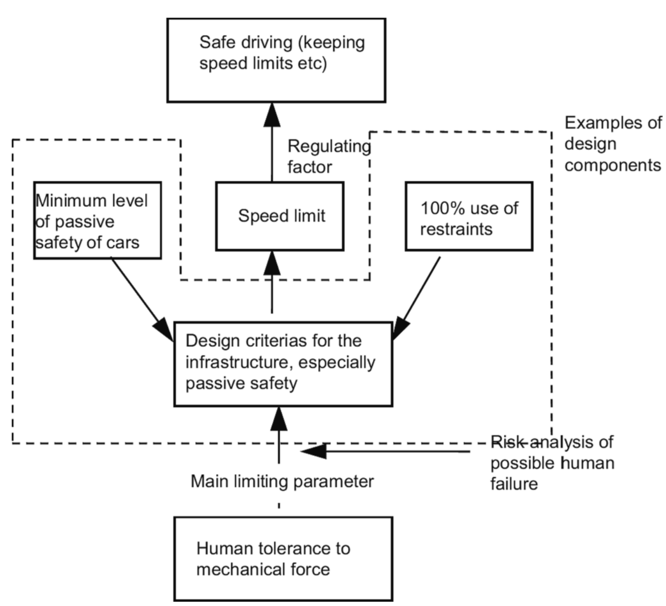

Fig. 1. A multidimensional model for safe travel in a vehicle (Tingvall et al., 2000.Page 67).

the design components in the system interact and how the safety performance of the components also controls the safe speeds that are possible. Weaknesses in one component can be compensated by stricter demands on one or several other components. One example would be that if the system should accommodate users not having their seat belts on, the demands on the vehicles can be higher or the speeds go down. The most typical way to change the safety level is to lower the speeds in the system. Most investments in improved safety will result in higher"safe" speeds. Models for other road users were developed later. Figs. 2 and 3.

It is clear that the Vision Zero approach is concentrated on prevention of death and serious injuries rather than crashes. However, it is the combination of components of the road transport system, tied together by design, that forms one or several safety nets for the fallible human. In doing so, reducing the risk of a crash as well as protecting the human in a crash are equally important to include in the analysis of effective prevention strategies and combinations. While the preferred situation supports the users of the system to act in a conscious and safe way, the design principle is to cater for foreseeable situations of errors and mistakes. Even some deliberate violations by the users should be included as they might not be prevented by measures such as enforcement, vehicle safety features or other safety technologies. Today one example of a common violation is moderate speeding. Both road side (Belin, 2012) and in vehicle technologies plays an important role in tackling this.

There are many alternative actions to prevent deaths and serious injuries resulting from road crashes. Many of these were explored by William Haddon Jr. in the article"On the escape of tigers" (Haddon, 1970). On a high level, the main alternatives are to prevent a crash itself, to modify the crash by lowering the amount and/or the direction of kinetic energy, or to protect the users by personal gear, better crash protection of vehicles, etc. (for a given crash severity). The challenge in saving many lives is to combine different prevention principles and protection methods in an efficient way to cover as many potential cases as possible. Reducing travel speed, modifying the road infrastructure, and increasing the use of safe vehicles and personal safety gear are all examples of broad interventions that, even today, have the potential to save many lives. In combination, a safe mix of the components of the road transport system can generate almost zero fatalities and serious injuries (Stigson, 2009, Tingvall et al., 2010). Theoretically, this happens when no crash exposes the human to a mechanical force beyond the human biomechanical tolerance. A good example could be a passenger car with good crash protection (including seat belt reminder), technology that prevents the car from driving off the road, speed limiter and technology to prevent driving too close to other road users, driving on roads with median barriers and safe side areas, and having a speed limit set on the basis of safety. This is an example of how different prevention principles are combined to reduce the risk of a crash, reduce the severity of a crash and eliminate the risk of death if a crash still occurs, as the threshold for a serious injury cannot be reached.

The road infrastructure can play several roles in preventing and /or mitigating fatalities and serious injuries. There are road treatments that reduce speed (e.g., elevated crossings), modify angles and speeds (e.g., roundabouts), and interventions that reduce crash severity (e.g., guardrails and mid barriers). In summary, there are treatments that reduce crash risk, modify crashes and reduce crash severity. Some of them, like roundabouts and mid barriers, have been shown to reduce the risk of death by 80–90 % for relevant crashes compared to earlier road designs like signalized high speed intersections and undivided roads (Stigson et al., 2023).

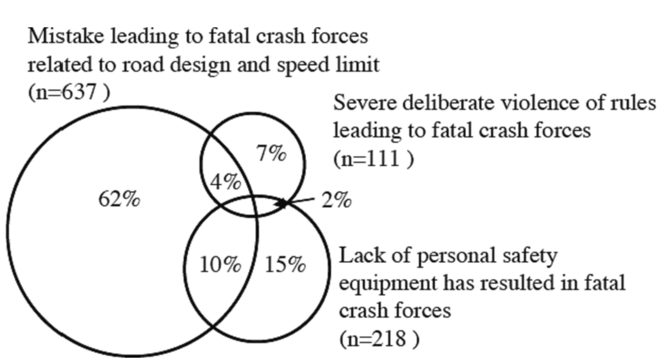

Fig. 2. From Lie A, Tingvall C. Governmental Status Report to ESV conference. 17th ESV Conf. Amsterdam 2001.

Vehicle designers have nowadays taken significant steps to protect both passengers and other road users with whom the vehicle may collide (Eugensson et al., 2011; Eugensson and Ivarsson, 2022; Schöneburg and Baumann, 2022). The crash protection for occupants is at least five times better if we compare the outcome when an older and a newer car crash into each other (Folksam, 2019). But also the crash severity has been addressed by autonomous emergency braking, which can reduce the speed by up to almost 35 km/h before the impact. And other systems can reduce the risk of a crash by steering in critical situations. Today, modern seat belt reminders have been shown to reduce the size of the unbelted driver population by around 80 % (Lie et al., 2008, Lie, 2012). The technology content of modern cars is growing, adding elements of self-driving capabilities and driver monitoring (Euro NCAP, 2022). Using the vehicle's new sensors and actuators, we might even expect, in the near future, that vehicles can detect impaired drivers and take adequate action (Lie et al., 2023).

Energy is what typically kills and injures road users in crashes. The most critical energy levels are correlated to speeds (Rizzi et al., 2023a). The vulnerable road users have a very direct link between injury risk and the speed of a colliding vehicle. In vehicles with elaborate protection systems, the link to travel speed is less direct.

When the components of road infrastructure and vehicles are brought together, there is a maximum safe speed that can be set. Setting a speed that is too high in relation to the safety of the components results in a risk of fatalities and serious injuries. And if one or several of the safety components of the road infrastructure or vehicles fail, or are absent, this would pose a risk of serious consequences. The same situation occurs if the driver chooses to drive above the set speed limit. In any case, if one or several of the components fail or do not comply with the design or intended operation, the safety of the system is potentially compromised.

Speed limits are being reduced, especially in areas where vehicles and vulnerable road users, especially pedestrians/bicyclists, interact. This is identified as a priority area in the Stockholm Declaration from the Third Global Ministerial on Road Safety 2020 (Trafikverket, 2020). Lower impact speeds allow the pedestrian and bicyclist protection properties of modern cars to work optimally. Lower travel speeds also contribute to better co-operation between vulnerable road users and motorized road users, and the cities become more livable.

The Vision Zero multidimensional model for safe travel illustrates a multi-sectoral and holistic approach to road safety. Looking for single crash and injury causes in the model is problematic and of no, or limited, value. There is even a risk that the single cause approach results in the belief that the solution lies only in that cause. If human error is the dominant cause for crashes, with an estimated proportion of over 90 %, according to NHTSA (Singh, 2015), changing the human behavior is not necessarily the main solution. The systems approach can offer more alternatives in the search for efficient solutions.

Late in the 1990s, the Swedish Road Administration set up in-depth studies of all fatal road crashes in the country (Swedish Road Administration, 2004). These studies were performed to better understand the individual crashes and to give the management of the administration day-to-day information about the fatalities as well as emphasizing the understanding that every fatality must be seen as a deviation of the desired safety quality of the road transport system. This made the crash and injury problem better understood and complemented statistical overviews as well as building an understanding that in most cases, there

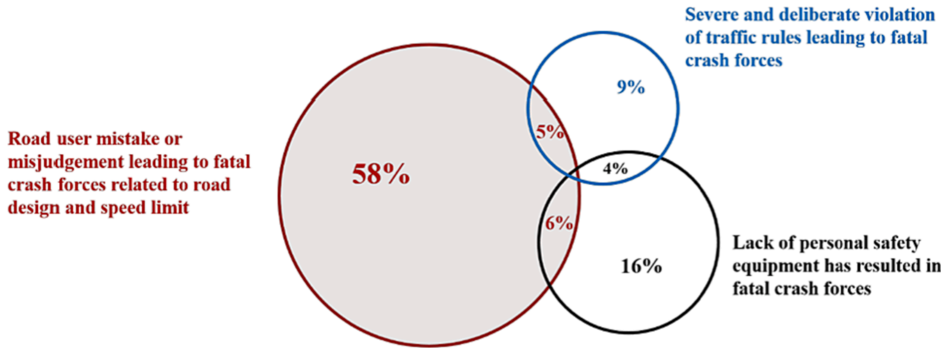

Fig. 3. From Rizzi M, Fredriksson R, Krafft M. Government Status Report Sweden, 27th ESV Conf. Yokohama 2023.

is an action needed from the Road Administration and/or other stakeholders. Data were collected from crash sites, the involved vehicles and from medical injury reports, including autopsies. The data were mainly case files, but some information was coded mainly to enable searches for crash/injury types.

From the very beginning of Vision Zero the aim of policies and initiatives has been the elimination of fatal injuries as well as injuries leading to long term health losses. The Swedish Governmental bill from 1997 clearly identified the need for a development of methods to identify these the most severe health losses. Therefore, in parallel with the development of the Swedish in-depth studies, the definition used in Sweden of a serious injury was altered to also cover injuries that resulted in a long term loss of health. The basis for the classification was studies made by Folksam Insurance Group that showed the relationship between initial medical diagnoses and the long term consequences (Malm et al., 2008). While there is a link between the crash severity and the risk of death (Evans, 1994) and the risk of long term health losses, there are injuries that clearly have a high risk of impairment but a low of risk death. One such injury is whiplash that often results in long term pain and reduced quality of life (Malm et al., 2008). However, for many serious injuries the conclusion was that prevention aimed at reducing the risk of death would also be relevant for serious injuries. The exceptions from this conclusion needed, and still need, special consideration. As of today there are no Swedish national in-depth studies of crashes leading to long term health losses.

3. Vision Zero multidimensional model for crash classification

There are examples of crash statistics on fatalities, divided by system components and their relationship to what would have been a safe design and safe behavior of the drivers/road users. In a study presented in 2001, Lie and Tingvall (2001) used the Swedish in-depth studies of fatal road crashes occurring in the years 1998 and 1999. These fatal crashes were analyzed using the Vision Zero multidimensional model for safe travel, with every case classified into one of three groups. One group contained cases where the road user had made a minor mistake or misjudgment leading to the fatal crash. A second group contained people who had neglected to protect themselves, primarily by seat belts. The third group contained deliberate violations. These violations were mainly associated with severe speeding, reckless driving and deliberately going against a red traffic light. The analysis was made with injury causation in focus. The results were presented in a Venn diagram.

In a recent follow-up study from the Swedish Transport Administration (Rizzi et al., 2023b), every fatal crash in 2016–18 was coded according to the same three categories.

The two studies mapping fatal crashes show similar results. They are both using identical classification categories, and with a small team of researchers doing the classification. The method allow fatalities to be categorized in more than one category. About two-thirds of the fatal injuries are attributed to everyday road users making everyday mistakes, around a quarter of the fatalities are related to lack of personal safety equipment and only a small proportion, 13 % and 18 % respectively, are related to deliberate and severe violations of traffic rules. The part related to severe violations has grown between the two studies. This seems logical as significant investments in newer vehicles and improved road design mainly benefits the road users complying with rules and regulations. Eradicating serious violations would today only save less than 20 % of lives lost in Swedish traffic.

A study from Australia (Wundersitz et al., 2014) with a similar aim, classified crash causation in three separate categories, (system failures, illegal system failures and extreme behaviour) and found that less than slightly half of the crashes could be attributed to extreme behaviour. The definition of extreme behaviour/severe violations differed from the Swedish study differed but the general conclusions were in the same direction. Both the Swedish studies and the Australian used a very small group of researchers to do the final classification into the categories. That approach ensures consistent results. Even if some individual cases can be hard to classify, the general conclusions In the Swedish studies, are clear.

Tingvall et al. (2010) used the Vision Zero multidimensional model for crash classification. Using individual fatal crashes, the team tested the hypothesis that the same crash would have happened on safe roads (Euro RAP five stars), in safe vehicles (Euro NCAP five stars) and with safe behavior (no alcohol, no speeding and use of seat belt). The study found that very few fatalities would occur if these factors were fulfilled. A simulated combination of divided roads, sober driver, restrained occupants and no excessive speeding generated a reduction of 95 % compared to the real outcome of car occupant fatalities in Sweden 2004 (Stigson, 2009).

Strandroth and Rizzi (Strandroth, 2015; Rizzi and Strandroth, 2022) have taken the methods further by analyzing actual fatal crashes, in combination with known safety development of vehicles and roads to make projections. With these factors, back-casts from future targets can be made to validate the fulfillment of safety goals. The method generates knowledge about the cases that are not covered with present approaches. As we develop towards stringent traffic goals, these back-casting studies can indicate areas that need further focus. As examples, the analysis shows that more attention must be paid to vulnerable road users, particularly bicyclists and motorcyclists, and to the safety of vehicles transporting heavy goods, especially on roads without median barriers.

4. Discussion and recommendations

The design and operation of a safe road transport system is complex, time-consuming and concerns many stakeholders. Despite this, most jurisdictions today aspire to develop a road transport system without serious health losses. On the highest levels, like the United Nations (UN, United Nations (2020)), the World Health Organization (WHO, 2020) and the European Union (European Commission, Directorate-General for Mobility and Transport, 2020), the targets about zero deaths and serious injuries are clear. Also in the private sector, the aspirations are clearly communicated by many companies (Trafikverket, 2020, WHO, 2020). It seems logical that these high aspirations should be accompanied by good knowledge of the situations and preventive actions, together with a relatively detailed plan of how to take significant steps towards the goal. Statistical data are a weak starting point when ambitions are to be transformed into actions. While statistical data identify areas of interest, prevention must be based on causal relationships established through scientifically-sound methods and processes that link actions to effects.

The idea about prevention of crashes and/or injuries is not new. The history of preventative road safety interventions goes back to the 50s and 60s. With Haddon, the principles and categories of prevention were systematically developed. Haddon's broad approach to injury prevention has, unfortunately, widely been reduced to the Haddon Matrix. The commonly used matrix divides the system components into users, vehicles and environment, together with the timeline of pre-crash, crash and post-crash. These divisions naturally interact, but there is a risk that every cell in the matrix is looked upon in isolation, resulting in a risk that the interactions are neglected and the available prevention possibilities missed. Searching for a single cause in every crash risks masking a wider, more holistic approach.

The Swedish in-depth studies of fatal crashes inspired the development of the Vision Zero multidimensional model for safe travel. The model shows how different components of the road transport system interact, as well as what is needed to generate safe traffic. The model has been used to understand fatal crash scenarios and illustrate how different areas of prevention interact. The Vision Zero multidimensional model for safe travel has also been used for backcasting exercises, helping the planning process to focus both on what to improve and when to do it. Analysis using the model is based on elements of subjectivity, the most challenging being"severe deliberate violation of rules leading to fatal crash forces". The definition of"severe" is very much based on crash energy, with extreme speeding falling into this category, while"everyday mistakes made by everyday people" lies at the other extreme. One should bear in mind that the legislation, based on the Vienna convention, defines virtually all crashes as violations of rules. Vision Zero takes a more forgiving perspective in striving to protect road users, who by their nature, possess human weaknesses that lead to errors and mistakes. One should not blame the victim. Vision Zero's responsibility chain puts the ultimate responsibility for a safe system on the system designers.

Today, the common view in many sectors and jurisdictions, seems to be that safety is built by many cornerstones, and that the safety philosophy today is to design a system that is tolerant to human errors, mistakes and misjudgments. These basic concepts are better developed in some areas, like labor protection, but less developed in the road safety sector. However Vision Zero is stressing that human weaknesses should not lead to death and serious injuries in traffic. It is therefore clear that the ultimate aim is to design the system on the basis of the fallible human (minimizing crashes) and the human biomechanical tolerance to mechanical force (reducing injuries). This design philosophy always seems to be built on a common understanding that road infrastructure, vehicles and users must be brought into a systems analysis that is tolerant to non-compliance in one or several of the components. There is an evident challenge to get a fruitful collaboration between human factors, vehicle safety, road design practitioners and researchers. Such a joint approach is essential when the effects of different prevention strategies are estimated. It is also clear that the knowledge areas can interact. Modern seat belt reminders can be seen as a technical system, but they are clearly influencing vehicle user's behavior.

Because of the intrinsic interactions in the safe system, to define a single"cause" of a fatality risks being rather misleading. Furthermore, to base prevention interventions solely on"causes" of crashes could be ineffective in targeting many crash types, and"causes" could differ from what would have stopped a crash itself from taking place (Hauer, 2016). One obvious example is a mid-barrier on a road, where crash severity is mitigated irrespective of the reason behind the crash into the barrier. Another example is, again, seat belts that protect in a multitude of crash situations, regardless of the crash cause. Shifting the focus from the cause of a crash to the cause of severe injury or fatality is a step in the right direction, but in a systems analysis, it has to be further expanded with prevention as the main objective.

The challenge with prevention is to find combinations of design and operational factors that in a n effective way prevent death and serious injury. To look only at the road user's behavior and maneuver (or lack of action) immediately prior to a crash, and base possible preventative interventions on such knowledge would seriously limit the scope for reducing serious crashes (Reason, 1991). The classification of crashes into categories, as shown above, of human failures and serious, deliberate violations, combined with a lack of a balance between the preventative performance of the road infrastructure and vehicles, given the allowed maximum speed, shows that the system performance is the real problem. In Sweden serious offenses are estimated at around 20 % and, therefore, are not a dominant factor in explaining the deaths of road users. Instead, it is recommended to focus"upstream" from the event to find wider system failures and opportunities for improvement in system performance. Combinations of preventive action can give very positive results as the benefits of every layer of protection build. The study from Tingvall et al. (2010) showed that meeting basic demands on roads, vehicles and drivers (i.e., being sober, not speeding and using the seat belt), together, could almost eliminate road fatalities in Sweden.

It is not a given that different societal areas share the same goal. Road safety authorities, practitioners and researchers in Sweden seem today to share the concepts of Vision Zero. However, the Swedish judicial system dealing with road crashes does not seem to have picked up the gradual movement from the road user as the sole perpetrator of crashes to a balanced view of what constitutes safety and should be done from a prevention perspective. Instead, the judicial system has continued to search for individual road user faults and the possibility to prosecute drivers. Even if a crash has been initiated by an error or mistake of a road user, the"guilty" driver can be sentenced on the basis of having caused the death of another person. The courts are making their decisions on the Swedish road rules that are based on the Vienna Convention. Therefore the police investigations, that are performed to support the courts, are using the same approach basis as well.

With a judicial system that, without doubt, has a major road safety role in the current society, the approach taken might have detrimental effects on effective prevention. And the preventative results of a judicial system focussed on finding and prosecuting individual road users, most of whom have made an error, have little, or possibly no, effect as a general deterrent. The concentration of effort on finding a guilty individual in a crash is reinforced by insurance systems' and insurance providers' handling of guilty vs non-guilty partners. Premiums, deductibles and compensations are all based generally on the road rules and the same principles as the judicial system. The communication with the community via media based on the police investigation, and the decisions by prosecutors and courts, would most likely also impact on the general understanding of road crashes and their origin, and lead to a biased view in the public. It can be assumed that road users don't change their behaviour significantly if they believe that they normally drive in a safe way and that the main problem is severe violations by a limited subset of the population.

Kullgren et al. (2023) studied recent fatal crashes in Sweden with the police's and prosecutor's investigation process in focus.The study showed that that the judicial system still concentrates on the individual road user but also fails to use the wider preventative legislation that is available. The study also showed that occupational health and safety legislation would have been adequate to pursue in almost 40 % of all fatal crashes. None of these was investigated by the police or prosecutors as workplace events. Further, many crashes involved possible negligence from road infrastructure providers, possible negligence from organizations with a commercial permit to operate transport services and some crashes also involved defects on cars that involved automotive industry responsibilities or lapses in the mandatory car inspection. None of the crashes was investigated by the police and prosecutors in a way that could enable such possible violation of rules and regulations to be found. The search for a specific road user single"cause" that could be prosecuted still seems to prevail and undermines the efforts to implement serious and wider prevention tools already available. These findings were based on data collected in Sweden, but other jurisdictions might have the same experience. Countries that have ratified the Vienna Convention have regulations based on the convention and can be assumed to have similar judicial practice. In any case, it is recommended that jurisdictions act to use already existing or new legislation to include organizations to better focus prevention.

The parliamentary decision in Sweden in 1997, and the introduction of a"shared responsibility" between the providers and the users of the road transport system does not seem to have led to any substantial new legislation concerning the shared responsibility and prevention. The"-safe system principles" that have been adopted in many jurisdiction across the world do not seem to have permeated into the necessary legal structure and principles in a similar way. The Vienna Convention for road rules has not changed as a result of these new principles. There do not seem to be any rules for speed limits or road design, or provisions for safe infrastructure for vulnerable road users.

There are, however, other processes in the community that might lead to the use of existing or new tools that underline the importance of organizations, rather than individuals, engaging in prevention. Going beyond the individual opens opportunities for including organizations in the prevention mix. Occupational health and safety regulation has a better balance between the responsibility of the employer and the employed. It is recommended that experiences from occupational health and safety legislation is introduced into the legal system around road crashes. Such a balance would also be fruitful for effective prevention in the road safety sector and, as there is a common overlap between general road crashes and road crashes that involve the employed, there is a scope for learning without adding new prevention legislation.

The inclusion and integration of road safety in the United Nations 2030 Agenda opens up for both the private and public sector to contribute to sustainability (Trafikverket, 2020; UN, United Nations (2020); WHO, 2020). Public procurement, sustainability practices and reporting, safe working conditions and sustainable mobility are all examples of tools and aspirations that would naturally lead to a preventative approach to road safety (Trafikverket, 2020). If an organization wishes to reduce its safety footprint (defined as the number of killed and seriously injured in road traffic within the entire value chain of the organization) in a systematic way, it would need to apply evidence based interventions. And if an organization wishes to reduce the number of killed employees, contracted and third parties as a part of its commitment to safe workplaces, it would be natural to apply simple principles like following road rules, only use the safest vehicles, and investigate non-compliance and crashes in road transport.

The development of digital maps, sophisticated sensors, actuators and actions on modern cars, and the aspirations of vehicles that are semi or fully automated lead to new questions about the vehicle's ability to detect and react to the driver's status, concentration and driving style. If a modern vehicle does not react to input from the driver that leads to serious violation of road rules, this could be seen as negligence, as well as if the driver is not reacting to significant and relevant stimuli.

In summary, the search for an isolated cause of fatalities and serious injuries as a result of road traffic crashes has no longer any substantial role in prevention. Modern road safety preventative methods are based on stopping or mitigating a sequence of events in the most effective way. These modern methods are, to a high degree, disconnected from the more traditional finding of singular causes. Furthermore, effective prevention is based on combining interventions, while potential actions may even be based on certain predefined conditions (e.g., guard rail design is based on a car occupant using seat belts). A single cause, therefore, has limited substance in guiding us further in prevention and might even blind us. It can, therefore, be seen as counterproductive that the judicial system still concentrates on finding a cause related to an individual road user. The current road rules are constructed to always make it possible to prosecute an individual road user for a crash, and the current legislation is therefore not supporting prevention as the main, and probably only, way towards the ambitious targets set by the community. It is, instead, nurturing an outdated culture of blame. How organizations both designing and using the road transport system can take significant responsibilities for safety is not, at least in Sweden, supported by the legislation today. A better legal framework inspired by occupational health and safety legislation is recommended.

There is, however, a risk that a concentration on systems' safety might be misunderstood or misinterpreted. The road user should also in the future follow basic road rules, and there should be enforcement, technical support and monitoring to make sure the norms in the traffic are aligned with the rules. We recommend, in particular, professional users of the road transport system to make sure that road rules are the norm and to report on their success.

Finally, we recommend the scientific community avoids using the term"cause" in a simplistic way when referring to crashes. Further, blaming individuals for system failures should be avoided. Instead, the concentration should be on the search for effective prevention. Systematic prevention is normally better developed and performed in an organizational context and with a sophisticated analysis behind actions taken.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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