IATSS Research 40 (2017) 66–71

Contents lists available at ScienceDirect

IATSS Research

Review article

The future of road safety: A worldwide perspective☆

Fred Wegman

Delft University of Technology, The Netherlands

ARTICLE INFO

Article history:
Received 10 May 2016
Accepted 13 May 2016
Available online 19 May 2016

Keywords:
Safety data
Road safety developments
Road safety management
Developing countries
Safe System approach

ABSTRACT

Estimates by the World Health Organization suggest that, on a yearly basis, road crashes kill 1.25 million people—nearly 3400 road fatalities per day—and injure up to 50 million. Traffic injuries are not equally spread over the world, however; some countries are hit harder than others, and the chance of being killed in a road crash depends on where one lives. Almost 90% of all traffic casualties occur in low- and middle-income countries (LMIC). Globally, the number of fatalities per 100,000 population (mortality rate) ranges from less than 3 to almost 40. The rate is less than 9 in high-income countries (HIC) but averages around 20 in LMIC, with the African region demonstrating the highest rate (26.6). While road safety trends have been positive in HIC over the last few decades, trends in LMIC are not telling a positive story: road fatalities are expected to increase to almost 2 million road fatalities per year by 2020.

The United Nations has adopted several resolutions on road safety and proposes actions to tackle the global road safety crisis. Considering the current level of road safety to be unacceptable, the UN has taken several initiatives. One effort, the Decade of Action for Road Safety 2011–2020, has generated substantial activity around the world over the last couple of years. Furthermore, it is very encouraging that the UN included road safety in the Sustainable Development Goals that it laid out in September 2015. Road safety is part of the public health agenda and the urban development agenda. Measured in "real actions," however, the responses so far from the overall global community and individual countries do not suggest that we are already on the right track to bringing down the death toll on roads.

The future of road safety is uncertain and definitely not the same for all regions of the world. Countries with a mature road safety approach and an ambition to make further progress are expected to move in the direction of a pro-active approach: a Safe System approach. It is reported that many LMIC, meanwhile, are on the brink of designing road safety strategies and implementing action plans. The international community is willing to support LMIC, but LMIC cannot simply copy successful HIC strategies because local circumstances differ. The principles of successful HIC strategies are applicable, but the priorities and action plans should take root in and align with local conditions.

Contents

1. Measuring (progress in) road safety

Measuring road safety is not as simple as measuring temperature. There are various ways to define road safety. When measuring road safety, therefore, it is of the utmost importance to make clear which elements are included in a definition and which are not. The most common measures to define road safety are the number of road crashes,

☆ This article is based on the keynote address delivered at the 1st Global Interactive Forum on Traffic and Safety (GIFTS), organized by the International Association of Traffic and Safety Sciences (IATSS) on November 28, 2015 at United Nations University in Tokyo, Japan.

Peer review under responsibility of International Association of Traffic and Safety Sciences.

http://dx.doi.org/10.1016/j.iatssr.2016.05.003

the number of road casualties, and the associated negative consequences [1]. However, this definition is not universal in its scope of use. Problems related to the use of different definitions are part of the reason why making international comparisons is so difficult. Issues like poor data collection methods, data incompleteness, and problematic data availability also complicate the comparison process [2]. The United Nations (UN ECE) has taken the lead in working to standardize the various international definitions. In almost all countries, police forces register information on crashes. For several reasons, these registrations are always incomplete. This is called underreporting. Further complicating the matter is the phenomenon of biased underreporting, which results in certain crash types not figuring into official statistics. For example, cycle crashes are notoriously underreported; these types of crashes are victim to underreporting far more often than crashes with motorized vehicles are. Moreover, the consequences associated with road crashes (at an individual level and a societal level) are known only to a limited extent. Fortunately, many countries in the world are aware of problems in the quality of their road safety data and working to make improvements.

It has long been a tradition in road safety to analyze road safety data to understand why crashes occur, which factors influence risks, and what determines crash severity, and based on this understanding, to arrive at reliable conclusions on how to prevent them most effectively and efficiently. We call this a data-driven approach [3] or "going fishing where the fish are." In this approach, we derive priorities by using crash data, background data, exposure data, and data of safety performance indicators.

Fig. 1 shows an example of this approach. Risks for males and females (serious injuries per kilometer traveled) are presented for different age groups. We observe relatively high risks for young drivers, especially young males, and for elderly drivers. Naturally, we want to find an explanation for these spikes in the distribution and subsequently an answer to the question of how to reduce the high risks. In order to establish a good understanding of the situation, it would be worthwhile to identify the conditions and circumstances under which high-risk crashes occur: time of day/night, alcohol involvement, and road type, etc. Generally speaking, however, we cannot derive a fully satisfactory answer through crash data alone. We also need to incorporate exposure data, data on safety performance indicators [4], and, of course, scientific literature that might guide further analysis.

The basic idea behind this *go-fishing-where-the-fish-are* approach is the general assumption that it would be easier (and more effective and efficient) to reduce higher risks than it would be to reduce lower risks. This is the same type of reasoning as used to address safety problems in locations with high numbers of crashes: improving intersections with numerous of crashes is easier than improving those with low numbers of crashes.

It can also be helpful to learn from others by comparing one's own performance with that of others. For example, one could compare the reduction in the number of fatalities in a country with reductions in others (Fig. 2).

For instance, one might look at Fig. 2 and think about what kinds of action plans Spain implemented to achieve a 70.9% reduction (2000–2013)—a result that makes Spain an "outperformer" and a country to learn from [2]. One could also investigate matters the other way around: how has Spain been inspired by the achievements of other countries, such as the positive results in France? If we study the international literature to understand how countries have improved their safety performance over the years, we find a multitude of potential explanations. Researchers have developed benchmarking methodologies to learn from international comparisons (see, for example, [5,6]). Designing meaningful benchmarking and identifying "working ingredients" are rather complicated tasks, considering that countries often implement a variety of road safety interventions over a single period. Moreover, other developments have an impact on road risks (which researchers call "confounding factors"). It is, to the best of our knowledge, fair to say that no country has a full explanation of the progress made. However, it is also fair to say that our knowledge and understanding of why countries made progress has increased significantly over the last few decades.

Traditional road safety areas are tackled with rather well-known interventions:

- Improving human behavior (speed, alcohol, seat belts, and helmets) through legislation, enforcement, and campaigns;
- Safer infrastructure through planning and design; and
- Safer vehicles through better crashworthiness, active vehicle safety, and vehicle inspections.

The Handbook of Road Safety Measures [7] gives a comprehensive overview and illustration of how various interventions impact road safety. Almost all the research in the Handbook comes from studies in high-income countries (HIC) or highly-motorized countries. However, simply transferring this knowledge to other regions of the world is not a valid approach; the transferability of research results relies first and foremost on the extent to which the reported safety effects of interventions depend on the circumstances in which the research was carried out [8]. Still, it is an encouraging development to see how low- and middle-income countries (LMIC) try to improve their road safety records by learning from HIC [9]. Furthermore, it has become rather popular to produce "best or good practice manuals" that provide a foundation for learning. In the United States, for example, one manual identifies 23 key emphasis areas that affect highway safety. Each of the 23 emphasis areas (such as speed, head-on collisions, novice drivers, collisions with utility poles, distraction, aggressive driving, and unsignalized intersections, etc.) includes strategies and outlines of the requirements for implementing each strategy (http://www.trb.org/Main/Blurbs/152868.aspx). Experts in Europe carried out the "Supreme" project, resulting in a report called "Best Practices in Road Safety: Handbook for Measures at the Country Level" (2007). The final report of the Supreme project consists of 14 volumes (http://ec.europa.eu/transport/roadsafety_library/publications/supreme). The European Road Safety Observatory ERSO has an interesting knowledge base of "fact sheets," and the World Health Organization prepares "how-to" road safety manuals for LMIC (http://www.who.int/roadsafety/publications/en/). As I stated before, however, local experts have to assess if and how results from these studies can be transferred to their own settings.

When trying to explain why Spain made such an enormous progress, for instance, the fact that Spain was not the only country with a massive

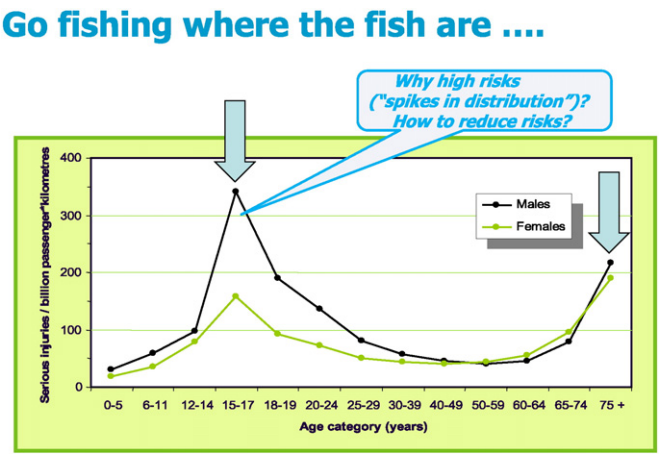

Fig. 1. Relationship between age category and injury risk (serious injuries per billion passenger kilometers) among males and females.

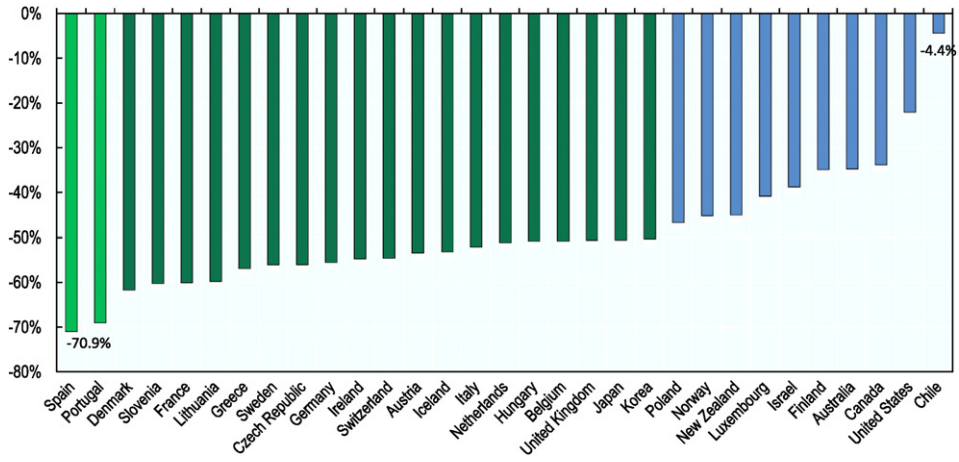

Fig. 2. Medium-term changes in road fatalities from 2000 to 2013 [2].

reduction in the number of fatalities is an important point to note. Almost all the highly-motorized/high-income countries in Fig. 2 show a substantial reduction in the number of fatalities, suggesting the need for further research into the question of whether these reductions arise out of common factors or country-specific conditions.

Although this topic of research finding common features to explain road safety progress—is not a well-traveled theme in road safety, a recent study shed some light on the issue [10]. The researchers examined the relationship between economic and road safety developments and observed that the financial and economic crises, which started in many OECD-countries in 2007, was accompanied by marked falls in annual numbers of road deaths. The study covered fourteen countries and concluded that the economic downturn in 2009–2010 may well have contributed to about two-thirds of the overall decrease in fatalities from 2008. In the study, researchers correlated economic indicators with road safety indicators. Several studies reported in [10] tried to test the underlying causes of the identified correlations. The researchers could not fully establish the mechanisms explaining the underlying causes, but they uncovered some indications and concluded that decreases in fatalities are not so much a function of the reduction in traffic volume (a consequence of the economic downturn) but rather a product of the reduction in fatality rates. This rate reduction is associated with less exposure to the risks of high-risk groups in traffic (young people), fewer heavy goods vehicles, and, perhaps, less dangerous driving. This is certainly an area for further research, but it is important to understand that researchers found correlations between the economic crisis and the reduction in road traffic fatalities. Policymakers should be aware of these findings when setting road safety targets for the future. Another area for further research is to determine if economic recovery will have an impact on traffic volume and traffic risks.

When comparing with the road safety performance of a country in order to learn how to improve the performance of another country, one needs to take three requisite elements into consideration: a meaningful comparison of road safety data, a thorough understanding of research results, and the capability of transferring knowledge from one setting to another through well-qualified and trained professionals. Looking at Fig. 3, we see that there is certainly room for improvement in many countries. The figure presents mortality rates for the countries that are members of IRTAD (the International Road Safety Data and Analysis Group, which works under the umbrella of the International Transport Forum ITF). Mortality rates range from below 3 fatalities per 100,000 inhabitants to more than 12. If we include other regions of the world, the picture starts to become alarming.

2. Road safety worldwide

Annually, road crashes kill 1.25 million people and injure up to 50 million across the globe [11], and the 2015 WHO report [11] states that almost 90% of traffic casualties occur in LMIC. Fig. 4 clearly illustrates stark differences in mortality rates among different regions of the world, with the African region coming in at the highest rate (26.6). In addition to the human consequences of crashes and casualties, crashes also involve high costs that severely burden a country's economy. Road crashes result in medical costs, production losses, human losses, property damage, settlement costs, and more. Countries'

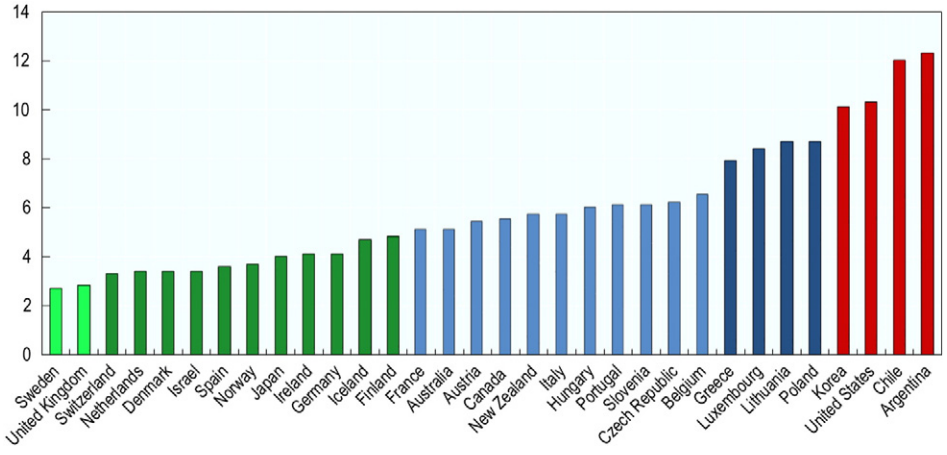

Fig. 3. Road fatalities per 100,000 inhabitants (mortality rates) in 2013 [2].

Fig. 4. Infographic on road traffic injuries.
Source: World Health Organization.

estimates of these costs range from 1% to 5% of GDP: 1.8 to 3.0% in LMIC and 2.2 to 4.6% in HIC [12].

Over the last few decades, we have witnessed an enormous progress in OECD/HIC countries when it comes to reducing the number of fatalities and fatality rates. In LMIC, however, a completely different picture emerges. We cannot fully rely on official statistics in many LMIC, but the WHO, having used several methods to correct for underreporting, estimated a total of 1.25 million fatalities to occur each year. The WHO concluded that the total number of road traffic deaths around the world has plateaued, meaning that the increases in total fatalities that we have seen in the past have now come to a standstill. A further detailed analysis of this conclusion would be beneficial, especially considering the results of an earlier report by Kopits and Cropper [13], who established correlations between economic development and road crashes. Projections of future traffic fatalities suggest that the global road death toll will grow by approximately 66% between 2000 and 2020. This number, however, reflects divergent rates of change in different regions of the world, as Fig. 5 shows. It is clear that the WHO results [11] and the conclusions of Kopits and Cropper [13] contradict each other. These divergent views demand further analysis.

With this predicted increase in mind, the international road safety community worked within the framework of the Decade of Action for Road Safety 2011–2020 to formulate a road safety target for 2020: halving the number of fatalities compared with the predicted number of 1.9 million—in other words, fewer than 1 million fatalities per year in 2020.

In 2015, the UN decided on seventeen "Sustainable Development Goals" (https://sustainabledevelopment.un.org/sdgs) two of which include road safety. One deals with health (ensure healthy lives and promote well-being for all at all ages), and the other with cities and communities (make cities and communities inclusive, safe, resilient and sustainable):

3.6 By 2020, halve the number of global deaths and injuries from road traffic accidents.

11.2 By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons.

Goal 3.6 is very specific (halving road deaths and injuries by 2020) but does not specify a reference value (halving compared with what). If we take the numbers for 2015 (1.25 million a year), reaching the target would be very complicated, if not impossible. If we use the results of Kopits and Cropper [13] as the reference value (1.9 million in 2020; halving would imply less than roughly 950,000 fatalities in 2020), it would still be a challenge to meet the goal. Assuming that the WHO is correct in stating that the absolute numbers of road traffic deaths are "plateauing," however, it would be crucial to understand what should be done worldwide to reach SDG-goal 3.6.

This brings us to the next set of questions:

- What could be the next steps for HIC to achieve further improvements in road safety?
- What are the first/next steps for LMIC to make progress in improving road safety?

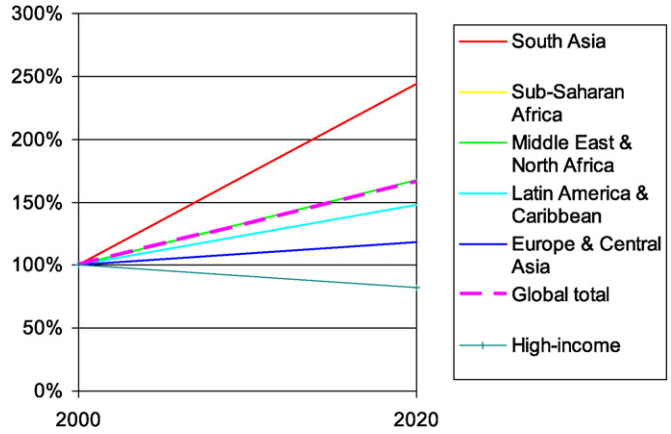

Fig. 5. Predicted future developments in the number of road fatalities in different regions of the world [13].

The answer to the first question could be twofold. First of all, HIC countries could design and implement traditional strategies in a better (more effective and more efficient) way. Second, countries could embark on the Safe System approach.

When it comes to low- and middle-income countries, the response could be to analyze road safety problems and design road safety strategies, using the experiences of HIC and thus speed up progress compared with HIC in the past. This is an interesting perspective because of the enormous knowledge resources accessible to the countries that need to make improvements. However, LMIC cannot simply "copy and paste" solutions from HIC—they need tailor-made solutions, adapted to local conditions and circumstances.

3. The Safe System approach

Many HIC have made great progress over the last couple of decades. As stated above, there is no way to provide a full, all-inclusive explanation of how countries have made that progress, but the performance is

remarkable—and even more impressive when one takes into account the enormous increase of traveled (motorized) kilometers on the roads [1]. As all countries in the world—even the safest—are still unsatisfied with the current level of safety (with a mortality rate of 3.0), however, the questions of how to make even more progress remain an important one to address.

There are two good reasons why the traditional approach (working on reducing "spikes in distributions") will become less effective and efficient in countries with mature road safety policies. The first reason lies in the fact that serious road crashes will occur as long as we leave the inherent unsafe conditions in road traffic untouched: the inherent risks come from a combination of the physical vulnerability of the human body and the levels of kinetic energy in crashes (a combination of speed and mass). These inherent risks also stem from the fact that the road transport system cannot be designed from the perspective of the human being as long as the it fails to defend against human errors and offenses that can result in crashes. Because of this, we are almost fully dependent on how well drivers, riders, and pedestrians perform their tasks. It is remarkable that, while the road transport system puts its faith in individual driving skills, the rail system and the aviation system are designed from a safety perspective—and even well-trained professionals like train drivers and airplane pilots are only allowed to operate under rather strict conditions.

A second good reason lies in the fact that our traditional policies have become less effective and efficient. Traditional interventions dealing with reducing relatively high risks are in the process of coming to the ends of their life cycle, suggesting that they may be subject to the law of diminishing returns.

In the Netherlands, these two underlying reasons have triggered a paradigm shift and resulted in the development of Sustainable Safety, the Dutch version of the Safe System approach. More details can be found in Advancing Sustainable Safety [14]. The line of thinking is to eliminate—or at least considerably reduce—serious injuries through the use of safe system architecture in designing new parts of our road network system or retrofitting the existing system, for example. Sustainable Safety is an integral, system-wide approach that operates on six main points:

- It is *ethical*, as we do not want to hand over a traffic system to subsequent generations (in environmental policies, what we call "sustainable development") at the current casualty levels but rather at considerably lower levels, with zero being ultimate aim;
- It is a *pro-active approach*, which means that it is not necessary to wait for crashes before acting; instead, we use the knowledge we have and adapt our knowledge to local conditions;
- It emphasizes the idea that "*People are the measure of all things*" in such a way that the vulnerability of the human body, as well as human capacities and limitations, are the guiding factors when designing a safe system;
- It is an *integral/holistic approach* that designs system components integrally and deals with the whole system, not just "spikes in distributions." "Integral" also means that other policy areas (infrastructure investments, environmental policies, urban planning, etc.) should meet certain safety levels;
- The safe system approach aims at *eliminating and/or reducing so-called "system gaps"* [15]. These are "latent gaps," or individual weaknesses in components of the system;
- It embodies a *preventable injuries approach* to identify priorities in actions 1) based on a good understanding of crash causes, 2) based on the expected effects of remedies and cures, and 3) starting with the most cost-beneficial interventions.

Approaches comparable to the Dutch Sustainable Safety approach were developed in Sweden and Australia along similar lines of thinking [16]. Other developments have embraced the "zero" target, including efforts in major US cities like New York City, Chicago, Los Angeles, San Francisco, and Boston. As we know, "the proof of the pudding is in the eating," so it is critical to monitor whether these rather theoretical approaches result in effective implementation. A recent assessment aimed to determine if the implementation of Sustainable Safety in the Netherlands met the high expectations [17]. The research suggests a 30–40% reduction in the number of fatalities with a cost–benefit ratio of 4:1.

Safe System principles are rather universal. However, local conditions and circumstances will dictate how these principles can be translated into local action.

4. Conclusions

The future of road safety is uncertain, and definitely not the same for all regions of the world. The anticipated uncertainty has two reasons. First of all, we do not fully understand how or why countries make progress in road safety. Over the last few decades, our knowledge of the causes of crashes and potential remedies for eliminating crashes, reducing crash risks, and limiting their (negative) consequences has increased considerably. Still, we are far from a full explanation of crash developments at an aggregated level; certain important explanatory factors and developments remain out of our grasp. This can be illustrated by a recent study that analyzed crash causation using naturalistic driving data [18]. This innovative research offered the option to witness crashes via unobtrusive instruments (e.g. cameras and sensors) that automatically and continuously collect driving information of a relatively large sample size of crashes. The conclusion of the research was that distraction—a factor that tends to be very hard to prove with traditional crash statistics using data from the police—was detrimental to road safety.

However, the second factor always plays a role when dealing with future developments: distortions in trend lines. Of course, we can estimate the (safety) impact of future incremental changes. The safety impact of system innovations and drastic technological changes such as (semi)automated vehicles are very hard to predict, though. One of the fundamentals here is that we do not know how human beings will respond to given new developments—what we call "behavioral adaptation" [19]. We have only just started the journey to understanding user interaction with changes to the road traffic system that are not targeted by initiators of the change and sometimes called side effects.

Having said this, it makes sense to make a distinction between countries with a mature road safety approach and countries that are just beginning to implement such approaches. Many high-income countries are in the first group, while many low- and middle-income countries are in the second group.

Countries with a mature road safety approach—and an ambition to make further progress—are expected to move in the direction of a Safe System approach. A traditional "reactive" approach, which focuses on spikes in distributions, will come to the end of its life cycle. A Safe System approach deals with human behavior in a proactive and integral way by creating an environment for safe human behavior. It would be useful to explore how to use new technologies, which are on the brink of massive penetration in the vehicle fleet, to arrive at a considerably safer road traffic system. We do not depend on fully automated vehicles to achieve safer road traffic. Strong leadership and an active public sector are crucial to putting Safe Systems in place, and it is realistic to expect that sustained efforts will lead to substantial results. Political will is required to accomplish good results. The support of the private sector and civil society is vital, too, but this cannot replace an active public sector.

Many low- and middle-income countries (LMIC) face a different starting point. Reports indicate that there is a lack of almost everything: a lack of leadership, a lack of political priority, a lack of funding, a lack of expertise, etc. A positive signal comes from the international community, as expressed recently in the recent Brasilia Declaration [20]: the

international community is willing to support LMIC in taking the next steps toward improving road safety. One complicating factor is that, although LMIC could learn from HIC, they cannot simply copy successful HIC strategies. Local circumstances differ, which is why the principles of successful strategies could be used and perhaps copied—but the priorities and the action plans should be derived from and adapted to local conditions. LMIC should invest in local capacity building to carry out these tasks and create effective road safety communities that involves all players: the public sector (all tiers of government), academia, NGOs, and the private sector. Positive results will develop if lead agencies orchestrate strategy development and the implementation of action plans. Setting and monitoring road safety targets will likely be instrumental, and that process requires good data systems.

References

[1] F. Wegman, Traffic Safety, in: B. van Wee, J.-A. Annema, D. Banister (Eds.), The Transport System and Transport Policy. An Introduction, Edward Elgar, Cheltenham 2013, pp. 254–280.
[2] OECD/ITF, Road Safety Annual Report, 2015IRTAD, Paris, 2015.
[3] F. Wegman, H.-Y. Berg, I. Cameron, C. Thompson, S. Siegrist, W. Weijermars, Evidence-based and data-driven road safety management, IATSS Res. 39 (2015) 19–25.
[4] Road Safety Performance Indicators: Theory, in: A. Hakkert, V. Gitelman (Eds.),Deliverable D3.6 of the EU FP6 Project SafetyNet, 2007.
[5] M. Koornstra, D. Lynam, G. Nilsson, P. Noordzij, H. Petterson, F. Wegman, P. Wouters, SUNflower: a Comparative Study of the Development of Road Safety in Sweden, the United Kingdom and the Netherlands, SWOV, Leidschendam, 2002.
[6] Safety Science, Scientific research on road safety management. Special issue, Saf. Sci. 48 (9) (2010) 1081–1224.
[7] R. Elvik, A. Høye, A. Vaa, M. Sørensen, The Handbook of Road Safety Measures, 2nd Revised Version, Emerald Group Publishing Limited, Bingley, 2009.
[8] OECD/ITF, Sharing Road Safety, Developing an International Framework for Crash Modification Factors, OECD, Paris, 2012.
[9] M. Peden, R. Scurfield, D. Sleet, D. Mohan, A. Hyder, E. Jarawan, C. Mathers, World Report on Road Traffic Injury Prevention, World Health Organization, Geneva, 2004.
[10] OECD/ITF, Why Does Road Safety Improve When Economic Times Are Hard? IRTAD, Paris, 2015.
[11] World Health Organization, Global Status Report on Road Safety 2015, Supporting a Decade of Action, WHO, Geneva, 2015.
[12] W. Wijnen, Social Costs of Road Crashes: an International Comparison, Contribution to the 16th Road Safety on Four Continents Conference, China, May 15–19 2013.
[13] E. Kopits, M. Cropper, Traffic fatalities and economic growth, Accid. Anal. Prev. 37 (1) (Jan 2005) 169–178.
[14] Advancing Sustainable Safety, in: F. Wegman, L. Aarts (Eds.), National Road Safety Outlook for 2005–2020, SWOV, Leidschendam, 2006.
[15] J. Reason, Human Error, Cambridge University Press, 1990.
[16] OECD/ITF, Towards Zero: Ambitious Road Safety Targets and the Safe System Approach, OECD/ITF, Paris, 2008.
[17] W. Weijermars, F. Wegman, Ten years of sustainable safety in the Netherlands. An assessment, Transp. Res. Rec. 2213 (2011) 1–8.
[18] T. Dingus, F. Guo, S. Lee, J. Antin, M. Perez, M. Buchanan-King, J. Hankey, Driver Crash Risk Factors and Prevalence Evaluation Using Naturalistic Driving Data(PNAS Early edition) 2016.
[19] M. Rudin-Brown, S. Jamson, Behavioural Adaptation and Road Safety, Theory, Evidence and Action, CRC Press, Boca Raton, 2013.
[20] WHO, Brasilia Declaration Second Global High-level Conference on Road Safety: Time for Results Brasilia, November 18–19 2015.