Road safety Development – A Continuous Learning About The Importance Of Knowing What You Do, And Why

12th Annual TRIPP Lecture

04th December 2020

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Transportation Research and Injury Prevention Programme
Indian Institute of Technology Delhi
Acknowledgement

The TRIPP Annual Lecture on Sustainable Transportation is organised with partial financial support from the Volvo Research and Educational Foundations, Sweden.


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Road safety Development – a continuous learning about the importance of knowing what you do, and why.

TRIPP lecture 2020
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Abstract

The time to discuss road safety is “now” for several reasons, among which we can find:

- The 3rd ministerial global conference on road safety, in February 2020, closed by the “Stockholm Declaration” and a renewed 10-year road safety goal;
- The high pace of technology development and innovations, e.g. regarding connectivity and automation, and in the IT sector;
- A lot of data is available and can be created – and is asked for by “all”.

Irrespective if “now” is today, or was a couple of years ago, road safety is and has been a concern, and there have been several calls to “act now”. Ambitious targets have been set - and missed. Actions and improvements have been introduced, but so have also new areas of risk. While this is the time to discuss road safety, it is also the right time to reflect on experiences gained so far and bring in gained insights as we look ahead.

This paper will discuss the importance of a real world understanding when addressing road safety from different angles. Examples from how this understanding has led to concrete actions are given and they mirror the expansion of the context of “road safety”. The future role of safety research will also be reflected by looking at automated vehicles.

Background

Road safety can be discussed in terms of statistics, economic burden of road accidents, cause of death, number of severe injuries, vulnerable road user (VRU) exposure, truck driver fatigue, distraction,... The perspective can be global, national, regional, local, societal, public, corporate, individual,...
Without claiming that this is the exhaustive list, the multitude of aspects point out the importance of understanding the CONTEXT in which road safety is addressed. This is particularly important when transferring results from one study or place to another, when trying to learn from existing and past knowledge and experience.

The context that forms the background to this paper is my 30+ year career in road safety. It encompasses all parts of the “triple-helix” – government, research and over two decades working with safety at Volvo Cars, which explains the selection of learnings.

Sweden, the country that invented “Vision Zero”\(^1\) has been my main basis. This high-income country is half as long as India, with over 10 million persons living on a surface 1/8 of India’s. The Swedish context is very different from many other places - still many of the learnings can be generalized.

First learning: the importance of a method to know what you do

As mentioned, I had the pleasure of serving Volvo Cars for over 20 years, starting as a crash engineer when limited attention was given to road safety. In the late 1980’s Governments in USA, parts of Europe and Sweden focused on fatality reduction. The Haddon Matrix established in 1970, which included the following elements, was an early sign that road safety is an interplay between several elements (Fig 1).

\(^1\) Government offices of Sweden1996/97:137: "Nollvisionen och det trafiksäkra samhället" (Vision Zero and the Traffic-Safe Society)
Volvo was then one of the few car makers actively talking about road safety, which was a part of its brand promise. “Vehicle” and “During” in the matrix received major attention. Already in 1972 an accident research team had been established. The team investigated in-depth accidents involving Volvo cars in the vicinity. The documentation (photos, measurements, verbatims) taken would then be entered into a database, and accompanied by medical records or autopsy protocols for the occupants. Accidents that took place further away were documented when undergoing inspection for insurance and repair, according to a less detailed protocol. The database thus included both in-depth studies and material allowing statistical analysis – an excellent foundation for KNOWLEDGE, for defining priorities and undertaking research.

Despite meeting legal requirements, crashes and fatalities were however still happening. To know what to do be “leading in safety” it was essential to understand why and how accidents happen, what the outcome was and how to influence this by vehicle design. A structured method was developed to make use of world knowledge by transferring it into cars (fig 2). Examples of the practical application of the knowledge, method and use of data are given in the following sections.
The importance of understanding the real world to know what to do

Based on the extensive collection of real-world data for existing vehicles Volvo researchers developed a method for predicting real-world performance for a new or modified car design over the whole range of crash severities where injuries occur.

The procedure can be used for predicting the overall effect of a safety design. By correlating accident data with lab test data in equivalent crash modes, it was possible to develop an injury probability function associated with dummy responses.

Figure 2. Methodology safety development

Figure 3. Calculating injury risk / dummy response
A real world reason for “why” you do what you do pays off!

To cover the wider spectrum than the basic performance prescribed by regulation, Volvo’s crash safety in house requirements encompassed already since the late 1970’s a variety of crash types, crash speeds and directions. Dummies of various sizes were used. The method described above was elaborated to select solutions that would give real world improvements. One application was in the development of a new vehicle family and that resulted in launching SIPS, Side Impact Protection System, in 1991 (fig. 5).
Initially regulators’ interest in crash tests focused frontal impact. However, in the 1990’s side impacts in highly motorized countries made up over 25% of the vehicle crash fatalities. This had been noted by Volvo who developed its own requirements aiming for a 25% reduction in occurrence of severe to fatal chest injuries. Using the real-world prediction model, an ambitious side impact program was launched. Tests were run at 25, 30 and 35 mph in the US method.\textsuperscript{2} In 1991 the new Volvo 850 was launched with the SIPS system as one of several safety features. Two “world firsts” followed: the side impact airbag, the SIPS-bag, in 1994, and an inflatable curtain for head protection in 1998 (Fig. 6). Real world data has since shown an over 55% reduction of severe chest injuries for SIPS together with SIPS bag.\textsuperscript{3}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{sips.png}
\caption{SIPS - Side Impact Prediction System. Source: Volvo Cars}
\end{figure}


What was going on regarding regulations? It took until the mid-nineties until regulators introduced side impact tests with moving barriers and dummies:

- EU 1996: barrier test at 50 km/h, perpendicular impact.
- USA 1997 barrier test at 30 mph (48 km/h) (“Crabbed configuration”)

Already in 1993 NHTSA (National Highway Traffic Administration, part of the US Department of Transport) had tried to increase the public attention to road safety by introducing the New Car Assessment Program, NCAP. It was initially based on dummy values from the frontal barrier regulatory test, run at an impact speed 5mph higher than the regulated 30 mph in FMVSS\(^4\) 208. A 5-star rating system was introduced in 1993 aiming to make this consumer information more user-friendly. Various other actors, including US institutes and German press, also developed their own ratings and tests with the purpose to demonstrate differences between vehicles. In Europe the EuroNCAP was introduced in 1996. Occasionally media headlines, some quite dramatic, could announce the failure (more often) or success (rarely announced) of a certain make. Safety performance had become a marketing element!

When compared to real world accident data, which had been gathered by e.g. insurance organisations, it could however be observed that a high score in a rating test didn’t necessarily translate into good real-world performance. The risk of focusing one single test in one single

\(^4\) FMVSS = Federal Motor Vehicle Safety Standard (USA; ex: FMVSS208 = frontal impact, FMVSS214= side impact)
situation, with one single size of occupant type – leading to a top score could be shown by use
of the prediction model above.

Ratings are typically run at a very high speed compared to the speeds where most crashes
occur. Human tolerances vary across the occupant population, and injuries will occur also at
lower speeds. To secure a good overall occupant protection it may be equally important to
perform well at lower crash severities, since a small deterioration at the more frequent crash
severities can easily outbalance an improved performance at high speed. For example
characteristics of impact areas or triggering of airbags may incur a suboptimization effect if
not designed for the real world speed spectrum.

Suboptimization

Figure 7. The risk of suboptimization (Source: Volvo)

Repeatedly real-world studies confirm the importance of having knowledge, of using it wisely
and to apply it not only for a single top mark, but for the purpose of making a true positive
impact. Today structures similar to SIPS and side-bags and are widely present in cars. Doing
the right thing for the real world pays off!
Do what you can with what is known to move in the right direction

“Data” is often asked for. More data, even more data, big data, different data, access to data... Still a lot is available, and there may be creative ways of making use of what is already there. Requesting more data before acting based on the obvious should never be an excuse for indecisiveness.

Whiplash injuries in rear end crashes is one example of a real-world problem that had to be tackled in a step-by-step fashion. Early work at Volvo had resulted in a sturdy head restraint positioned high up against the head.

Figure 8. Headrest Volvo Cars 1980's

Taking stock of the database, several accident studies were undertaken with medical experts during the 1980s and '90 to try to determine why some persons who had been in low speed
rear end crashes sustained a whiplash injury, while others didn’t, and to understand how the car could provide better protection for the neck in rear-end impacts. At the time, there were neither agreed definitions nor diagnosis methods for whiplash, and injury mechanisms and criteria were missing. Existing dummies, Hybrid II and Hybrid III, were designed to be reasonably biofidelic in frontal crashes at 50 km/h, and were far too stiff in lower speed rear-end impacts.

Based on the knowledge of real-life accidents a computerised model of the human body was developed. With the help of the model, unique at the time, effects of different seat parameters on the spine’s movement patterns could be studied. Successively guidelines for a seat design could be developed, resulting in a complete seat design – the WHIPS (WHIplash Protection System).

The main principle is to keep the spine curvature intact throughout the crash sequence. By the help of a specially designed hinge (red in fig. 9) the seat absorbs energy by translating rearwards instead of “whipping” the occupant forward. Finally, the seat back tilts slightly backward while absorbing the remaining crash energy. Real world injury reduction between 30-50% has been reported.

Figure 9. Whiplash Protection System
Whiplash injuries have since these pioneering research steps been included in EuroNCAP\(^5\). These tests use the BioRID dummy, the first crash test dummy built for rear-end collisions (Fig. 10). It was developed by Swedish industry and academia, and launched in the end of the 1990’s. BioRID is designed to move just like a human body does when subjected to a rear-end crash. The resulting forces on the dummy’s neck are measured and the probable injury risk estimated. BioRID has since become a standard equipment of the industry.

It should be noted that additionally to reducing suffering and pain, the Swedish innovation agency, Vinnova, in 2004 reported that the Swedish society has gained about 5,5 bn SEK (approx. 45 bn INR) from the whiplash research, as well as export opportunities for Swedish businesses.

\(\text{Figure 10. BioRID}\)

BioRID\(^6\).

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\(^6\) Source: [http://webfiles.ita.chalmers.se/~mys/BioRID-Pictures.html](http://webfiles.ita.chalmers.se/~mys/BioRID-Pictures.html)
Enlarging the safety scope – Applying a systems thinking

Sweden’s Vision Zero was adopted by the parliament in 1997. The basic starting point is that no-one should be killed or suffer lifelong injury in road traffic, thus switching focus from the prevention of crashes to mitigating serious injury and death. An intermediate objective to halve the number of killed people of Swedish roads until 2008 was established. Although revised and updated several times, it has initiated numerous research studies and several measures. Vision Zero takes a systems-oriented approach, in which it is recognized that to achieve effects it will not be sufficient to address single elements in isolation.

Today Vision Zero is adopted on the global level. It was a theme of the 3rd global ministerial conference on road safety taking place in Stockholm, February 2020, which can be interpreted as a societal readiness to take on road safety, not least because of the increasing cost for road accidents.

Technology development is one important enabler for a systems approach to address road safety in a holistic Vision Zero manner. Already in the early 2000’s several vehicle technologies that aimed for mitigation and prevention of crashes were launched. Advancements in sensor, camera and materials technology were essential in enlarging the action sphere of vehicle measures as shown by the example from 2007 (fig. 11).

![Technology as Countermeasure in the Holistic Perspective](image)

**Figure 11. Technology as countermeasure in the holistic perspective**
Maturity matters -- both for trends and when defining priorities

Most examples in this paper have so far looked at vehicle aspects. To effectively contribute to a sustainable development, e.g. the Sustainable Development Goals (SDG) in Agenda 2030\(^7\), a global perspective is essential when looking at scenarios, trends and measures. Data is, as always, important but when looking ahead it is also evident that data will not always be available. It is therefore even more important that measures are developed with a systems mindset, and that they are based on an understanding of the real-world conditions and contexts.

While real world situations are sometimes unclear, this is even more true when looking ahead. There is generally no shortage of scenarios and trends projections, analyses and speculations. In the project “PROS” (Priorities in Road Safety) \(^8\) a compilation of reports with potential relevance for transport was made (Fig. 12). By looking at the background data it became clear that some of the identified global trends have a high certainty, whereas others can be said to be wishes or even hopes, dreams.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{main-societal-trends-scenarios.png}
\caption{Main global trends identified by PROS in 2013 and their estimated certainty level (used as input into discussions on research funding schemes).}
\end{figure}

\(^7\) https://sdgs.un.org/goals
\(^8\) https://cordis.europa.eu/project/id/314427/reporting
A renewed look at the trends in 2020 shows that trends entirely built on data are still valid (in particular Population Growth, Demographic Changes). Others may depend more on politics and market forces, such as Economic growth, Globalization and Energy & resource, and therefore are less stable. The oil price has e.g. dropped significantly since 2013, whereas connectivity has increased. Today the worries about Climate change and the CO₂ concerns are more pronounced.

The belief in the necessity of real world understanding, of data and of collaboration to get ahead in road safety is also illustrated in development work of a Swedish strategic research and innovation agenda for road safety in 2014, “Safe Future in business and society”. Safety was here considered to be a matter of public health both globally and nationally, and also a trigger for business opportunities and innovation. A systems thinking was applied, and four of the global trends mentioned above with impact of road safety were used as input.

4 world trends with impact on traffic safety

- We are getting older
- Climate change worries
- Increasing urbanization
- Connectivity for persons & society

Figure 13. Global trends with impact on road safety, used in the R&I agenda “Safe Future in business and society”.

The agenda expressed 18 ambitions for accident free traffic (Fig. 14). “Accident free” goes beyond Vision Zero’s focus on avoiding severe injuries and fatalities, since a crash also can be a disturbance in the transportation system, affecting e.g. emissions and congestions.
Road users, vehicles, traffic environment and the overall transport system are addressed. Vulnerable road users and public transportation play an important role. Some of the ambitions are “more mature”, supported by a lot of available data and knowledge compared to ambitions with lower maturity for which societal readiness to handle the topic may also be low.

Examples of maturity grading (12 maximum maturity points):

- crash safety of car and truck: 10-11
- VRU’s and public transportation safety: 5-6 points
- Connected and automated transport alternatives:
  - 3 in 2014
  - 6-8 in 2020 – despite frequently labelled as “safe and secure” and despite research efforts, experience, evidence and data is still not highly mature

Activities need to be tailored to the individual ambition and its maturity. The context plays an important role. Examples of possible activities can be:

- Feasibility analyses, methods development.
- Concepts, use of new approaches.
- Real world applications of solutions, pilot studies, business cases.
- Stakeholder involvement, changes in behaviours and laws.

The 18 ambitions also point to the necessity of real world understanding, of data and of collaboration to get ahead in road safety. This extract from the one related to public transportation safety, which had 5 of 12 maturity points, is one example:

**Figure 15. Ambition 14, Safe future” R&I agenda**

The vulnerable road users are mentioned in several of the agenda ambitions, and research needs include:

- Mapping of the risk for different pedestrian categories, e.g. age and level of fitness – including their behavior and distraction.
• Study on factors influencing the pedestrian’s choices and risk-taking, e.g. crossing at red light. Can different designs in the traffic environment trigger different behaviors?
• Analysis of how other types of road users act with respect to pedestrians – both at zebra crossings and in non-regulated situations. Also investigate solutions for handling mixed traffic, e.g. paths shared by pedestrians and bicyclists.
• New concepts for using infrastructure to influence and include safety of pedestrians, consider special needs of children.
• ICT-based tools for informing about, and supporting, safe sidewalks – e.g. to/from school, bus stops, shopping.
• Vehicle based concepts for detection and mitigation of pedestrian collisions.
• New concepts for urban infrastructure using bicycle safety as the starting point for the planning. *(could also be applied to powered two wheelers, PTW)*

To know what to do in the future we still need a sound understanding of the real world. And yes – there is a role for road safety research also when looking ahead.

As can be seen above, road safety has over time become a more integrated, and complex, area – on several fronts. Data continues to be an essential ingredient to move towards targets and objectives. Collaboration and cooperation between a growing amount of actors and across sectors is increasingly important, as is coupling to a spectrum of societal goals. Evidence can be found e.g. in the UN Agenda 2030 and 9 recommendations related to the Stockholm Declaration of road safety⁹.

The fast technology development, not least within digitalisation and ICT, is often pointed out as an enabler, if not the big enabler. Ideally, we could solve all kinds of societal challenges related to transport by leveraging digitalisation and automation without having to do sacrifices or using measures that are unattractive for citizens. Some examples can be seen in Fig. 16.

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⁹ [https://www.roadsafetysweden.com/contentassets/b37f0951c837443eb9661668d5be439e/stockholm-declaration-english.pdf](https://www.roadsafetysweden.com/contentassets/b37f0951c837443eb9661668d5be439e/stockholm-declaration-english.pdf)
On the transport R&I arena considerable attention is being given to “connected and automated”, “cooperative” and “digital”. There are many activities related to automated driving, strongly driven by the telco-sector and the auto-industry, for example focusing sensors, in-vehicle enablers, driver support, vehicle systems, platooning. Sought-after benefits include freeing up time for the driver, allowing the driver to do other things during the ride, and giving persons who today are disqualified as drivers a chance to independently ride a car. Truck platooning and self-driving shuttle buses are other examples attracting research interest. There is a drive to do large scale testing, pilots and implementation, which in most markets requires a permit for public road testing. The process to get this approval varies, but typically includes a risk assessment with identified mitigation actions.

One of the strongest arguments for CAD (Connected and Automated Driving) is that it will improve safety by reducing, and eventually eliminating, driver error. It is assumed that the number of crashes will be drastically decreased (Fig. 17). Some years ago, the strongest optimists even talked about possibilities to reduce vehicle weight by taking out structural and interior components related to crash protection and manual driving. The projections would have the potential to significantly impact the road safety research, where some fields could even be considered obsolete.
The hype around self-driving vehicles from some years ago has given place for insights about the challenges and difficulties to even make simpler implementations work. Authorities, operators, vehicle and infrastructure providers, industry and researchers are all learning about the complexities of making new technologies work in reality. This has matured with experience and moved from a mindset of “The technology is ready” to a recognition of technologies’ limitations. One effect is the definition of “Operational Design Domains”\textsuperscript{11}. When a vehicle leaves its ODD the driver must be ready to take over. How to engage the driver in a safe way, human machine interfaces, fitness to drive assessments are examples of research fields associated with this hand-over. The higher the automation level, the more possibilities for the driver to engage in different activities. This means that the typical design position of a driver – facing forward with the hands on the wheel – may be replaced by a larger variation of postures and activities, even involving swiveling of the seat. Biomechanics, potential injury risks and consequences on interior protections system designs will need to be researched.

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|}
\hline
Critical Reason Attributed to & Number & Percentage* \pm 95% conf. limits \\
\hline
Drivers & 2,046,000 & 94\% \pm 2.2\% \\
Vehicles & 44,000 & 2\% \pm 0.7\% \\
Environment & 52,000 & 2\% \pm 1.3\% \\
Unknown Critical Reasons & 47,000 & 2\% \pm 1.4\% \\
Total & 2,189,000 & 100\% \\
\hline
\end{tabular}
\caption{Driver, Vehicle, and Environment Related Critical Reasons}
\end{table}

\textit{Figure 17. Example of fraction of driver behaviour related critical situations (USA)}

\textsuperscript{10} (https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812506)

Approval processes are being updated with new experience, and central to any approval is the safety risk assessment. “Mixed traffic” will be a reality for a very long time, with interaction with other road users, in particular VRU’s. Pedestrians, cyclists, motorcycles etc. provide challenges not only for sensors and detection systems, but also for traffic management. These “soft mode” road users are harder to predict, to manage and steer, and will require further research attention – irrespective of automation level.

The examples above show that in “safe and secure connected and automated mobility”, “safe” doesn’t come by default and that “Classic Safety” R&I is still needed. Even if infrastructure has not been discussed in this paper it is equally important to consider, also from a road safety perspective – and for any automation level.

**Concluding Reflections**

The objective with this paper was to share insights and learnings obtained throughout my experiences with road safety research and strategy. Although this journey still goes on, I’m convinced that it will remain important to…

- understand the real world to know what to do
- have a method to know what you do
- have a real world behind what you do - it pays off “doing right thing”
- scrutinize cries for “more data” – indecisiveness based on (uncomfortable) existing data should not be a reason for not doing what is possible
- do what you can with available knowledge good enough for indicating that you move in the right direction
- - when enlarging the safety scope – apply a systems thinking, and pay attention to the contexts
- consider maturity – not all topics are equally advanced – important when making priorities, tailoring actions, interpreting trends

To know what to do in the future will still require a sound understanding of the real world. With 1.3 million road deaths annually and a “mixed traffic scenario” for the foreseeable future – there is a role for road safety research also when looking ahead.