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Review

Specific road safety issues in low- and middle income countries (LMICs): an overview and some illustrative examples

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Abstract: This paper gives an overview of the work of PIARC Working Group 3.1.1 'Specific road safety issues for LMICs'. The working group performed its activities in the period 2019–2023. We prepared two deliverables: (*a*) a literature review, and (*b*) an overview of illustrative examples. The review started from the notion that the road safety problem requires a multi-disciplinary approach. The Safe System approach is generally considered as the central concept for this purpose and this starting point is also taken in this study. However new directions are needed to make the Safe System concept work in LMICs. The period of the first UN Decade of Action for Road Safety has brought us a series of valuable problem analysis and overview articles prepared by a variety of institutions and institutes. As a PIARC working group we did not repeat this effort, but used it as a starting point to indicate which specific issues do require a boost in LMICs for the coming period up to 2030. We concluded that the following 12 issues deserve special attention. Strategical: (*i*) Sustainable Development Goals integral approach, (*ii*) safety culture, (*iii*) road safety management and leadership, (*iv*) building road safety expertise and science; Tactical: (*v*) transportation system as a whole, (*vi*) city design, architecture, land use, rural planning, (*vii*) cost effectiveness, (*viii*) legislation and enforcement; Operational: (*ix*) speed, (*x*) sustainable safe roads, (*xi*) vehicles as a Safe System component, (*xii*) post-crash health care. As a result of our discussions and analyses we also concluded that it is worthwhile and necessary to make a distinction between the issues in terms of levels of approach. Making roads and vehicles safe may be considered as operational safety measures on a component level, whereas city design and transport system issues do represent a more tactical approach. On top of that, organisational and cultural aspects do have a more strategical nature. As in many managerial and planning tasks the distinction between strategical, tactical and operational levels of approach is needed in the road safety field. It illustrates that the Safe System concept asks for a multi-level vision, thus preventing a silo approach with a limited focus on human behaviour, safe roads or vehicle safety. A further analysis for each of the selected issues resulted in priority areas, i.e. topics that deserve special attention in the LMIC context. In a similar line of reasoning we also described illustrative examples, i.e. LMIC related before-after studies that show the perspective of certain measures on an evidence basis. Although we found some illustrative cases for each of these issues, our search for evidence based cases confirmed the findings from recent overview articles indicating the lack of LMIC related road safety research. A more widespread implementation of effective road safety measures in LMICs would require a stronger national commitment and leadership from the road safety agencies point of view in the first place. Moreover an evidence based policy asks for a strong national and regional knowledge infrastructure. Ultimately road safety policies and road

safety research programs are to be considered as inseparable. A strong local knowledge infrastructure may thus become the basis for an effective national road safety policy.

Keywords: evidence based policy, low- and middle-income countries (LMICs), road safety, Safe System approach

1 Introduction

Road crashes continue to be a major cause of death and serious injury for low- and middle-income countries (LMICs). At the global level, 90% of traffic deaths occur in these countries. In comparison to high-income countries, where the number of road deaths is 8 per 100 000 population, the fatality rate for middle income countries is double at 16 per 100 000 population and the fatality rate for low-income countries is even higher, at 21 per 100 000 population (WHO, 2023, 2018). Almost half of these deaths are among the most vulnerable road users, including people who cycle, walk and use motorcycles. These rates would suggest that much opportunity exist within these countries to build institutional capacity, with a focus on addressing known safety problems, as well as through careful countermeasure selection and adoption of design standards in urban and rural areas.

Given this perspective PIARC installed a working group on Specific Road Safety issues for LMICs as part of the PIARC programme 2020–2023. The intent of this effort has been to assess and identify those road safety issues that are of particular importance for low- and middle-income countries, and to gather successful examples of safety measures related to these issues. In the period 2020–2023 the working group delivered two outputs: a literature review (PIARC, 2023a) and an overview of illustrative examples (PIARC, 2023b). The present paper gives a summary of these reports. Results will be incorporated in the PIARC Road Safety Manual (PIARC, 2019).

The working group performed its activities at about the starting moment of the second Decade of Action for Road Safety. The first Decade of Action, 2011–2020, has brought a series of initiatives and introduced new road safety programs on a variety of areas (WHO, 2010). During the past decade, numerous studies were initiated all over the world and several, extensive overviews, problem analyses and visions for the future has been prepared. At the third Global Ministerial Conference on Road Safety (Stockholm Declaration, 2020; Academic Expert Group, 2019), the results of these efforts were presented and evaluated. Many countries made progress through road safety management and better legislation addressing risks such as speeding, drinking and driving, failing to use seatbelts, and infrastructure improvements. However, the intended reduction in casualties strongly lagged behind the original goals. Continuation of programs and new approaches are needed to reach a breakthrough, particularly in LMICs. The Stockholm Declaration (2020) gives an important motivation towards new initiatives and makes a plea to connect road safety to the broader set of UN Sustainable Development Goals.

When preparing the PIARC reports, we experienced a special moment in time that was characterized by the COVID-19 pandemic. Going forward in road safety will also be influenced by mobility changes stimulated during the pandemic. Many cities developed a program of re-allocating road space to pedestrians and bicyclists. At the same time speed of motorists has risen as a result of lower traffic densities, while travel behavior changed due to societal demands on public transport and air transportation. The pandemic effects thus clearly illustrate that our roads are part of a transport system, which in turn serves as a facilitator in the broader societal context. This insight has made us realize again that making roads safe is a matter of making the system safe. The pedestrian killed when crossing a busy urban arterial should be considered as a victim of a chain of policy and design decisions.

2 Method

As indicated, the period of the first Decade of Action has brought us a series of valuable problem analyses and overview articles prepared by a variety of institutions and institutes. In order not to repeat the work done by many colleagues during the last decade, we used a two-phase approach to indicate which specific issues do require a boost for LMICs in the coming period up to 2030. In phase 1 we gathered a series of recent overview reports and articles through a literature review (PIARC, 2023a). This review made use of a series of regular databases, such as Pubmed, Scopus, TRID, DART-Europa, and TRR

Online. We used search terms such as 'road safety', 'low- and middle-income countries', 'vulnerable road users', country names, and the like.

Appendix A gives an overview of the resulting articles and the issues mentioned in each of these reports. As a working group we analysed and discussed the issues mentioned. Members were invited to give their comments on the issues from the LMIC point of view. This resulted in a selection, which was commented on in a second round. This process resulted in the list of issues, presented in section 3. In a next step we analysed the selected issues in further detail from the LMIC point of view. As a result section 4 gives a vision on the future priority areas as considered most promising for LMICs. Based on this vision we also collected one or more LMIC-related examples of road safety measures, that may serve as an illustration for that particular issue (PIARC, 2023b) and which are also presented in section 4. The collection of examples thus gives an impression of local initiatives, which may be used to build on in the future for each of the issues.

3 Specific road safety issues for LMICs

The studies presented in Appendix A give a number of profound observations about the nature of the road safety problem in LMICs. However a general look also suggests that the issues for LMICs do not strongly differ from those in HICs. And indeed, at the macro level the principles behind the issues may be considered as more or less the same. However, the operational approach needed and the way of implementing measures may differ strongly. In LMICs safety culture, traffic composition, legislation level, enforcement strategies, spatial design of urban areas, all of these differ strongly, between or even within countries. Based on this perspective we selected 12 issues that bear the perspective of building successful road safety developments in LMICs.

As a result of our discussions and analyses we also concluded that it is worthwhile and necessary to make a distinction between the issues in terms of levels of approach. Making roads and vehicles safe may be considered as operational safety measures at a component level, whereas city design and transport system developments do represent a more tactical approach. On top of that, organisational and cultural aspects do have a more strategical nature. As in many managerial and planning tasks the distinction between strategic, tactical and operational levels of approach is needed in the road safety field. It illustrates the relevance of approaching the Safe System concept as a multi-level vision, thus preventing a silo approach with, for example, a limited focus on human behaviour, safe roads or vehicle safety.

Given this perspective we organized the issues by the following three levels.

Strategical:

- Sustainable Development Goals
- Safety culture
- Road safety management and leadership:
- Building road safety expertise.

Tactical:

- The transportation system as a whole
- City design, architecture, land use, rural planning.
- Cost effectiveness
- Legislation and enforcement.

Operational:

- Speed
- Sustainable safe roads
- Vehicles as a Safe System component
- Human protection and health care.

4 Priority areas for LMICs and illustrative examples

Together PIARC (2023a) and PIARC (2023b) give a state of the art for each of the issues described above and a number of illustrative examples per issue. This paragraph presents a summarized overview of our findings.

4.1 Sustainable Development Goals (SDGs)

4.1.1 Motivation

Worldwide measures are taken to improve climate, air and sustainability. Road safety can benefit from these measures, because climate and road safety measures may show a strong synergy. Welle et al. (2018) give a vision on how a Safe System will promote a sustainable system. The system approach is not only needed to improve road safety, but may also support broader

environmental, social, and health goals. By promoting public transport, walking, and bicycling, it can help mitigate climate change and improve air quality, i.e. by reducing carbon dioxide emissions from transport. Increasing the safety of public transport, walking, and bicycling also increases people's physical activity and enhances their quality of life and ability to access jobs and education. A mobility system that offers a variety of safe transportation options can better address the needs of a variety of demographic groups, including women, poor people, elderly people, the very young, and people with limited mobility. ITF (2023) gives an quantitative estimate of the expected link between road safety and decarbonization policy, see Figure 1.

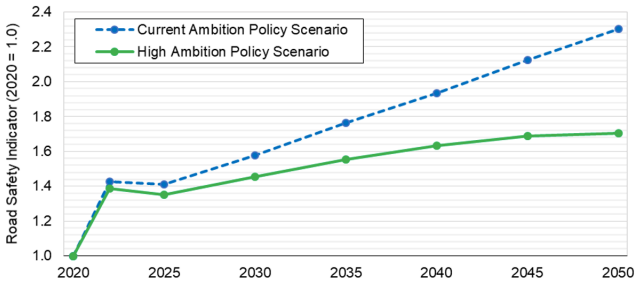

Figure 1 Effect of decarbonization policy on traffic crash risk (ITF, 2023)

In PIARC (2023a) we mention the following priority areas for the SDG issue:

- countries to integrate road safety strategies as an integrated component of their sustainable development goals;
- countries to stimulate a multi-sectorial approach with all relevant stakeholders involved.

4.1.2 Illustration: bicycle safety in Bogota (Carvajal et al., 2020)

The city of Bogota has developed a comprehensive policy framework to support safe bicycling. Carvajal et al. (2020) give a deep analysis of the road safety effects related to a series of programs and policies. In the period considered there were five main policies and programs to promote bicycling in Bogota. The first is the national policy 'Ley Probici [Bicycle Law]' which gives both a half-day free from work and a free trip in public transport for every 30 bicycle trips to work; the law also makes mandatory to have parking spaces for bicycles in all car parking lots. The second program is the local 'Plan Bici [Bicycle plan]' for Bogotá which main objective is to make bicycling the primary mode of transport for the citizens of the city through its infrastructure, safety, culture, environment, and health components. The third program is 'Al Colegio en Bici [Let's bike to school]' which is part of the city's school transport strategy to eliminate the access barriers to education for low-income students by providing bicycles and safe routes to children living 2–3 km away from school. The fourth program is the 'Ciclovía [Open Street program]' of Bogotá in which every Sunday and holidays, during 7 hours, the main streets are closed to motor vehicles and open exclusively to individuals for bicycling, walking, running, and other leisure activities. The last policy is the global road traffic safety policy known as the Vision Zero to which Bogotá committed in 2016. The bicycling policies implemented in Bogotá have the potential of increasing the number of bicyclists, but evidence regarding bicyclists safety is limited.

The findings from Carvajal et al. (2020) indicate that from 2011 to 2017, the fatal bicycling collision rates per bicyclists' population have remained constant for females while decreasing by 53% for males. Additionally, the authors identified high-risk areas located in the west, southwest, and southeast of the city, where the rate of occurrence of fatal events is higher than what occurs in other parts of the city. Finally, results show associated risk factors that differ by sex. Overall finding was that collisions are positively associated with factors including collisions with large vehicles, the absence of dedicated infrastructure, steep terrain, and night time occurrence. Findings support policy-making and planning efforts to monitor, prioritize, and implement targeted interventions aimed at improving bicycling safety conditions while accounting for gender differences.

4.2 Safety culture

4.2.1 Motivation

Cultural differences between countries are generally considered one of the major challenges when introducing road safety strategies. Culture may be described as an anthropological item, with mobility behavior as a particular topic. Consequently cultural aspects may result in large differences in traffic behavior. The challenge of developing and enforcing a proper road safety culture among communities and the population at large may be considered as far more difficult than adopting best practices in principle and creating appropriate legislation.

A general review of available literature, as well as first-hand experience, reveals a number of reasons as to why such culture is not entrenched in some countries and societies (King, 2015). These include :

- A pervasive influence of fatalism in certain religious beliefs, leading to a disconnect between behaviour and effect.
- Multi-cultural societies, encompassing many different languages and beliefs, which mitigate the adoption of a common goal. In South Africa, for example, there are 11 official languages.
- A culture of 'speed is king', where getting to a destination within a certain time is seen as a badge of honour.
- A lack of enforcement. In many LMICs, legislation does not equate to compliance. Reductions in blood alcohol limits and posted speed limits have little if any impact when not enforced.
- A culture of 'convenience' resulting with individuals walking directly across a busy highway to the shops, rather than use the pedestrian underpass or overbridge, which entails an additional 100 meter walk.

In order to deal with cultural differences, it is worthwhile to approach this issue with a broad societal perspective including responsibilities for authorities, community, and the private sector.

The *authorities* should develop a road safety strategy on the basis of the Safe System principle, i.e. accepting that human errors will occur, and taking the local culture into account. This approach requires knowledge about the relation between local habits and human traffic behavior. When developing legislation, traffic rules and infrastructure guidelines this local culture should be taken into account. This will also influence the nature of educational programs, i.e. school curriculums as well as driver training programs. The introduction of road safety awareness into the school curriculum, as well as outreach programs by road authorities for the education sector, are among the initiatives in LMICs aimed at fostering a road safety culture from an early age

Co-ordination between government departments is also considered as a major challenge in some LMICs. This is equally true at a national level, where different ministries do not interact effectively, including the interactions between national and provincial departments.

The boundaries of national, provincial and municipal responsibility can be blurred, to the extent that no-one takes responsibility for the implementation of long-term strategies. The tendency to allocate funding on the basis of annual budgets, as opposed to long term goals, could be a contributing factor in the lack of co-ordination.

At the *community level*, strong organizations are needed to develop a correct understanding of the traffic problems encountered in a particular area (SSATP, 2004). Local working groups (parents, schools) and NGOs may serve as the eyes and ears of the authorities in order to develop effective measures. Advocacy groups founded by road crash victims may play an effective role as well. A strong link between Community teams and Centres of excellence is needed to provide coordination. Funding of community teams should be considered as an important element of a country's road safety leadership. At a more local level, the engagement of communities in the road safety effort is essential. It is a feature of some LMICs that building houses, i.e. so called ribbon development, takes place along national or provincial roads which were originally constructed to rural geometric standards. For various reasons, including a lack of spatial development planning, local communities see the rural highway as the main arterial route. This results in pedestrians and livestock using a road which was not built to cater to these users. Research projects should deliver a clearer understanding of communities' usage of rural roads in order to formulate design features and standards which will improve the overall safety. Engagement and understanding will no doubt encourage acceptance of road safety measures, rather than imposing barriers and restrictions on communities.

Private sector companies under contract to agencies to manage public transport services are important influencers of a proper safety culture in their company. The Bangladesh traffic safety crisis (Global Alliance, 2018) may serve as an illustrative example. Many of the country's buses are not registered, and often drivers have not been trained or had their eligibility to drive a bus verified. Buses are often rented to drivers who feel they need to drive fast to collect enough fares to pay for the bus. The case illustrates particularly that a multi-level approach is needed. Improving driver training is necessary but not sufficient by itself. The

underlying causes of speeding should be considered, i.e. the incentive to collect as many fares as possible. Drivers should also receive incentives for safe driving.

After a serious crash near Sakal, northern Senegal, on 16 January 2023, where 19 peoples were killed when a bus and a truck collided (Figure 2), Christopher Kost, the Africa Program Director at the Institute for Transportation and Development Policy, an urban planning nonprofit, says that in order to improve road safety, African countries need to shift public transportation business models. '*In so many African countries, we're still operating with a target system where driver incomes are directly related to the number of people they carry. And as a result, they rush as fast as possible to the destination, and that leads to a lot of the road safety challenges that we have. Switching to a salary system would incentivize drivers to drive safely instead of cramming their buses full and speeding to their destinations*', Kost said.

Figure 2 Crash between bus and truck in northern Senegal on 16 January 2023

In PIARC (2023a), we mention the following priority areas for the safety culture issue:

- authorities developing a strategy with traffic rules and design guidelines that are based on knowledge about local behavioural characteristics;
- strong organizations that represent the local community and serve as the eyes and ears regarding traffic problems and solutions;
- transport companies to develop and/or uses effective incentive systems with the focus on safe driving;
- development of and access to education and training programs.

4.2.2 Illustration: how driver compensation affects bus system performance (Johnson et al., 2015)

Prior to 2007, two systems of bus driver compensation coexisted in Santiago, Chile: one paid drivers per passenger transported, while the other paid a fixed wage. Per passenger drivers engaged in 'The War for the Fare', altering their driving patterns to compete for passengers. Examining these systems on similar routes in Santiago, we observed two key findings. Compared with the fixed-wage system, the per-passenger system leads to (*1*) 13% shorter passenger wait times, via reduced bunching of buses and (*2*) 67% more accidents per kilometer driven, via more aggressive driving. The paper discusses implications for the design of incentives in public transit. Figure 3 shows how bus driver compensation schemes are effecting the number of crashes.

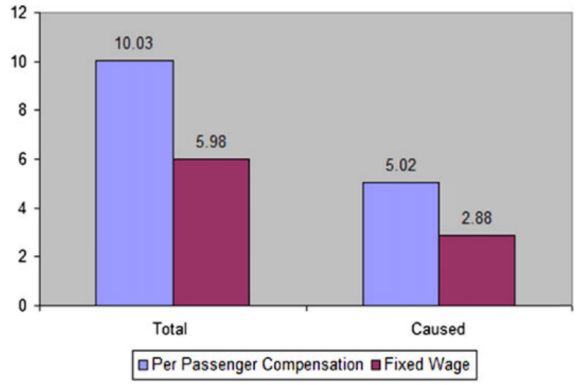

Figure 3 Effect of bus driver compensation scheme on number of crashes per millions km traveled (Johnson et al., 2015)

4.3 Road safety management and leadership

4.3.1 Motivation

An efficient management system and leadership body are key requirements for the implementation of an effective road safety improvement program. During the first Decade of Action (WHO, 2010) strong emphasis has been placed on the development of road safety lead agencies (RLSAs) In many LMICs steps were made in this direction, but still the organizational structure of the management system may suffer from deficiencies, thus weakening the institutional functions across key road safety players. In fact, countries may differ strongly in their starting point. There may be cases with a lack of leadership, a lack of political priority, a lack of funding,

a lack of expertise, etc.

According to the World Bank (2020), the success and effectiveness of RSLAs in coordinating preventative road safety interventions in developing countries is dependent on a number of key elements. They should have a full-time expert staff, legally endowed powers, permanent funding, political support, and access to relevant road crash and other complementary data. Based on that they may develop road safety strategies with clear intermediate and final targets and outcomes.

In this line of reasoning PIARC (2023a) mentions the following priority areas for the management and leadership issue:

- development of a strong lead agency which has full-time expert staff, legally endowed powers, permanent funding, and political support;
- development of a robust road safety data system;
- development of a robust set of local guidelines and regulations.

4.3.2 Illustration: road safety institutions in Argentina (Bhalla & Shotten, 2019; Raffo et al., 2011)

Traffic injuries remain a leading health concern in most low- and middle-income countries (LMICs). However, most LMICs have not established institutions that have the legislative mandate and financial resources necessary to coordinate large-scale interventions. Argentina provides a counterexample. Argentina is a federal country where the decentralization of authority to provincial governments was a key barrier to effective national interventions. In 2008, Argentina passed a law establishing a national road safety agency and subsequently received a World Bank loan to build the agency's capacity to coordinate actions. Although traffic injuries in Argentina have not yet begun to decline, these developments raise important questions: Why did Argentina come to view road safety as a problem? Why was institutional reform the chosen solution? What was the political process for achieving reform? What are the broader implications for institutional reform in LMICs? These questions were explored using a descriptive case study (single-case, holistic design) of Argentina. The case illustrates that focusing events, like the Santa Fe tragedy that killed nine children, and advocacy groups are important for raising political attention and creating an opportunity for legislative reform. It highlights the importance of policy entrepreneurs who used the opportunity to push through new legislation. Though the political dynamic was predominantly local, international actors worked with local advocates to build demand for safety and develop solutions that could be deployed when the opportunity arose. Most important, the case emphasizes the importance of developing institutions with the resources and authority necessary for managing national road safety programs

4.4 Building expertise and science

4.4.1 Motivation

As noted a lot of road safety knowledge has been transferred to LMICs in the period 2010–2020. Guides and books, online and onsite courses, etc. were presented with many international organizations being involved: FIA Foundation, GRSF, WHO, UN, GRSP, NCAP, Bloomberg, ITF, IRF/PIARC, and others. As a result more and more countries indeed started implementing lead agencies, developing road safety strategies and taking their responsibility for road safety legislation and road safety data systems. Initiatives taken by (*a*) the World Bank and Multi Lateral Development Banks to build Road Safety Observatories and Centers of Excellence (SSATP, n/d; African Development Bank, 2019), and (*b*) to build networks of universities, strongly support this work (UNITAR, 2018).

However, despite this large international effort, countries do differ strongly in their level of national knowledge development and academic programs. Countries are stimulated to set up demonstration projects in order to build up a national evidence base. In this way research based evidence could serve as a foundation for an evidence based policy. However in many cases the effective use and safeguarding of this knowledge in the local LMIC context is limited. The lack of a robust knowledge infrastructure seems to us as one of the important reasons for the limited level of road safety improvements in many LMICS until now. Given that background—and despite existing capacity building programs–countries need strong(er) university programs and a national road safety research institute. Such a knowledge infrastructure seems a prerequisite to translate international road safety knowledge into local guidelines and to develop national research and demonstration programs. Most importantly this local infrastructure should serve as a national road safety knowledge memory.

In PIARC (2023a) we mention the following priority areas for the expertise and science issue:

- develop university road safety programs at bachelor and master level;
- build research capacity in national centers of road safety excellence;
- connect to regional road safety observatories;
- connect to international network of universities and centers of excellence;
- international organisations to strongly support these processes.

4.4.2 Illustration: macro-scale literature analysis on road safety research in LMICs (Haghani et al., 2022)

Road users in low- and middle-income countries (LMICs) are overrepresented in road trauma statistics. Despite the relative success of many high-income countries (HICs) in reducing deaths on their roads, not much tangible progress has been made in LMICs. Also, on the research front, the vast majority of road safety knowledge has been emerging from institutes of HICs. Considering significant differences in driving culture, legislation, and traffic law enforcement between LMICs and HICs, it seems essential that research on road safety within LMICs intensifies beyond the existing rate to produce the much-needed local knowledge and to develop initiatives that meet their safety needs and upgrade their practices. To facilitate this, here, the landscape and temporal trends of road safety research in LMICs are analyzed while contrasting them with those of the general scholarly literature on road safety. It is estimated that slightly less than 10% of the road safety research has been undertaken in the contexts of LMICs, which is extremely disproportionate considering the fact that most road traffic deaths and injuries occur in LMICs, see Figure 4. Questionnaire-based research on socio-psychological aspects of driving, cycling, and walking as well as statistical modelling of road crash data seem to have made up the dominant focus of LMIC researchers within the recent years. Areas of road safety research that are underrepresented in LMIC studies are also identified in this work. Patterns of authorship and co-authorship in LMIC studies are also analyzed at the level of countries, organizations, and authors. It is hoped that this effort can contribute to further invigoration of road safety research in LMICs and to highlighting the current knowledge gaps, while also giving better recognition to active road safety researchers of LMICs, and thereby, prompting more international collaborations in this domain.

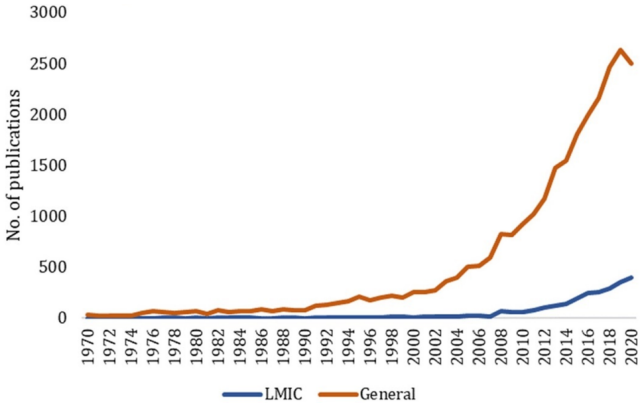

Figure 4 Number of academic road safety publications in general and in LMICs (Haghani et al., 2022)

4.5 The transportation system as a whole

4.5.1 Motivation

More and more LMICs take the position to develop a road safety strategy which is connected with their strategic development goals, see also Issue I. This policy implies the creation of urban and rural development patterns which stimulate the use of public transport, walking and cycling as primary modes of transport and which support vibrant, diverse, and liveable communities (World Bank, 2021). When developing cities this is achieved by concentrating urban densities, communities, and activities within a 5–10 minute walking distance from mass rapid transit stations (both bus and rail-based), developing quality urban space and providing convenient and efficient access to a diverse mix of land uses. Truong & Currie (2019) give a nice overview of the potential positive safety impacts of public transport, based on the Melbourne case.

A policy of improving public transport facilities and making urban and rural areas more attractive for walking and cycling should be based on a road safety strategy that focuses on the protection of these vulnerable road users.

In the period up to 2030 a strong international Transit Orient Development (TOD) movement is made under the umbrella of the World Bank (Ollivier et al., 2021; World Bank, 2021). Owing to the potential benefits,

cities around the world—both in HIC and LMICs—are adopting TOD planning practices for smart growth and improving quality of life for their residents. This gives a plea to link TOD with road safety, particularly in LMICs. A five step framework is presented based on the Safe System approach. The five steps include:

1. **Assess.** To evaluate the road safety status of a city by evaluating the existing conditions, focusing on demographics and road crash data assessment; infrastructure conditions and spatial assessment; and policies, regulatory frameworks, and capacity assessments.
2. **Enable.** To develop an enabling environment that facilitates institutions and stakeholders to be aware of road safety challenges and allows a TOD project to fill gaps identified in the previous step and act as a catalyst for achieving road safety
3. **Plan and design.** To plan and design infrastructure that addresses networking challenges within a TOD station area and the elements designed are equitable and equipped to cater to the increased volume of users and their requirements.
4. **Finance.** To develop innovative financing tools for the local authorities, enabling institution, developers and property owners that help allocate funds and provide incentives for ensuring road safety.
5. **Implement.** To overcome barriers for implementing road safety within a TOD station area by addressing various gaps as identified and evaluate the effectiveness through key road safety performance indicators.

Huang (2017) provides examples of cities that were in such a transition phase until 2019 before the pandemic period. Since then, this process has accelerated strongly as a result of the mobility effects of the pandemic.

In PIARC (2023a) we mention the following priority areas for the transportation system issue:

- develop a public transport system, with road safety criteria included;
- promote a Transit Oriented Development with road safety criteria included.

4.5.2 Illustration: road safety impact of bus rapid transit system in Bogota (Bocarejo et al., 2012; Duduta et al., 2012)

The design choices made in the planning of a new bus rapid transit (BRT) or busway corridor (e.g. use of a center-lane or curbside configuration, counterflow lanes, and open or closed stations) affect not only the operational performance of the system but also the risks of crashes, injuries, and fatalities on the facility over its lifetime. With data from nine BRT systems and busways around the world (including Bogotá in Colombia, Curitiba in Brazil, Mexico City in Mexico, and New Delhi in India), some of the road safety impacts of major BRT-busway corridor design characteristics are illustrated. The approach included a combination of crash frequency modeling, road safety inspections, and interviews with transit agency staff and safety experts. Center-lane systems tended generally to be safer than were curbside systems, and counterflow lanes were the most dangerous possible configuration. Some of the features that provide higher passenger capacity (such as multiple bus lanes and multiple docking bays at stations) may introduce new types of conflicts and crashes. In the planning of any bus system, trade-offs often need to be made between capacity, safety, and pedestrian accessibility along the corridor. This study provides the necessary elements for successfully integrating road safety considerations into the design and operation of future BRT systems and busways. Figure 5 gives the traffic safety impact on Avida Caracas, Bogota, before and after the implementation of the BRT system.

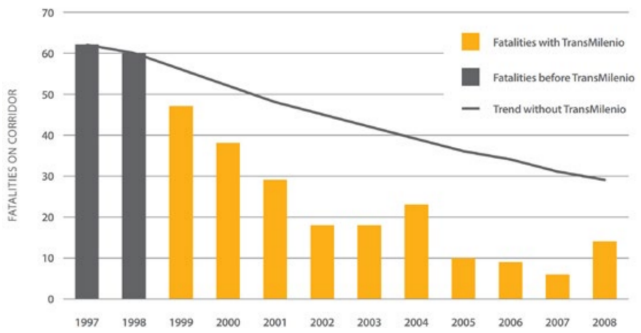

Figure 5 TransMIlineo's traffic safety impact on Avida Caracas, Bogota, before and after the implementation of the BRT system (Bocarejo et al., 2012; Duduta et al., 2012)

4.6 City design and architecture

4.6.1 Motivation

In strong relation with the developments under the issue described in 4.5 (transport system as a whole), ultimately, the worldwide movement to make cities cleaner and safer will effect the design of cities and the distribution of space between vulnerable road users and cars. Giving more space to active transport modes like walking and cycling as compared to car use, does not automatically result into more safety. Firm measures are needed for a safe integration of motorized vehicles and vulnerable roads users, i.e. speed limitation to 30kmh in cities, car free zones and comfortable and relatively cheap public transport. ITF (2021) gives nice illustrations, examples and instructions for new designs. Initiatives like Global Designing Cities Initiative (n/d) and Design for Life (FIA Foudation, n/d) are stimulating these developments.

In PIARC (2023a) we mention the following priority areas for the city design issue:

- adopt through a systems-oriented approach to put road safety and public health policies in a broad context of improved transport and health;
- embrace the compact city approach of shorter distances, slower speeds, higher residential and population densities, and design that promotes walking, cycling, and public transit;
- develop evidence-based transportation plans that undergo a participative process.

4.6.2 Illustration: reshaping safe and sustainable mobility in Fortaleza (Koon et al., 2021)

Fortaleza, a city known for its sunny beaches, night life and historic landmarks, is also now recognized for dramatically improving the safety of its streets. The city of 2.5 million saw a 40 percent reduction in road crash deaths in just four years, from 2014 to 2018. A strong mix of political will and local expertise are behind this success. This mix spurred Fortaleza's step-by-step investment in measures to promote road safety: increased law enforcement around key risk factors, mass media campaigns, better data collection, and redesigned intersections that prioritize pedestrians and cyclists. The partners in the Bloomberg Philanthropies Initiative for Global Road Safety used this recipe for road safety in 10 cities around the world, and Brazil's fourth-largest city is among the most successful.

'*Fortaleza has seen particularly strong results because of a combined effort of political leadership, a strong technical staff and ever-growing community engagement*', said Jonas Romo, Regional Deputy Director for Latin America at Vital Strategies. '*The city took a multi-pronged approach to enforcing helmet use, drink driving and speeding, day in and day out, and redesigned streets to give more space to pedestrians and cyclists. Changing the approach to road safety from just a transportation issue to a public health issue demanded a lot of planning and coordination.*'

During the program, cycling infrastructure in the city nearly tripled, and more than 4 000 square meters of asphalt originally designed for cars has been returned to pedestrians. The city also invested more than $600 000 USD on mass media campaigns addressing the risk factors that cause most of deaths and injuries on Fortaleza's roads: drink driving and lack of helmet use. The city also trained journalists, which resulted in better coverage of road crash stories and better analysis of the road safety interventions the city has been implementing.

Fortaleza has become one of just a few cities in the world on track to meet the United Nations Sustainable Development Goal road safety target of halving traffic fatalities by 50% by 2020.

During 2020, 193 road traffic deaths were recorded traffic and health authorities, compared to 377 deaths in 2014. Figure 6 and Figure 7 give an overview of measures in Fortaleza during the years 2014–2020 and the development of the number of fatalities in Fortaleza during these years.

4.6.3 Illustration: School Area Road Safety Assessment and Improvements (SARSAI) programme in Tanzania (Poswayo, 2019)

The purpose of this study was to determine the impact of a pediatric road traffic injury (RTI) prevention program in urban Sub-Saharan Africa. In the city of Dar es Salaam household surveys were conducted in catchment areas around 18 primary schools; the catchment areas were divided into control and intervention groups. Collected data included basic demographic information on all school-aged household members and whether or not they had been involved in an RTI in the previous 12 months, and, if so, what the characteristics of that RTI

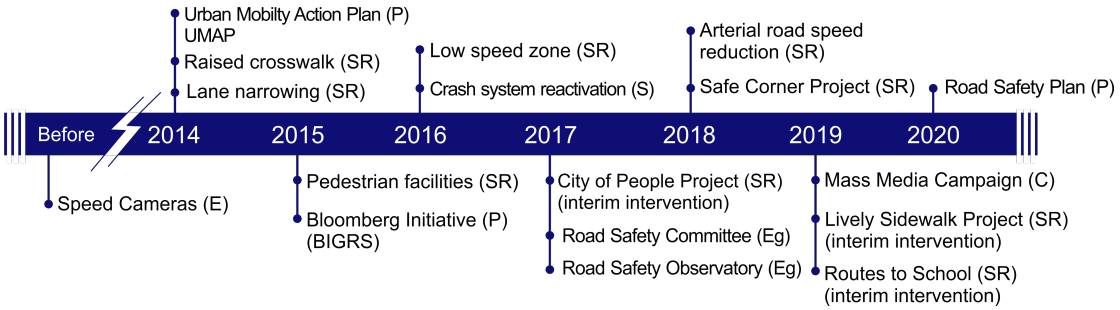

Figure 6 Overview of measures in Fortaleza during the years 2014–2020

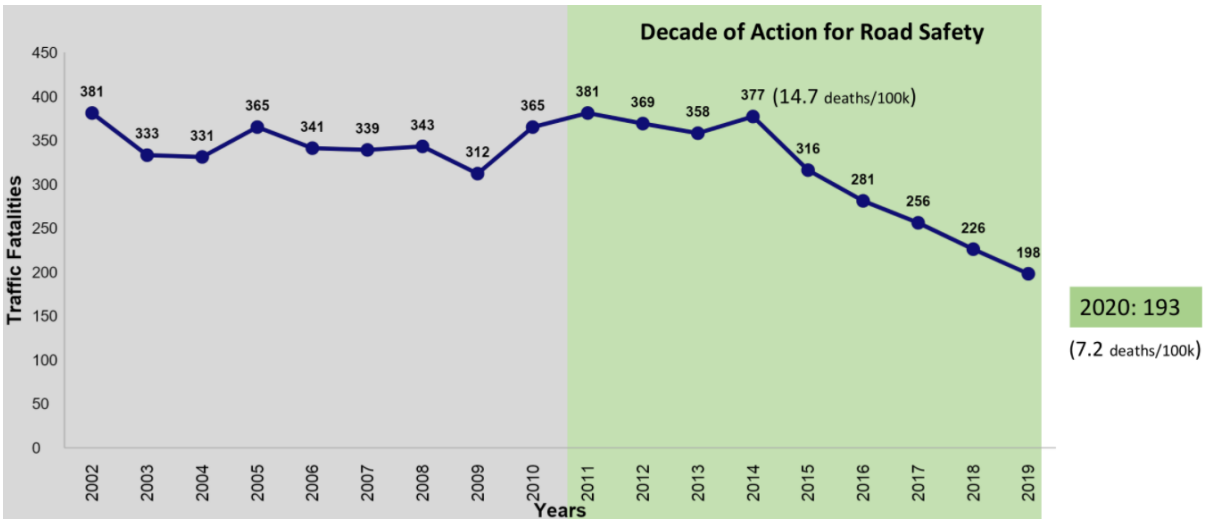

Figure 7 Development of the number of fatalities in Fortaleza during the years 2002–2020

were. Based on these findings, a separate road safety engineering site analysis and consultation with the communities and other stakeholders, an injury-prevention program was developed and implemented, consisting of infrastructure enhancements and a site-specific educational program. The program was initially implemented at the intervention schools. After 1 year, data were collected in the same manner. The control group received the same intervention after follow-up data were collected.

Data were collected on 12 957 school-aged children in the baseline period and 13 555 school-aged children in the post-intervention period, in both the control and intervention communities. There was a statistically significant reduction in RTIs in the intervention group and a non-significant increase in RTI in the control group. The greatest reduction was in motorcycle-pedestrian RTI, private vehicle-pedestrian RTI, and morning RTI.

The program demonstrated a significant reduction in pediatric RTI after its implementation, in very specific ways. This study demonstrates that for a reasonable investment, scientifically driven injury prevention programs are feasible in resource-limited settings with high pediatric RTI rates.

4.7 Selecting cost-effective measures

4.7.1 Motivation

The application of cost-effective interventions has benefits in terms of saving lives as well as reducing costs to society, which are relevant to LMICs and HICs alike. In the absence of established road safety policies to support large scale interventions to systematically address road safety risks, in LMICs specifically, where rural road and highway infrastructure is expanding, the cost burden of crashes is likely to increase for individuals and their communities (Mohan et al., 2020).

Ralaidovy et al. (2018) nicely describe how policy-makers work under resource-constrained conditions and must make decisions about competing programs. For this reason a phased approach is recommended, that ensures the implementation of the most cost-effective individual interventions at first, with an expansion

strategy that can be employed as more reliable data and better resources become available. This also allows interventions to be better targeted towards the road user groups which are of particular concern or at greater risk within certain countries or regions. There are a number of interventions which thus have been found to be successful and cost-effective in LMICs (Ralaidovy et al., 2018).

Random breath testing. Random breath testing is defined as an intervention where impaired driving legislation is introduced and enforced via random breath testing of drivers at roadside checkpoints. This was found to be the most cost-effective single intervention in Southeast Asia, where the highest proportion of road fatalities (39%) are among car drivers and passengers.

Enforcement of speed limits. Enforcement of speed limits is defined as a sustained effort by traffic enforcement teams to raise the perceived risk of drivers being caught via the use of mobile/hand held speed cameras at randomly chosen checkpoint sites. The study found it to be the most cost-effective single intervention in sub-Saharan Africa, where pedestrians account for 55% of road fatalities.

Motorcycle helmet use. Motorcycle helmet use is defined as legislation and enforcement of helmet use among riders of mopeds and motorcycles. This was found it to be the second most cost-effective single intervention in Southeast Asia, where a high proportion of road fatalities (24%) are among motorcycle drivers and passengers.

World Bank (2020), chapter 4, gives a clear indication about the millions of fatalities and injuries that can be avoided worldwide through proper investment in safer road infrastructure with a cost benefit ratio estimated as 1 to 8. The PIARC Road Safety Manual (PIARC, 2019) also gives an overview of the expected percentage reduction in crashes as a result of infrastructure interventions and their costs.

PIARC (2023a) and Ralaidovy et al. (2018) indicate that a combination of enforcement measures (speed, helmet use, safety belts, breath testing) and safer road infrastructure are among the most cost effective road safety measures. Vanderschuren et al. (2019) give an extensive overview of the South African case, which make clear that local analyses are needed and that for the Cape Town province the use of rumbles trips, improved lighting and the implementation of motorcycle-based emergency services are most cost-effective.

In PIARC (2023a) we mention the following priority areas for the cost effectiveness issue:

- developing a road safety strategy based on a selection scheme of cost-effective measures that are based on a local analysis;
- selecting low hanging fruit: defining a list of low-cost proven countermeasures.

4.7.2 Illustration: cost effective traffic enforcement in Uganda (Bishai et al., 2008)

In October 2004, the Ugandan Police department deployed enhanced traffic safety patrols on the four major roads to the capital Kampala. The objective of this action was to assess the costs and potential effectiveness of increasing traffic enforcement in Uganda. Record review and key informant interviews were conducted at 10 police stations along the highways that were patrolled. Monthly data on traffic citations and casualties were reviewed for January 2001 to December 2005; time series (ARIMA) regression was used to assess for a statistically significant change in traffic deaths. Costs were computed from the perspective of the police department in USD 2005. Cost offsets from savings to the health sector were not included.

The annual cost of deploying the four squads of traffic patrols (20 officers, four vehicles, equipment, administration) was estimated at $72 000. Since deployment, the number of citations increased substantially with a value of $327 311 annually. Monthly crash data pre- and post-intervention showed a statistically significant 17% drop in road deaths after the intervention. The average cost-effectiveness of better road safety enforcement in Uganda is $603 per death averted or $27 per life year saved discounted at 3% (equivalent to 9% of Uganda's $300 GDP per capita).

The data clearly illustrate that the costs of traffic safety enforcement are low in comparison to the potential number of lives saved and revenue generated. Increasing enforcement of existing traffic safety norms can prove to be an extremely cost-effective public health intervention in low-income countries, even from a government perspective.

4.8 Legislation and enforcement

4.8.1 Motivation

In the undisputed context that road safety is an issue of public health concern, Bates et al. (2012) note that governments throughout the world rely on traffic law and enforcement programmes to modify driver behaviour and enhance road safety.

Stanojević et al. (2013) state that traffic enforcement has traditionally been an important means of improving traffic safety, and that 'many studies have provided evidence of connections between the level of police enforcement and both driving behaviour and the number of traffic accidents'.

Bates (2014) concurs that traffic law enforcement programs are used to alter driver behaviour and thus enhance road safety with police operations a key component of the enforcement process.

WHO (2016) reiterates that '*law plays an important role in improving road safety*', and offers that '*key areas for law reform may include: setting and enforcing speed limits on roads, introducing traffic-calming measures, introducing and enforcing offences for driving while intoxicated, introducing a graduated licensing system (with mandatory speed restrictions) for novice drivers, prohibiting drivers from using hand-held electronic devices while driving, requiring motorcycles to use running lights during daytime, and mandating the use of seat belts and child restraints in cars, and helmets by people using motorcycles and bicycles*'.

Echoing WHO (2016), a key message in the Global Status Report on Road Safety (WHO, 2018) is that enacting and enforcing legislation '*…are critical components of an integrated strategy to prevent road traffic deaths and injuries*'. World Bank (2020) confirms that '*establishing and rigorously enforcing laws to address key risk behaviours is effective in reducing road crash fatalities and injuries*'.

WHO (2018) also reports that member states, with the support of WHO, the United Nations Economic Commission for Europe, UNICEF, World Bank, and other agencies, have agreed to 12 Voluntary Global Performance Targets for Road Safety Risk Factors and Service Delivery Mechanisms. Van den Berghe et al. (2020) describe how each of the twelve performance targets can be addressed via a three-stage logic in which an 'action' properly implemented has outcomes which result in (typically) a reduction in the number of injuries and fatalities.

In the context of legislation, Van den Berghe et al. (2020) indicates that by 2030, all countries accede to one or more of the core road safety-related UN legal instruments, with the associated global indicator being the '*number of countries that have ratified or acceded to one or more of the core road safety-related UN legal instruments*'. At a tactical level, six of the twelve targets include key action elements that are to be achieved by 2030 requiring legislation and enforcement. These are:

- Target 6 Speeding
- Target 7 Motorcycle helmets
- Target 8 Vehicle occupant protection
- Target 9 Driving under the influence
- Target 10 Distraction by mobile phone
- Target 11 Professional drivers.

Literature on each of these elements in the context of legislation and enforcement is both broad and deep, so the focus is to draw out good/best practice, and where possible, focus on experience in low- and middle-income countries (LMICs).

In PIARC (2023a) we mention the following priority areas for the Legislation and enforcement issue:

- LMICs to develop and implement legislation and enforcement strategies to tackle speed, helmet use, seat belt use, drink driving, mobile phone use and regulation of professional drivers;
- legislation must be both enforceable and enforced to have effect;
- strategies need to be communicated to and accepted by the community;
- LMICs need to be open to considering strategies that are tried and tested in other jurisdictions. This might include adoption of novel technologies such as alcohol interlocks and seat-belt warning systems.

4.8.2 Illustration: helmet act in Thailand (Ichikawa et al., 2003)

This study investigated the effect of the helmet act for motorcyclists on increasing helmet use and reducing motorcycle-related deaths and severe injuries in Thailand. Data were derived from a trauma registry

at the Khon Kaen Regional Hospital in the northeast Thailand. Helmet use and outcome in motorcycle crashes were compared 2 years before (1994–1995) and after (1996–1997) enforcement of the helmet act. During the study period, there were 12 002 injured motorcyclists including 129 death cases in the municipality of Khon Kaen Province who were brought to the regional hospital.

After enforcement of the helmet act, helmet-wearers increased five-fold while head injuries decreased by 41.4% and deaths by 20.8%. Those who had head or neck injuries or died were less likely wearing a helmet. Compliance of helmet use was lower at night. Fatality of injured motorcyclists did not significantly decrease in the post-act period and among helmet-wearers. It is concluded that enforcement of the helmet act increased helmet-wearers among motorcyclists but helmet use did not significantly reduce deaths among injured motorcyclists. Motorcyclists should be instructed to properly and consistently wear a helmet for their safety.

4.9 Speed

4.9.1 Motivation

Speeding is to be considered as one of the most important causation factors of road unsafety. GRSP (2023) gives an extensive background paper, describing how speed can be influenced through legislation, enforcement and roadway engineering measures. This Speed Management Manual also gives evidence based cases and illustrative examples from LMICs. Recently, Turner et al. (2024) presented a related report with a clear guide for safe speeds with all background aspects involved and practical approaches needed. Godthelp (2023) argues that new vehicle technologies like intelligent speed adaptation (ISA) do deserve more attention when considering practical measures to safely regulate vehicle speeds.

In PIARC (2023a) we mention the following priority areas for the Speed issue:

- adopt the 20 mph / 30 kmh speed limit regime in areas with a mix of motorized and VRU traffic;
- explore new enforcement strategies like section control;
- explore the potential benefits of speed control systems like ISA in cars, motorcycles and motor-tricycle.

4.9.2 Illustration: evaluation of speed management measures in Bangladesh (van der Horst et al., 2016; Vet et al., 2018)

With 21 000 people annually killed in road traffic (estimated figure by World Health Organization), Bangladesh has one of the highest fatality rates in the world. Vulnerable road users (VRUs) account for over 50% of road traffic casualties, and 70% of casualties occur in rural areas. As in many LMICs, the official road accident statistics are incomplete and biased.

Safe Crossings (Netherlands) and the Centre for Injury Prevention and Research Bangladesh (CIPRB) (Bangladesh) received permission from the Bangladesh government in 2014 to design and implement an integrated speed management program, (consisting of a combination of small-scale infrastructural measures, active community involvement and road user education) at three locations where a national highway intersects small communities. The infrastructural countermeasures to improve road safety consisted of speed humps, rumble strips, signs and road markings and were designed following the Dutch road design guidelines. In a before-after study design, we used a combination of three research methods to monitor and evaluate the road safety interventions. We created our own traffic accident recording system with trained local record keepers, we conducted laser-gun speed measurements of motorized traffic (both at intervention and control locations), and we applied the Dutch Objective Conflict Technique for Operation and Research (DOCTOR) for observing serious traffic conflicts at the intervention locations. The latter was based upon DOCTOR scores from video recordings of the behavior at the three experimental locations before and after the interventions.

Prior to installing the intervention program, the three locations combined had, on average, about 100 serious accidents, 10 deaths, and 200 injured people on a yearly basis. In April 2015, all infrastructural measures were completed. In the after period (till the end of October 2015), the alternative accident recording system showed a 59% reduction in the number of serious accidents, a 71% reduction in the number of injured people, and a 64% reduction in the number of people killed.

The unobtrusive laser-gun speed measurements resulted in a net reduction of 13.3 km/h (or 20% in

relative terms) on average at the intervention locations by taking the general speed development at the control locations into account. According to Nilsson's power law this would result in a 59% reduction of the number of people killed, well in line with the actual accident figures.

The paper referred to van der Horst et al. (2016), is based on an analysis at two out of the three intervention locations, for which traffic conflicts were scored in the before and after period. The total number of serious conflicts (only DOCTOR scores 3, 4, and 5) was significantly reduced from 65 serious conflicts per location in a 4.5 hour period before to 30 serious conflicts in the after period, on average (Poisson distributed variable, $p < 0.01$), or a 54% reduction in relative terms (52% reduction when taking the traffic volumes into account). Besides, no conflicts of the highest severity category occurred in the after period. Buses represent the largest portion of road users involved in serious conflicts at all three locations, followed by cars and CNGs (Compressed Natural Gas vehicle). By far, the most frequently occurring conflict is of the type head-on conflict between an overtaking bus or car that is encountering a road user in opposite direction (for the greater part a CNG).

All three evaluation measures point to a similar impact of the intervention program and unveil an improvement in road safety between 52 and 60%. Figure 8 shows the results from the speed management measures: 67% reduction in fatalities and 59% reduction in serious injuries. As there are thousands of traffic black spots with similar characteristics as the three intervention locations in Bangladesh, this integrated approach may well offer similar road safety improvements elsewhere.

4.10 Sustainable safe roads

4.10.1 Motivation

Road design is generally considered as one of the most effective ways to traffic influence behavior. Roads should be self-explaining and forgiving. They may be divided in categories related to their function: through roads for traffic flows, access roads with a mix of traffic and distributor roads connecting the both. Road designs are related to these functional characteristics. On through roads motorized traffic will be separated from vulnerable road users, whereas Access roads will have a harmonized low speed mix of both. Road design will 'explain' these functions to the users. Access roads will limit speed and regulate safe interactions between different users. Connection with distributor roads can be safely designed through roundabouts. A clear speed regime in urban and rural areas is a fundamental part of such an approach. Road safety Inspections and audits are to be used to verify the safety level of roads for roads in operation or at the design table. Mitra et al. (2021) give an extensive overview of how safety may be implemented in road design.

In PIARC (2023a) we mention the following priority areas for the sustainable safe roads issue:

- developing road design guidelines and regulation, based on principles of self explaining roads and on local safety culture, including a clear road categorization scheme;
- developing a robust audit and inspection protocol;
- making roads in cities and villages safe for vulnerable road users, based on 30 km protocol.

4.10.2 Illustration: assessment and treatment of high risk roads in Bangladesh (Hoque et al., 2014)

Road safety has emerged as one of the most challenging issues in Bangladesh like many other low- and middle income countries. Road infrastructure deficiencies are considered to be one ofthe most significant factors attributable to predominant crash types. Crashes are so clusteredthat about 40% of the reported fatal crashes are concentrated on 2% of total highway network.Death rates on Bangladesh highways are up to 10 times higher than that of Australian Highwaysand Britain's most persistently high risk roads. The safety problems especially for vulnerableroad users are greatly compounded by the lack of appropriate facilities. Concerningly themajority of the highway sections are rated as 2-star or less (out of possible 5-star) as revealedfrom the results of the iRAP risk assessment of around 1400 kilometres of highways. Significantsafety gains can be achieved by implementing affordable road infrastructure measures targetingpriority crash types on such high risk highway sections. Bangladesh is committed to achievingthe goal of reducing fatalities and serious injuries by 50% over the period 2011–2020 and eliminating high risk roads based on the Safe System approach. Recent site specificinfrastructure improvements through modification of alignments, curvatures, roadside hazardsremoval and delineation treatments have resulted in marked reduction in crashes

	LRK data				Power model	
	Before	After	Difference (absolute)	Difference (relative)	95% Confidence interval[1]	Best estimate[1]
Average speed[2] (km/hr.)	63,6	51.1	-/- 12,5	-/- 19,7%		
Number of fatalities	9	3	-/-6	-/- 67%	[-/- 58%...-/- 68%]	-/- 63%
Number of serious injuries	69	28	-/- 41	-/- 59%	[-/- 10%...-/- 70%]	-/- 54%

Figure 8 Results from the speed management measures: 67% reduction in fatalities and 59% reduction in serious injuries (van der Horst et al., 2016)

andcasualties, up to 70%. This paper has discussed the latest developments in investigating andassessing the high risk road network characteristics using iRAP (2022) methodology as well as through extensive field observations. The paper also discussed the details of the preliminary results of such road infrastructure design improvement schemes and the accrued safety benefits resulted from the reduced crash incidences.

4.10.3 Illustration: exclusive motorcycle lanes in Malaysia (Sohadi et al., 2000)

This paper presents a multivariate analysis on the impact of the exclusive motorcycle lane on motorcycle accidents along the Federal Highway Route 2, Malaysia. A number of statistical models have been developed to explain the relationship of motorcycle accidents and explanatory variables relevant to motorcycle safety. The best model showed that motorcycle accidents are directly proportional to the cubic power of traffic flow and reduced by approximately 39% with the motorcycle lane. A clear benefit of this lane is observed when the traffic flow exceeds 15 000 vehicles per day per lane for motorcycle proportion of between 20% and 30%. Besides supporting the notion for motorcycle segregation, this finding provides an initial guideline on the warrants for an exclusive motorcycle lane for highly motorcycled countries in Asia.

4.11 Safe vehicles

4.11.1 Motivation

During the history of the automobile major efforts have been made to improve the safety of its occupants and other traffic participants. Particularly after the 1970s programs of crash testing resulted in strong improvements. In 2009 the Insurance Institute for Highway Safety showed a crash test of a 2009 Chevrolet Malibu and compared that with a 1959 Chevrolet Bel Air sedan. It clearly demonstrated the effectiveness of modern car safety design over 1950s design, particularly regarding rigid passenger safety cells and crumple zones. Presently a rich set of passive and active safety systems exist. And not only for cars, but also for motorcycles, buses, etc. Passive safety systems intend to limit the damage caused to driver and passengers in the event of a crash. Airbags, seatbelts, helmets, whiplash protection system etc. are common passive safety systems deployed in vehicles these days. Active safety systems play a preventive role in mitigating crashes by providing advance warning or by providing the driver with additional assistance in steering/controlling the vehicle. Anti-lock braking systems and electronic stability control are examples that are frequently used in today's modern vehicles and or motor cycles.

Unfortunately in many LMICs vehicle safety is not effectively regulated through design standards or maintained through mandatory vehicle inspection schemes. Recent studies show that a well-chosen combination of passive safety measures and new techniques like electronic stability control may give a strong benefit in LMICs road safety. Bhalla & Gleason (2020) analyzed the potential life-saving effects of nine proven vehicle technologies for the Latin American (LAC) region.

In PIARC (2023a) we mention the following priority areas for the Safe vehicles issue:

- adapt and enforce regulations regarding vehicle safety of new and imported vehicles;
- HICs to regulated the quality of used vehicles exported to LMICs;
- automobile companies and tier suppliers to explore options to implement new technologies like ISA in new and used vehicles to give a boost to road safety in LMICs.

4.11.2 Illustration: effects of vehicle safety design in Latin America (Bhalla & Gleason, 2020)

The Sustainable Development Goals, which aim to halve global traffic deaths by 2020, will not be met by most low- and middle-income countries (LMICs). In Latin America and the Caribbean (LAC) region, traffic deaths have remained stable at a high-level despite strong progress in other health domains. We evaluated the effects of road safety interventions in LAC and estimated the benefits that vehicle design improvements would have in this region.

Bhalla & Gleason (2020) used a counterfactual analysis to assess the reduction in deaths and disability-adjusted life years (DALYs) lost if eight proven vehicle safety technologies were made more widely available in LAC countries. We estimated: (*1*) country-level incidence of traffic injuries, (*2*) the effectiveness of technologies through a systematic literature review, (*3*) the prevalence of car safety technologies, and (*4*) the lives saved and DALYs averted if all cars had these technologies. We characterised uncertainty in estimates by reporting the sensitivity of the results to alternative modelling assumptions.

Findings Increasing availability of electronic stability control, which includes antilock-brake systems, would have the largest benefits in the LAC region, estimated at 19.4% (sensitivity analysis range 8.6%–31.1%) fewer deaths and 17.0% (5.7%–29.2%) fewer DALYs. Increasing use of seatbelts would reduce deaths by 12.1% (9.1%–15.5%) and DALYs by 12.6% (9.4–16.3%). Optimisation for side-impacts would result in 6.3% (3.1%–6.5%) fewer deaths, and improvements to vehicle front-end design would result in 6.0% (2.2%–10.4%) fewer deaths. The overall effect of improved vehicle design in the region would be 28.1% (12.8%–39.2%) fewer deaths, and 29.1% (13.5%–39.8%) fewer DALYs. Other safety technologies modelled, including airbag (front and side), side door beam, and side structure and padding, have smaller benefits.

The authors conclude that regulating and encouraging the use of proven vehicle safety technologies in LMICs would have large gains and needs to be prioritised in the SDG agenda for 2030.

4.12 Post crash health care

4.12.1 Motivation

WHO (2016) gives an overall impression about the need for improving post crash health care in developing countries. It is argued that the proportion of patients who die before reaching hospital in low- and middle-income countries is over twice that in high-income countries, suggesting that strengthening prehospital systems could have enormous global impact. Optimal prehospital care is provided by a responsive system that can rapidly dispatch equipped ambulances with trained providers – and extrication services where needed – but where this is not available, there are many ways to improve basic care at the scene of a crash. In countries where there are areas with limitedor delayed access to care, protocols for mobile phone notification of community-based layresponders have been shown effective as a bridge to formal prehospital care. In the manycountries without any ambulances or certified prehospital providers, organized systems fortraining and dispatching trained lay providers have been shown to improve care.

In PIARC (2023a) we mention the following priority areas for the post crash health care issue:

- LMICs to improve pre-hospital trauma care;
- LMICs to improve quality of trauma centers;
- LMICs to improve the training of first responders.

4.12.2 Illustration: dispatching rapid emergency care for crash victims in Viet Nam (WHO, 2007)

A project in Hanoi dispatched emergency care providers by motorcycle to road traffic crashes. The average response time was 5.18±4.5 minutes, compared to an average ambulance response time of 11.16±6.2 minutes (WHO, 2007).

5 Discussion and conclusions

During the first UN Decade of Action for Road Safety 2011–2020 (WHO, 2010), many initiatives were taken to develop road safety management structures in LMICs. As a result several countries installed lead agencies and developed national road safety strategies. Also a mass of road safety knowledge has been transferred to LMIC through books, guides and numerous online and onsite courses. In many cases

the Safe System approach is propagated as the leading universal concept. Despite these large efforts the implementation level of effective road safety measures stays relatively low. And as a result the reduction in number of fatalities in LMICs stays behind predictions.

The present paper gives an overview of the analysis prepared by PIARC Working Group 3.1.1 'Specific road safety issues for LMICs'. The Safe System concept is described in terms of 12 issues that—taken together—do give an impression of the multi level approach needed to improve road safety on a systemic level. Based on an analysis for each of the 12 issues a series of priority areas is presented, indicating which aspects do deserve special attention in the LMIC context.

At the strategic level LMICs might integrate road safety strategies as a fundamental component of their sustainable development policy. Transferring Safe System characteristics towards LMICs should be primarily be based on knowledge about local cultural and behavioural characteristics. For this purpose organizations that represent the local community and serve as the eyes and ears regarding traffic problems and solutions, might play an important role. Also governmental lead agencies should have a strong links to provinces and communities. And of course they should be provided with full-time expert staff, legally endowed powers, permanent funding, and political support. May be most fundamental is the development of a robust local knowledge infrastructure, i.e. research facilities and university programs, see also Godthelp et al. (2024).

Such an infrastructure is needed to serve as a national road safety knowledge memory.

At the tactical level LMICs are suggested to develop and implement legislation and enforcement strategies to tackle speed, helmet use, seat belt use, drink driving, mobile phone use and regulation of professional drivers. Most of these are relatively cheap measures that may be part of a policy to focus on low-cost proven countermeasures as a primary approach. A more long term approach at the tactical level is to adopt city design policies that promote walking and cycling and the use of newly introduced public transport systems. The illustrative examples of Bogota and Fortaleza show that impressive results are possible, also on a relatively short notice.

At the operational level speed regulation, sustainable safe road and vehicle designs play a central role. Speed is generally considered as the number one causation factor of serious crashes. The adoption of the 30kmh limit in areas with a mix of motorized traffic and vulnerable road users is a fundamental part of a road safety policy. Sustainable safe road design more or less automatically regulate a safe interaction between traffic participants. On a medium term new vehicle technologies may give a boost to road safety in LMICs.

For each of the 12 issues described here, the present paper also gives examples of evidence based road safety measures. As such these examples serve as an illustration of the potential of the specific road safety issues for LMICs as presented. However our search for evidence based LMIC cases also confirmed the findings from recent overview articles indicating the lack of LMIC related road safety research. As stated in Haghani et al. (2022), it seems essential that research on road safety within LMICs intensifies beyond the existing rate to produce the much-needed local knowledge and to develop initiatives that meet their safety needs and upgrade their practices. Tavakkoli et al. (2022) studied the effectiveness of interventions in low- and middle-income countries looking for evidence based measures during the period of the first Decade of Action. Their conclusion is similar to that in Haghani et al. (2022): many interventions remain understudied and more holistic approaches capturing the complexity of road transport systems seem desirable.

A more widespread implementation of effective road safety measures in LMICs requires a strong national commitment and leadership from the road safety agencies point of view in the first place. Moreover an evidence based policy that can be effectively implemented asks for a strong national and regional knowledge infrastructure. This would make it possible to base effective road safety policy on knowledge about evidence based measures in the local context.

CRediT contribution statement

Hans Godthelp: Conceptualization, Methodology, Visualization, Writing—original draft, Writing—review & editing. **Ahmed Ksentini:** Writing—review & editing.

Declaration of competing interests

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For the illustrative examples presented in section 4, citations were used from the original articles.

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A Recent overview studies about road safety in LMICs and their resulting focus areas

ITF (2016):

1. Think safe roads, not safer roads.
2. Provide strong, sustained leadership for the paradigm shift to a Safe System.
3. Foster a sense of urgency to drive change.
4. Underpin aspirational goals with concrete operational targets.
5. Establish shared responsibility for road safety.
6. Apply a result-focused way of working among road safety stakeholders.
7. Leverage all parts of a Safe System for greater overall effect and so that if one part fails the other parts will still prevent serious harm.

Welle et al. (2018):

1. Land Use Planning
2. Street Design and Engineering
3. Improved Mobility Options
4. Speed Management
5. Enforcement of Laws and Regulations
6. Education and Capacity Building
7. Vehicle Design and Technology
8. Post-crash Emergency Response and Care
9. Prioritizing Finances
10. Strengthening Institutions and Frameworks
11. Strengthening laws, regulations, and guidelines.

WHO (2018) and WHO (2023):

1. Institutional management
2. Legislation and road user behavior
3. Managing speed
4. Reducing drink-driving
5. Increasing motorcycle helmet use
6. Increasing seat-belt use
7. Increasing child restraint use
8. Reducing distracted driving
9. Reducing drug-driving
10. Safe roads iRAP
11. Safe vehicles.

Heydari et al. (2019):

1. under-reporting
2. global best practices
3. vulnerable groups
4. disabilities

5. road crash costing
6. vehicle safety
7. proactive approaches
8. data challenges
9. social/behavioural aspects
10. capacity building.

World Bank (2020), pillar approach:

1. Road safety management activity (presence of a lead agency, and development of road safety targets and strategy)
2. Safe roads and roadsides (road audit and star rating scores and investment potential to improve roads in a cost-effective manner)
3. Safe speeds (application of speed limits and their enforcement, as well as infrastructure to support compliance with these speeds)
4. Safe vehicles (vehicle registration, standards, and regulations)
5. Safe road users (laws relating to seat belt use, helmet wearing, and drink driving)
6. Post-crash care (access to care and health coverage).

Academic Expert Group (2019), 9 recommendations:

1. Sustainable practices and reporting
2. Procurement
3. Modal shift
4. Child and youth health
5. Infrastructure
6. Safe vehicles across the globe
7. Zero speeding
8. 30 km/h
9. Technology

Van den Berghe et al. (2020), 12 targets:

1. National action plan
2. Global alignment
3. New roads
4. Existing roads
5. Vehicle standards
6. Speeding
7. Motorcycle helmets
8. Vehicle occupant protection
9. Driving under the influence
10. Distraction by mobile phone
11. Professional drivers
12. Timely emergency care