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Decade of Action for Road Safety, 2011–2020

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This informal document outlines the Safe System approach. The document suggest ways to modify the 1968 Conventions on Road Traffic and on Road Signs and Signals as well as the Consolidated Resolutions on Road Traffic and on Road Signs and Signals to reflect this approach a greater extent.

Road safety and transport system design principles

Background

1. The development of road safety is undergoing major changes now and most certainly in the next ten years. The global community has reacted strongly on the predictions of the impact of poor safety and the growth of road traffic, on the society and the health of the population. It has been estimated that death trough a traffic accident will become the third or fourth most common source of death within 10-20 years, unless major and effective actions are taken. The UN has declared 2011-2020 as “the Decade of Action” asking for contributions from all countries and stakeholders to diminish a world epidemic of road casualties that not only impact on health but also on economy and economic growth in particular in low and middle income countries. The concern is related to safety, but the overall aim of the future is to develop a sustainable transport system where safety, environment, energy and accessibility are integrated. Such integration is complex and system design necessary as a tool to find synergies and limitations.

2. Current traffic safety approach in large parts of the world is “Vision Zero” or “Safe System”, two expressions of an identical policy. Recently, in the white paper on transport “roadmap to a single European transport area —Towards a competitive and resource efficient transport system “- the European Commission has adopted Vision Zero, with the target that by 2050, the number of fatalities due to road traffic crashes should be close to zero. Also the guiding principles underlying the global Plan for the Decade of Action are those included in the "safe system" approach. The forthcoming ISO 39001 management standard for traffic safety specifies that the standard is only relevant for organizations that wish to eliminate death or serious injury in road traffic crashes. OECD has recommended that the Safe System approach should be used to manage traffic safety (OECD/ITF-report: “Towards Zero: Ambitious Road Safety Targets and the Safe System Approach”). In the private sector, Volvo Cars has set a target of zero deaths and serious injury in or by a Volvo 2020. Other car manufacturers have expressed zero as their vision, but not specified when this is supposed to be fulfilled. All these examples have one thing in common, except from explicitly aiming for elimination of death as a result of road traffic crashes, and that is the system’s perspective.

3. Hence it is a challenge of utmost importance for UNECE WP.1 to adopt the Safe System approach in its work with the purpose to make the Vienna Convention and the Consolidated Resolution on Road Traffic (R.E.1) to a greater extent reflect this approach.

Basic principles

4. The basis in this kind of system design are twofold, the biomechanical tolerance to mechanical force and the possible crash scenario that can be foreseen. In working out possible scenarios, the human behavior is the key for understanding what might lead to a crash with energy enough to harm the human. The balancing act is to maintain accessibility and mobility of the road transport system, but limitations in safety should be counteracted by reduced kinetic energy, which in most cases mean reduce speed. The alternative to reduce speed is an investment into the system that leads to maintained or even increased speed. This is why progressing in safety in the end is an investment in mobility.

5. Working out the interrelations between the components of the system in order to maximize the output in terms of a safe system is the challenge for system design and policy making. In doing so, it must be understood that the road transport system is open, complex

and only possible to partly manage by rules and regulations. Therefore the progress must be based on the understanding that it will take a long time, many components have a long life time, and there are other processes of the society that impact on the composition, nature and use of the road transport system. It must also be understood that some components are designed or maintained locally while others are national, regional or even global. It must also be understood that the main functionality of the road transport system is accessibility for more or less the whole population and that there are other aspects, like the environmental impact, that must be handled as well. Strategies for improvement must therefore be robust, flexible and sustainable, or reduced mobility and/or kinetic energy.

Human error

6. The overarching concept of a safe transport system contains two imperatives, known for thousands of years. The first is that “it is human to err” (errare humanum est) meaning in this particular case that the human can never be trusted to repeatedly perform correct in all traffic situations, even if the intention is to maneuver in a safe manner. While it has been an imperative, the human imperfection in traffic has been validated in numerous studies, showing that while some behavior is no doubt illegal, it is not necessarily the intention to violate the rules. Running a red light or trying to cross an intersection despite there is conflicting traffic are typical examples of serious traffic offences that might have no intention behind. Forgetting to put on the seat belt, not turning on headlamps, losing control on a road with invisible ice are other such examples of possibly violating rules with no real intention behind, but possibly leading to lethal consequences. While this is all clear and logic, the road transport system has not been designed from ground with the aim to absorb or mitigate common human error. There are many examples, though, where individual countermeasures have been introduced, but mostly in isolation and not with a system’s approach where components are tied together to create redundancy of the individual solutions. This is the reality still, although the knowledge today about human error is well studied and documented. It is also known, that human error is a repetition of a few scenarios on and on again, that is, easy to foresee.

7. There is still a fairly widespread belief that accidents are caused by human errors and that these could be significantly reduced by introducing additional regulations and procedures to ensure a "correct" behaviour and punish an "improper" behaviour of those who "violate" the rules. In such an approach those who design or maintain a complex system set out from an idealized model of how the system is supposed to work and how people in the system must behave in order to achieve an optimum level of safety. Rules and procedures are then developed with this model as a starting point. This presupposes that those responsible for the design and regulation of a complex socio-technical system can anticipate all possible and impossible situations, people can be put into due e.g. technical and organizational conditions.

8. Such an approach thus implies that human errors are defined as a deviation from a prescribed behaviour in an idealized model of a relatively static system. A complex system is however never static but change and evolve over time. Such changes can have a variety of reasons. Examples include technology development, organizational change, changes in economic conditions, etc. This means that the rules and procedures cannot fully reflect the system's safe operation. For this reason, participants in the system have to change their mental models of the system continuously and "break" the rules in order to maintain the system's safe operation. Breaking the rules and not following procedures need not always be detrimental to system safety, but can sometimes be a prerequisite for it.

9. Another reason for breaking the rules and not follow the prescribed procedures is that it is human nature and survival instinct to try to optimize their performance in order to

save time and effort A number of studies also show that the rules and procedures are rarely followed to the letter because the actors in the system trying to become more efficient and productive Often this is done gradually. People are starting to "chip away one rule in the edge." Usually nothing happens other than that the people in the system experience a gain in the form of e.g. saved time and increased efficiency. Since nothing happens in the form of accidents or other impacts continue rule violation and is likely to increase gradually until something happens. The same applies, of course, for example, road system where people can see different kinds of gains in breaking the traffic rules.

Biomechanical tolerance

10. The other imperative, today well and thoroughly verified, is the role of kinetic energy in case of a human error. Hippocrates wrote around 400 B.C. “Of those who are wounded in the parts about the bone, or in the bone itself, by a fall, he who falls from a very high place upon a very hard and blunt object is in most danger of sustaining a fracture and contusion of the bone, and of having it depressed from its natural position; whereas he that falls upon more level ground, and upon a softer object, is likely to suffer less injury in the bone, or it may not be injured at all.” (Adams, Francis (1891), The Genuine Works of Hippocrates, New York: William Wood and Company)

11. What is behind Hippocrates sentences is simply the strong relationship between the speed/energy and the object that finally stops us in case of a human error leading to a crash, and how such errors can be counteracted with lower speed and/or substituting or modifying surfaces that we hit. A high risk of human error can therefore be matched by reduced kinetic energy or less harmful contact surfaces.

12. Vision Zero or Safe System combines the two imperatives with back casting. If zero deaths and serious injuries are to be achieved, how do we combine human error with human biomechanical tolerances by minimizing human error, but when it occur to make sure that the human biomechanical tolerance is not exceeded. In doing so, it is simply necessary to develop design principles for system safety, and not simply treat each component individually. The characteristics of the road user, the vehicles, the road design and the speeds on a road all have to work together to achieve safety.

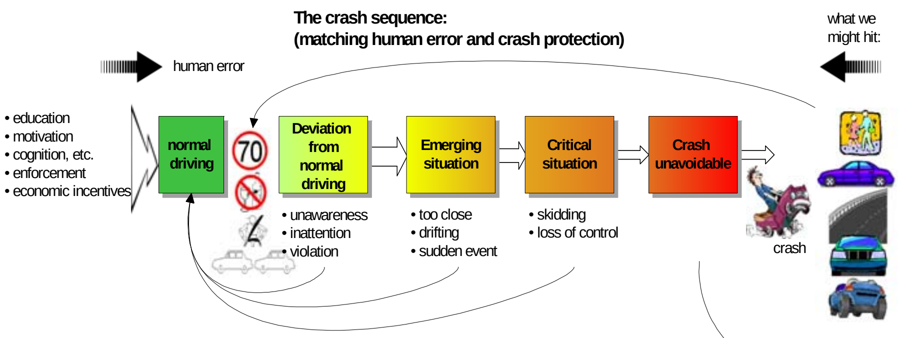
An integrated systems approach

13. The development of traffic safety should and must be based on scientific evidence and best evidence from experience. This should apply to all stages of the development, from target setting and management to detailed methods and products to diminish or eradicate trauma. In doing so, it is necessary not only to develop management systems but also to integrate safety solutions to all factors of a prevention process as well as identifying and align to other qualities that need to be solved. This is a general trend in the automotive sector since a few years back, but needs to be broadened to the entire road transport system. As an example; to seriously reduce pedestrian casualties, road user rules and behaviour, traffic environment, speed management, systems to brake a car automatically and friendly front end of the car must be combined in an optimised way. In isolation, the effect of each component may have some effect, but as they give each other preconditions to maximise benefit, the whole combination might give more effect than the sum of each component. If vehicles are improved to protect pedestrians at impact, but the speed at impact is higher than the design envelope of the vehicle, i e the protective potential of the car can only operate at lower speeds, the improvement of the car might be very small compared to a situation where speed management is tailored to the vehicle capability. The systems approach is a well known and an important research area in other socio-technical systems

with high risks. This approach can be expanded to more complex examples involving acceptance by the road user to new innovative safety systems as well as to other consequences like fuel consumption and costs. In doing so, the system approach to road safety must be aligned with other demands and needs like low emissions, minimised noise and congestion as well as accessibility in general and interfaces to other transport modes. The costs for achieving all these qualities must also be brought into the design process.

The integrated safety chain

14. The integrated safety chain (figure 1) seems to be generally accepted within the automotive industry, but not understood fully in the entire transport system. The automotive industry is developing systems and technologies for all steps in the integrated chain, and a number of systems have already been launched on the market, and in a few cases also been evaluated in real life scenario. On the whole, there are though a number of technologies that have not been evaluated yet, and in particular, not in combination with other systems. Beyond that, there is a complete lack of studies that cover also the other factors of the transport system such as the infrastructure design. While it is now a desire to bring all the factors together, there is still a way to go to explain the idea of integrated system design for safety.



• access to road transport system	• comfort • economy • social conformity	• warning system • supporting system	• intervention in driving	• immediate correction	• preparation for crash	crash protection
Vehicle	promote normal driving	(ISA, SBR, alcohol interlock)	(AICC, LDW)	(ESC, LDA, AICC2)	(pre-safe, emergency braking)	(seat belts, airbag, whiplash protection, pedestrian protection)
Infrastructure	promote normal driving	(speed warning, tactile warning, humps)	tactile edge lines	high friction surface		barrier design, roundabouts
Others	promote normal driving	• enforcement • insurance • contracts				• emergency service

Figure 1 The integrated safety chain

15. The possibility to build a safe system on an overall level is not complicated. The aim of such a system is to make sure that the biomechanical tolerance for a fatal or serious injury is not exceeded. The system design is built backwards from a possible event where injury might occur and both try to stop a possible hazardous event as early as possible in the integrated safety chain and simultaneously limit the amount of energy that might be exchanged in case of a crash. In a later part of the chain, safety systems that can limit the risk of an injury given a crash can be activated. The key is to link the possible outcome with

the speed that can be tolerated under normal driving conditions so that the amount of kinetic energy is not larger than what can be managed through the chain. The real challenge is both to combine the links of the chain to what is most effective, and to evaluate the combined effects.

Normal driving

16. It seems that the design model being developed over recent years, the integrated safety chain, will form the basis for understanding interrelation between safety solutions as well as how they interact over time. In this model, the concept of normal driving is fundamental. The term normal driving is used to define what can be expected from all users of the transport system, as they form the basis for how the rest of the system can cope with all possible events given normal driving. Therefore, it is expected that the parameters of normal driving are few and well defined. The parameters of normal driving must match the conditions in case of a crash, through the integrated safety chain. Based on the above example of protecting pedestrians from death and serious injury, the speed level chosen as normal driving cannot be higher than an impact that can be tolerated by the human body, unless there are systems or technologies that can mitigate or avoid the accident.

Driving outside the design envelope

17. Striving for eradication of death and serious injury means that the system must be tolerant and robust for not only normal behavior but also human behavior that is rather extreme. The choice is whether such behavior should and can be absorbed by the system design, or eliminated by some countermeasure. Drink driving or speeding are examples of behavior that must be handled in such a way as they are both no doubt factors that change the safety conditions. To design a safe system that can tolerate drunk drivers seem very challenging as well as designing for speed beyond the basic design of roads and vehicles. If so, the behavior in itself must be modified in order to fit into the other components of the system. In many cases, the decisions regarding tolerable or simply behavior that can or must be tolerated, are political, but must sooner or later be discussed.

18. There are also other behaviors that we might be forced to integrate into the design of the safe system. One such factor is the demand for communication while driving. Such communication might be the use of mobile phones, texting and reading or other forms of communication. This is a form of behavior that we might like to eradicate, but where the demand from the society and citizens is possibly stronger than the wish to not include communication in the safety design and as a part of normal driving.

Behavioral adaptation

19. The development of safety solutions will in many cases change the behavior of the driver, mostly as a desired outcome, sometimes as a side effect and in possibly some cases, introduces a new type of behavioral element. This is called behavioral adaptation (BA) and is a natural process when the driver changes behavior as a result of changes in the system of any kind. While it is now often understood, that safety measures that have a long or even mostly nonexistent feedback loop to the driver hardly lead to any BA there are other measures or qualities that has an almost immediate BA effect. In the first case, an airbag, a front under ride protection device on a truck or a more effective barrier in the roadside would not lead to any BA. Even technologies that sometimes would be expected to have a more frequent feed back to the driver, like stability control (ESC) does not seem to have any measurable BA, or at least small enough to give a very positive net effect. In the latter

case, where there is a clear feedback loop likely to be present very often, there are several examples. Better visibility in nighttime driving through reflective posts increase speed, better road grip through studded tires as well. Changing the right of way rules for pedestrians change the behavior of both car drivers as well as pedestrians when implemented. The use of mobile phones is also an example of BA as the user of a mobile phone tends to drive differently in several ways.

20. The introduction of support system for seat belt use, speed adaptation and adaptive cruise control can generate a desired outcome if designed carefully. There are clear findings of that intelligent seat belt reminders increase seat belt use effectively, but that the functionality of such a system can be designed in such a way that they have adverse effects. Intelligent speed assistance systems (ISA) can help the driver to choose a safer speed but also increase speed in some situations.

21. A special case might be an alcohol interlock system that possibly could lead to that more drivers would be driving under the influence of alcohol, although lower than the limit built into the system. If, as an hypothetical example, an interlock system would be set at 0,08 BAC, which is the legal limit in some countries, this would possibly lead to that many drivers would be able to drive drunk, while they would in a situation where they don't have the support of an interlock, avoid driving under such conditions. The possible explanation to this would be that drivers probably overestimate their BAC.

Design principles in summary

22. The design principles can be summarized on a high level as follows;

- The design of the infrastructure should guide the user to a safe behavior and mitigate the consequences of common errors, also for interactions between car drivers and unprotected road users.
- The speed limit setting must be aligned to the standard of the infrastructure and the type of vehicle in such a way that normal and common human errors can be managed as to eliminate the risk of serious injuries. Speed limits can be set on an objective basis.
- Speeding, driving under influence of alcohol or other drugs, not using restraint system or not using protective equipment are all serious errors or violations that might lower the effects of the system design must be met with special attention.
- New rules and regulations with the purpose to change human behavior must be developed from a Human Factors perspective taking into account the shortcomings and capabilities of the human being.
- Design solutions of the infrastructure and rules and regulations with the purpose to change human behavior must be evidence based.
- Safety systems, like driver support systems or autonomous systems aimed at improving safety, should not be switched off, unless it can be done without compromising safety.

The challenge for WP.1

23. As mentioned earlier it is a challenge of utmost importance for UNECE WP.1 to adopt the Safe System approach in its work with the purpose to make the Conventions of Road Traffic and Road Signs and Signals but also and the Consolidated Resolution on Road

Traffic (R.E.1) and Road Signs and Signals (R.E.2) to a greater extent reflect the design principles of the Vision Zero and Safe System approach.

24. Two areas that are of special interest and that could be integrated in the work of WP.1 are the following:

- The definition of normal driving must be clearly defined, in particular regarding the driver state, and which behavior that is a precondition for the system design. Speed limit compliance, use of restraints or other protective devices as well as being sober are examples of preconditions that guide the system design. There might be others, but in essence there must be an understanding that they must be fulfilled to 100 % to be reliable as cornerstones for system design.

- The understanding of which behavior that must be accommodated or mitigated by system design is fundamental, both from an accident and injury prevention perspective, as they serve as input for the rest of the system. Falling asleep, running a red light, distraction in itself and misunderstanding between road users might be examples of behavior or events that must be taken into account, even if they are regulated as violations of traffic rules

Proposal

25. Given the rapid and fundamental change of traffic safety policy and long term ambitions, including all elements and functions of the road transport system, the demand for also reviewing traffic rules and their interactions with the rest of the system, is needed. It is therefore proposed to start a common analysis of what aspects and areas that needs to be supported by a change of fundamental principles of road user legislation.

An example

26. Pedestrian crossings are a good example to compare the view of the Vienna Conventions, R.E.1 and R.E.2 with the design principles outlined in this document.

The Convention on Road Traffic

27. First of all it is important to understand that the purpose of the Convention on road traffic is to facilitate international road traffic and to increase road safety through the adoption of uniform traffic rules. However these rules are mainly directed towards the individual road-user in order to make him or her behave in a safe manner in road traffic. This principle presupposes that the road-user have the mental and physical capabilities to always follow the rules.

28. This principle is very clear in the articles regulating pedestrians crossing the road. Here are two examples:

Article 20.6: (a) Pedestrians wishing to cross a carriageway shall not step on to it without exercising care; they shall use a pedestrian crossing whenever there is one nearby;

Article 21.1: Every driver shall avoid behaviour likely to endanger pedestrians.

29. There are more examples in the Convention but they all are a product of the same principle namely that it is possible to regulate a correct behaviour of the driver of the vehicle and the pedestrian crossing the road. The only way to handle incorrect behaviour, which however mostly is seen as a deliberate violation of the rules, is to inform the road-users. This is expressed in paragraph 3.2.3 in R.E.1:

- “In order to make road users more aware of existing traffic rules and the behaviour they need to adopt to ensure that pedestrian safety is not compromised, the following points - especially with regard to campaigns and driving courses - should be stressed:................”

- The principles described in this section are clearly not in line with the imperative “to err is human” described in the section “Human error” above.

30. It is obvious that there are no regulations directed towards the system designers in order to handle the consequences of road-users who for various reasons can or will not follow the rules. This is of course in line with the purpose of the Vienna Convention since it only adopts common traffic rules and not rules governing the design of the infrastructure. Anyway it should be possible for UNECE WP.1 to adopt traffic rules with the purpose to change human behavior from a Human Factors perspective taking into account the shortcomings and capabilities of the human being. WP.1 could also facilitate work of understanding which behavior that must be accommodated or mitigated by system design is fundamental, both from an accident and injury prevention perspective, even if such behavior often are regulated as violations of traffic rules.

The Convention on Road Signs and Signals

31. The intention of the Convention is to create an international uniformity of road signs, signals and symbols and of road markings is necessary in order to facilitate international road traffic and to increase road safety. The Convention mainly prescribes the criteria for the design of the different signs and signals but also how they should be placed. In some cases there are also criteria for when they may be used. The latter is interesting since there may be possibilities to, at least in R.E.2, develop safety criteria or safety guidelines for the use of them.

32. One example is article 13 bis, paragraph 3 where it is stated that:

“Signs E, 12^a; E, 12^b or E, 12^c shall be placed at pedestrian crossings when the competent authorities consider it advisable.”

33. In this case it should be possible to state safety guidelines or criteria for when the competent authorities should consider it advisable. These should be based on the design principles based on the Safe System Approach.

R.E.1

34. In Part III of R.E.1 there are however recommendations of infrastructure and safety. Looking at pedestrian crossings there are some design recommendations. They are mostly aimed at guiding the user to a safe behavior which of course is important. But only in a few cases they are aimed at mitigating the consequences of common errors of pedestrians and drivers of vehicles. One example of that is a passage in 8.1.2.3 saying:

“At pedestrian crossings with no traffic lights, the speed of approaching traffic should be limited, to enable safe crossing for pedestrians.”

35. This recommendation is in line with the second design principle mentioned above even if it should be valid also for pedestrian crossings with traffic lights since drivers of vehicles will run red lights for various, but seldom intentional reasons. It should also be broadened to a systems approach where traffic environment, speed management, systems to brake a car automatically and a friendly front end of the car must be combined in an optimised way.

36. Since this is a very complex issue a first important step the recommendation could be changed in the following way:

"The design of pedestrian crossings should secure that the impact speed between vehicles and pedestrians cannot exceed 30 km/h irrespectively of the presence of traffic lights."