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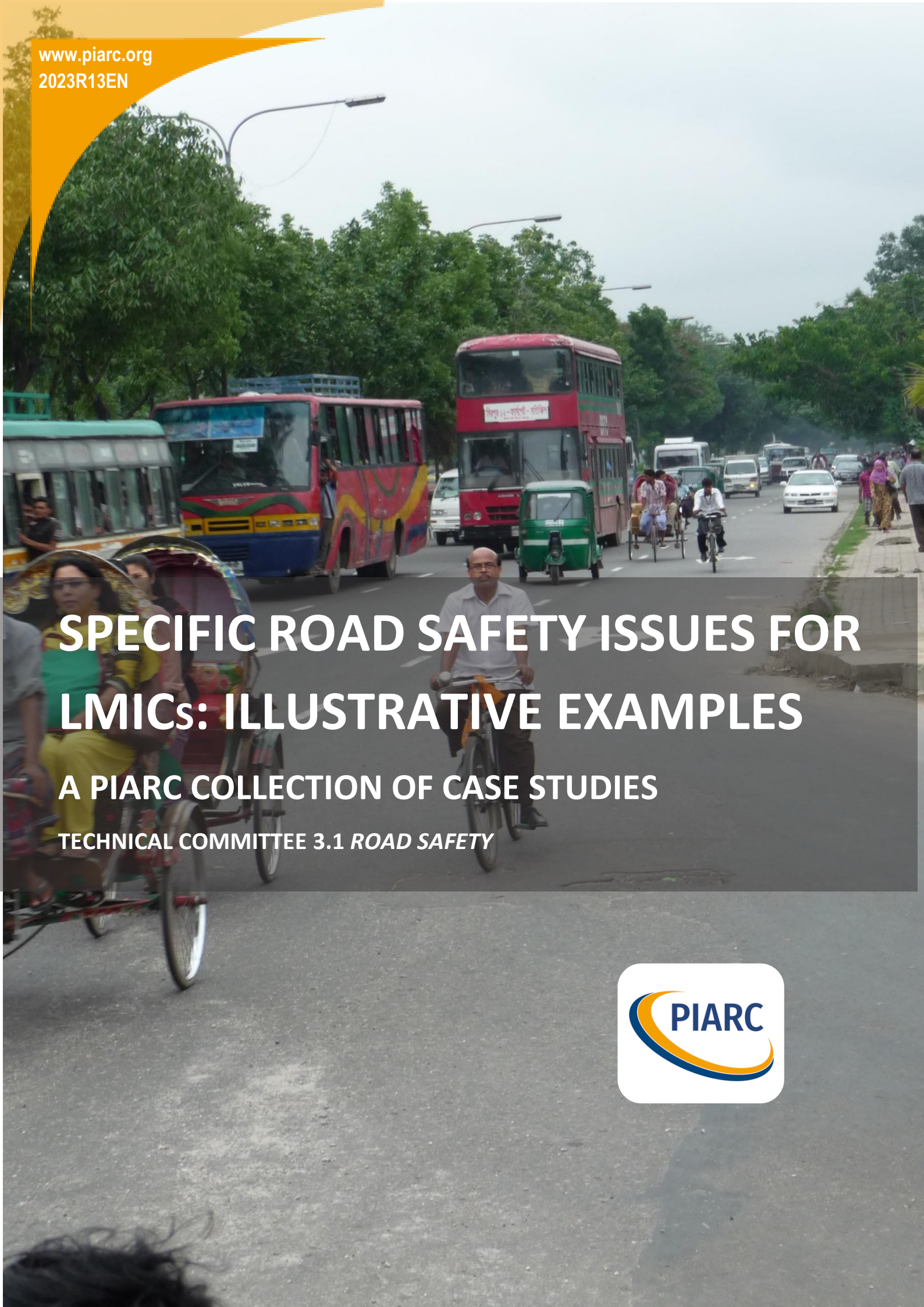

SPECIFIC ROAD SAFETY ISSUES FOR LMICs: ILLUSTRATIVE EXAMPLES

A PIARC COLLECTION OF CASE STUDIES

TECHNICAL COMMITTEE 3.1 *ROAD SAFETY*

STATEMENTS

The World Road Association (PIARC) is a nonprofit organisation established in 1909 to improve international co-operation and to foster progress in the field of roads and road transport.

The study that is the subject of this report was defined in the PIARC Strategic Plan 2020– 2023 and approved by the Council of the World Road Association, whose members are representatives of the member national governments. The members of the Technical Committee responsible for this report were appointed by the member national governments for their special competences.

Any opinions, findings, conclusions and recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of their parent organisations or agencies.

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The overview of illustrative examples of road safety measures in LMICs as described in this report has been prepared by the Working Group 3.1.1. Specific road safety issues for LMICs, which is part of the TC 3.1. Road safety. (2019 – 2023). The working group performed its activities at about the starting moment of the second United Nations Decade of Action for Road Safety 2021 - 2030.

The present overview is a follow up of an earlier WG activity, i.e. a literature review [2], in which we indicated which specific issues do need further attention in LMICs in the coming period up to 2030.

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EXECUTIVE SUMMARY

2023R13EN

SPECIFIC ROAD SAFETY ISSUES FOR LMICS: ILLUSTRATIVE EXAMPLES

A PIARC COLLECTION OF CASE STUDIES

The overview of illustrative examples of road safety measures in LMICs as described in this report is a follow up of an earlier WG activity, i.e. a literature review [2], in which we indicated which specific issues do need further attention in LMICs in the coming period up to 2030. The following issues were considered:

I. SDG's: integral approach
II. Road safety culture
III. Road safety management and leadership
IV. Building road safety expertise and science
V. The transportation system as a whole
VI. City design, architecture, land use and rural planning
VII. Selecting cost effective measures
VIII. Legislation and enforcement
IX. Speed
X. Sustainable safe roads
XI. Safe vehicles
XII. Post crash health care

The present report gives examples of evidence based road safety measures for each of the twelve issues, as listed below. As such they serve as an illustration of the specific road safety issues for LMICs as presented in [2]. Our search for evidence based LMIC cases confirmed the findings from recent overview articles indicating the lack of LMIC related road safety research.

I. SDG's: integral approach
   - Bicycle safety in Bogota

II. Road safety culture
   - How driver compensation affects bus system performance
   - How do contract types and incentives influence driver behavior?−An analysis of the Kigali bus network

III. Road safety management and leadership
   - Road safety institutions in Argentina

IV. Building road safety expertise and science
   - Road safety research in the context of low- and middle-income countries: Macro-scale literature analyses, trends, knowledge gaps and challenges

V. The transportation system as a whole
   - Understanding Road Safety Impact of High-Performance Bus Rapid Transit and Busway Design Features

VI. City design, architecture, land use and rural planning
- Reshaping safe and sustainable mobility in Fortaleza: achievements from the first Decade of Action for road safety

VII. Selecting cost effective measures
- Cost effective traffic enforcement in Uganda

VIII. Legislation and enforcement
- The case of an helmet act in Thailand
- Trends in motorcycle helmet use in Vietnam: results from a four-year study
- The case of Guangzhou, China

IX. Speed
- The case of Santo André, Brazil
- An evaluation of speed management measures in Bangladesh based upon alternative accident recording, speed measurements, and DOCTOR traffic conflict observations

X. Sustainable safe roads
- Road Safety Audit after the commissioning of the RN12 (from KP5 to KP49.8), the south-eastern bypass of Kairouan (from KP0 to KP6.8) and the north-eastern bypass of Kairouan (from KP0 to KP4.2) and of the RND1-RN12 interchange
- Assessment and treatment of high risk roads in Bangladesh
- Multivariate Analysis of Motorcycle Accidents and the Effects of Exclusive Motorcycle Lanes in Malaysia

XI. Safe vehicles
- Effects of vehicle safety design on road traffic deaths, injuries, and public health burden in the Latin American region: a modelling study The case of vehicle safety design in Latin America
- Comparing ASEAN NCAP Ratings between Editions of the Same Models

XII. Post crash health care
- Dispatching rapid emergency care for crash victims in Viet Nam

As argued in [2] a robust road safety policy requires an integrated set of measures at the strategical, tactical and operational. The safe system principles have to be translated to the local and regional context, i.e. considering local safety culture and traffic and transport characteristics.

At the strategical level a more widespread implementation of effective road safety measures in LMICs therefore 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. The lack of such a structure in many LMICs seems one of the important reasons for the limited level of road safety improvements until now. Given that background – and despite existing capacity building programs - countries need strong(er) university programs and a national road safety research organization. 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. Knowledge about the effective local use of the tactical and operational issues described in [2] will then become part of the national knowledge base. 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.

CONTENTS

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, ninety percent of traffic deaths occur in these countries. In comparison to higher income countries, where the road deaths per 100,000 inhabitants is 9.2, middle income death rates are double at 18.4 and low-income rates are 24.1 [1] Almost half of these deaths are among the most vulnerable road users, including people who bike, 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 through careful countermeasure selection and adoption of design standards in urban and rural areas. The use of infrastructure road safety audits could be of significant benefit in reducing fatal and severe injury rates.

Given this perspective PIARC installed Working Group 3.1.1 Specific Road Safety issues for LMICs as described in the overall PIARC Workplan 2020 – 2023. The intent of this effort is to assess and identify best practice type road safety activities with a focus on those most applicable to low- and middle-income countries, and to gather specific successful examples of safety management activities with a particular interest on the vulnerable road users. In the period 2020 – 2023 the Working Group delivered three outputs: a literature review, the present overview of case studies [2] and a final summarizing report [3]. At a later stage results will be incorporated in the PIARC Road Safety Manual [4] and in the PIARC Catalogue of case studies [5].

Part I of this study [2] presents an overview of 12 issues that are particularly relevant for road safety improvements in LMICs. Some of these issues may be relevant for LMICs because of their universal and generic value. Other issues may of particular importance because of the societal and/or road traffic characteristics that are typical for LMIC environments. Some may be effective on a short notice, others on a long term.

Taken together the issues described in [2] are to be considered as an integrated set of measures defining a so-called safe system, with strategical, tactical and operational aspects.

- At the strategical level countries are suggested to develop a strong management and research organization, where road safety policy may be connected with broader national development goals and with a clear national safety culture in mind.
- At the tactical level measures may be implemented to reduce the amount of traffic and dangerous traffic interactions. City design and public transport policy should be focusing on facilitating the safe integration motorized transport and vulnerable road users. That is through designing traffic calm areas with 20 mph/30kmh max speeds rather than by attracting large amount of high speed vehicles to cities. Such measures are very cost effective, but do also require a clear and strong legislation and enforcement policy.
- Last but certainly not least the safe system approach requires a road and traffic environment that excludes collisions with a high level of kinetic energy. This implies speed to be reduced to low levels (20mph.30kmh) in areas with a mix of motorized traffic and vulnerable road users and separation of the both in areas with higher speeds. The safe connection of access, distributor and flow roads may be regulated through clever solutions like roundabouts. This requires road designs that regulate speed and traffic interactions along the lines of a so-called self explaining roads concept. New vehicle

technology may become a part of this philosophy. In the ultimate case of a serious crash pre-hospital care is to be considered as an important element to reduce its consequences

In this line of reasoning an analysis of the 12 issues in [2] resulted in a series of focus areas that are considered as most relevant for future developments in LMICs. Table I gives an overview of the issues and their related focus areas .

The present Part II of the study gives a number of LMIC related studies, along the lines of the 12 issues and illustrating their potential impact. Cases are defined as studies that illustrate the before-after effect of certain measures in terms of fatalities/injuries and/or performance indicators. For each of such proven countermeasures references are given substantiating the evidence base.

Table I: Road safety issues and related focus areas for LMICs as defined in [2]

I. Strategic Development Goals: integral approach

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

II. Road safety culture

- LMICs to develop a strategy with traffic rules and design guidelines that are based on knowledge about local behavioral characteristics
- LMICs to develop strong organizations that represent the local community and serve as the eyes and ears regarding traffic problems and solutions.
- LMICs transport companies to develop and/or uses effective incentive systems with the focus on safe driving.

III. Road safety management and leadership

- LMICs to develop a strong lead agency which has full-time expert staff, legally endowed powers, permanent funding, and political support
- LMICs to develop a robust road safety data system
- LMICs to develop a robust set of local guidelines and regulations
- LMICs to develop a center of road safety excellence (see 4.IV, Capacity building)

IV. Building road safety expertise and science

- LMICs to develop university road safety programs at bachelor and master level
- LMICs to build research capacity in centers of road safety excellence
- LMICs to connect to regional road safety observatories
- LMICs to connect to international network of universities and centers of excellence.
- PIARC to support this network process.

<u>Tactical</u>

V. The transportation system as a whole

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

VI. City design, architecture,land use and rural planning

- LMICs to adopt through a systems-oriented approach which puts road safety and public health policies in a broad context of improved transport and health

- LMICs to embrace the compact city approach of shorter distances, slower speeds, higher residential and population densities, and design that promotes walking, cycling, and public transit.
- LMICs to develop evidence-based transportation plans that undergo a participative process

VII. Selecting cost effective measures

- LMICs to develop a road safety strategy based on a selection scheme of cost-effective measures
- LMICs to select low hanging fruit: defining a list of low cost proven countermeasures.

VIII. Legislation and enforcement

- LMICs to adopt legislation and enforcement strategies on speed, helmet use, seat belt use, drink driving and mobile phone use
- LMIC to explore new technologies regarding enforcement strategies, i.e. speed limitations, driver alcohol detection, seat belt warning, etc

Operational

IX. Speed

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

X. Sustainable safe roads

- LMICs to develop road design guidelines and regulation, based on local safety culture, including a clear road categorization scheme.
- LMICs to develop a robust audit and inspection protocol.
- LMICs to make roads in cities and villages safe for pedestrians/bicyclists/vulnerable road users, i.e. based on 30km protocol.

XI. Safe vehicles

- LMICs to 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.

XII. Post crash health care

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

2. METHOD

An inventory of LMIC related road safety countermeasures studies was made through a variety of methods. Particularly the focus was on before - after studies illustrating the effects of particular countermeasures. PIARC sent out a survey to the PIARC community, whereas WG members were invited to search literature and to contact experts in the LMIC road safety research arena. Use was also made of recent overviews presented by Worldbank GRSF [6] and ITF [7] Ultimately we selected studies, describing effects of particular countermeasures in a publication or report, clearly substantiating the evidence base.

The existing PIARC Catalogue of case studies [5] presents a limited number of LMIC related cases. Our inventory indicated that also in recent literature evidence based cases for LIMCs are scarce. This fact stresses the importance of issue IV, i.e. the need to build road safety research programs that help countries to develop their rules and regulations and to develop an evidence based policy.

For each of the 12 issues described in the literature review [2] chapter 3 gives one or more illuastrative examples of measures which have proven effective in LMICs for that particular issue. Each of the 12 paragraphs in Chapter 3 starts with a short introductory about the issues. A more detailed analysis of the issues is given in [2].

3. ILLUSTRATIVE EXAMPLES PER ISSUE.

I. SUSTAINABLE DEVELOPMENT GOALS: INTEGRAL APPROACH

a. Introduction

Worldwide measures are taken to improve climate. Road safety can benefit from these measures, because climate and road safety measures may show a strong synergy. [8] gives 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. [9] gives an quantitative estimate of the expected link between road safety and decarbonization policy, see Fig. 1.

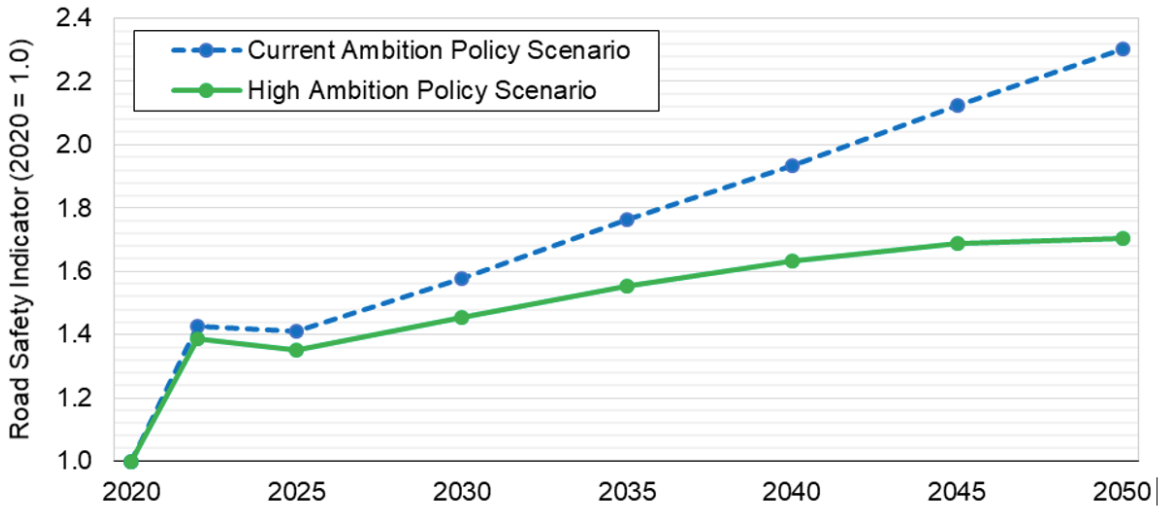

Figure 1 - Effect of decarbonization policy on traffic crash risk [9]

b. Illustrative example: Bicycle safety in Bogota [10]

The city of Bogota has developed a comprehensive policy framework to support safe bicycling. [10] gives a deep analysis of the road safety effects related to a series of programs and policies. These policies have a multi-sectoral perspective, including the mobility, sports and recreation, education, and health sectors. There are 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 bicycletrips 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 of Bogota (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 of Bogotá (Open Street program on Bogotá) in which every Sunday

and holidays, during 7 h, 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 Vision Zero to which Bogotá committed to in 2016. The bicycling policies implemented in Bogotá have the potential of increasing the number of bicyclists, but evidence regarding bicyclists safety is limited. In this context, in the current study, we examine spatiotemporal trends and potential contextual risk factors explaining bicyclists' collisions and fatalities in Bogotá (Colombia) for the 2011–2017 period. Specifically, the aims of the study are: (i) to analyze temporal trends in bicyclists mortality and non-fatal collision rates standardized by the bicyclists' population, and per- vehicle kilometers traveled (VKmT); (ii) to identify areas of high bicyclists' mortality; and (iii) to determine the individual and contextual risk factors associated with bicyclists' mortality.

Results

The findings from [10] indicate that from 2011 to 2017, the fatal bicycling collision rates per bicyclists' population have remained constant for females while decreasing 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, we find that fatal collisions are positively associated with factors including collisions with large vehicles, the absence of dedicated infrastructure, steep terrain, and nighttime occurrence. Our 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.

II. ROAD SAFETY CULTURE

a. Introduction

[11] gives a nice description of the concept of 'pragmatic driving' as a way to operationalize the behavioral effects of local traffic safety culture. A common theme in many accounts of road safety and road use in low and middle income countries is a widespread lack of compliance with traffic laws and related legislation. A key element of the success of road crash prevention strategies in high income countries has been the achievement of safer road user behaviour through compliance with traffic laws. Deterrence-based approaches such as speed cameras and random breath testing, which rely on drivers making an assessment that they are likely to be caught if they offend, have been very effective in this regard. However, the long term success of (for example) drink driving legislation has been supported by drivers adopting a moral approach to compliance rather than relying solely on the intensity of police operations. For low and middle income countries such morally based compliance is important, since levels of police resourcing are typically much lower than in Western countries. In the absence of morally based compliance, it is arguable that the patterns of behaviours observed in low and middle income countries can be described as "pragmatic driving": compliance only when there is a high chance of being detected and fined, or where a crash might occur. In [11] the potential characteristics of pragmatic driving in the macro, meso- and micro-context of driving and the enforcement approach that could address it are outlined, with reference to the limited existing information available.

[2] argues that safety culture may be effected on the level of the authorities, the communities and the private sector. Public transport business models may serve as an illustrative example. Serious crashes with buses in Bangladesh and Senegal in the 2020ties show the need to take measures.

Figure 2 - A serious crash near Sakal , northern Senegal, on Jan 16, 2023, where 19 people were killed when a bus and a truck collided.

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,” he said. Switching to a salary system would incentivize drivers to drive safely instead of cramming their buses full and speeding to their destinations, Kost said.

[12], [13] and [14] give an analysis of the effects of salary structure on behaviour of bus drivers.

b. Illustrative example: How driver compensation affects bus system performance [12]

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. Perpassenger 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. Fig. 3 shows how bus driver compensation schemes are effecting the number of crashes.

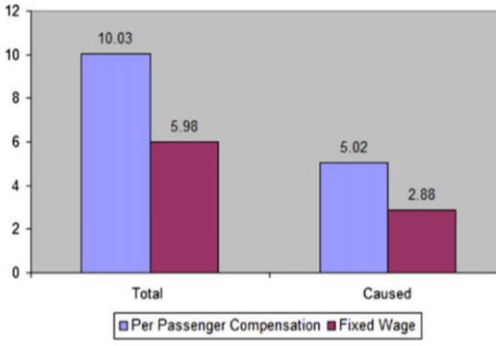

Figure 3.- Effect of bus driver compensation scheme on number of crashes per millions km traveled [12]

c. Illustrative example : How do contract types and incentives influence driver behavior?–An analysis of the Kigali bus network [14]

The rapidly growing city of Kigali has a bus network that is undergoing increased development as underlined in its Transport Master Plan. Two schemes of bus driver remuneration coexist in the city: One constitutes a hybrid salary and commission system, while the other pays a fixed monthly salary. This paper examines the effect of these differing compensation schemes on driver behavior in Kigali using survey data from 2019. The analysis applies linear models incorporating various aspects of driver behavior in a principal-agent framework. The results indicate that the performance-based compensation scheme is associated with higher per-trip passenger fluctuation and faster driving (possibly due to drivers aiming to accrue a higher income) compared to the fixed-wage system. Policy implications comprise the inclusion of further criteria in incentive contracts to internalize potential negative externalities on society, e.g., to hinder the endangerment of passenger safety by appropriately incentivizing drivers. In conclusion, bus drivers who are compensated by performance are more likely to alter their behavior, responding to the incentive scheme through several channels.

III. ROAD SAFETY MANAGEMENT AND LEADERSHIP

a. Introduction

An efficient management system and leadership body are key requirements for the implementation of an effective road safety improvement program. In many LMICs 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. In most cases there is a lack of leadership, a lack of political priority, a lack of funding, a lack of expertise, etc.

According to the World Bank (15) , the success and effectiveness of road safety lead agencies (RSLAs) in coordinating preventative road safety interventions in developing countries is dependent on the following key elements:

- Lead agencies with full-time expert staff, legally endowed powers, permanent funding, political support, and access to relevant data;
- Road safety strategies with clear intermediate and final targets and outcomes;
- Funding dedicated to road safety;
- Road crash and other complementary data
- Understanding of the causes and circumstances at road crashes location.

[19] and [20] give an illustrative example: the case of developing a road safety management structure in Argentina.

b. Ilustrative example: Road safety institutions in Argentina [19][20]

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? We explore these questions 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

IV. Building road safety expertise and science

a. Introduction

As describes in [2] 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: GRSF, WHO, UN, GRSP, NCAP, iRAP, Bloomberg, ITF, IRF/PIARC, and many others. As a result more and more countries started implementing lead agencies, developing road safety strategies and taking their responsibility for road safety legislation and road safety data systems. Also, the knowledge on road safety auditing and inspection has developed. Initiatives taken by the World Bank and Multi Lateral Development Banks like AfDB/ SSATP to build Road Safety Observatories [21]**Erreur ! Source du renvoi introuvable.** for different continents and Centers of Excellence by Unitar **Erreur ! Source du renvoi introuvable.** to build Networks of universities, strongly support this work.

However, despite this large international effort, countries do differ strongly in their level of *national* knowledge development and academic programs. 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 in these countries seems to 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.*

Erreur ! Source du renvoi introuvable. gives an extensive overview and analysis of LMIC related road safety research, which clearly illustrates the lack of research capacity in LMICs.

For the coming decade, it's of utmost importance to develop such local programs, i.e.

- university programs for bachelor and master education and
- national road safety research institutes

b. Illustrative example : Road safety research in the context of low- and middle-income countries: Macro-scale literature analyses, trends, knowledge gaps and challenges Erreur ! Source du renvoi introuvable.

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 analysed 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. 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.

V. THE TRANSPORTATION SYSTEM AS A WHOLE

a. Introduction

More and more LMICs take the position to develop a road safety strategy which is connected with their strategic development goals. 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 [22].

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 and Currie (2019) [23], 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. Based on the Bogota study of the Bus Rapid Transport system, Bocarejo et al (2012) [24] and Duduta et al [25] illustrate the need to give special attention to the improvement of pedestrian facilities and traffic calming measures.

b. Illustrative example: Understanding Road Safety Impact of High-Performance Bus Rapid Transit and Busway Design Features [25][26]

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, Colombia; Curitiba, Brazil; Mexico City, Mexico; and Delhi, 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.

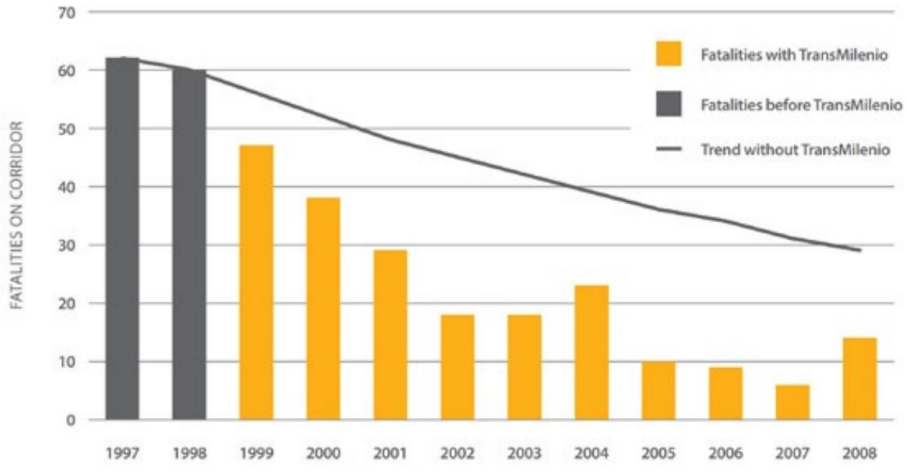

Fig. 4. TransMIlineo's traffic safety impact on Avida Caracas, Bogota, before and after the implementaion of the BRT system [26]

VI. City design, architecture, land use and rural planning

a. Introduction

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. [27][28] give nice illustrations, examples and instructions for new designs. Initiatives like Global Designing Cities Initiative, and Design for Life are stimulating these developments.

b. Illustrative example: Reshaping safe and sustainable mobility in Fortaleza: achievements from the first Decade of Action for road safety [29]

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.

Fortaleza Mayor Roberto Claudio recently announced that the city of 2.5 million saw a 40 percent reduction in road crash deaths in just four years, from 2014 to 2018. Mayor Claudio called the success a result of the "power of will." That will 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.

Vital Strategies and other partners in the Bloomberg Philanthropies Initiative for Global Road Safety are using 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."

Fortaleza Mayor Roberto Claudio announced that the city saw a 40 percent reduction in road crash deaths in four years (2014-2018).

In the last six years, 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 is now 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 2018, 226 road traffic deaths were recorded traffic and health authorities, compared to 377 deaths in 2014.

"Deaths and injuries caused by road crashes are not mere coincidences, and we see this problem as a public health epidemic," said Mayor Roberto Claudio. "We will continue to work tirelessly to reduce these [numbers] more and more. No death in traffic is acceptable."

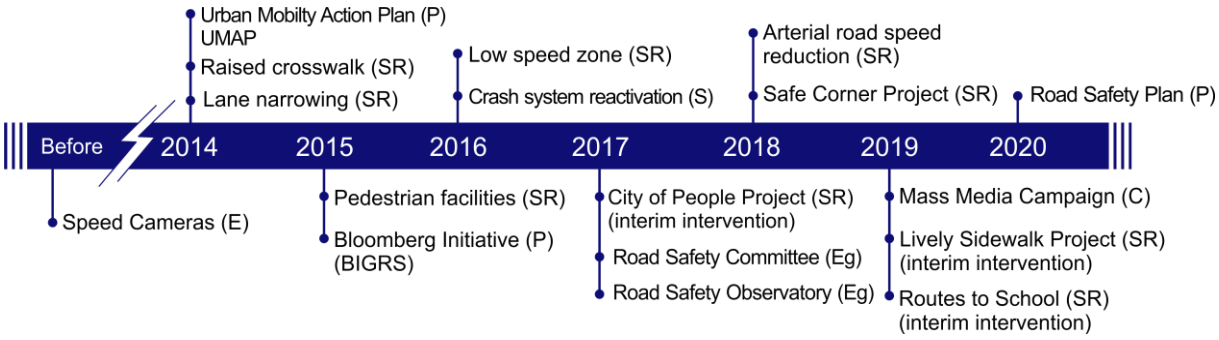

Fig. 5. Overview of measures in Fortaleza during the years 2014 - 2020

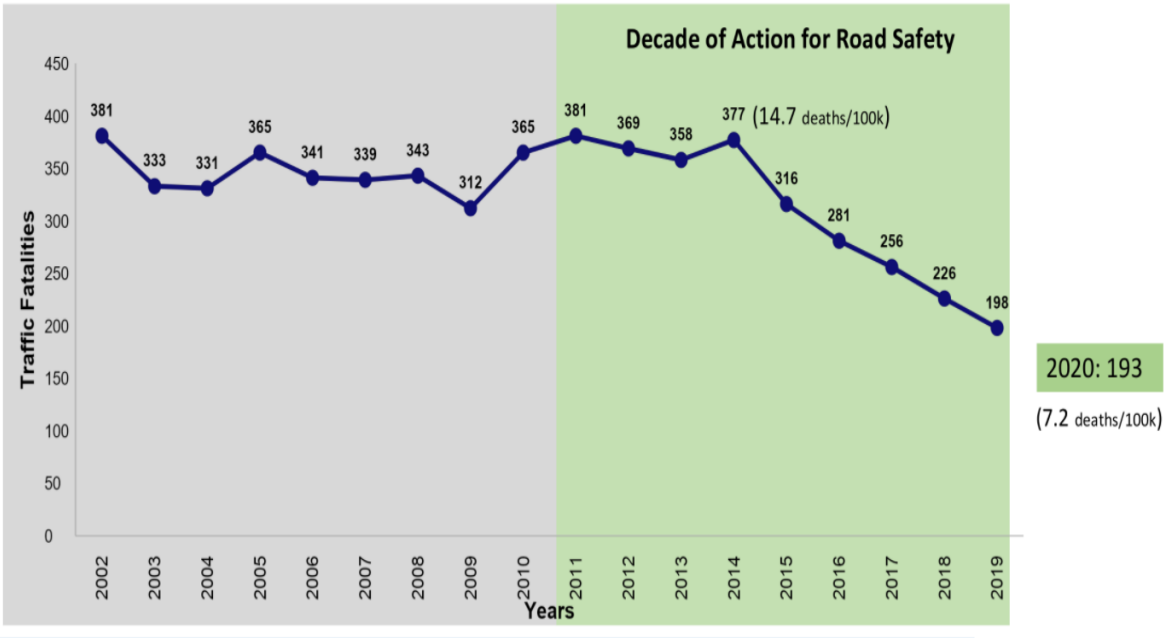

Figure 6 - Development of the number of fatalities in Fortaleza during the years 2002 - 2020

c. Illustrative example : The case of SARSAI in Tanzania [30]

Purpose To determine the impact of a paediatric road traffic injury (RTI) prevention programme in urban SubSaharan Africa.

Setting Dar es Salaam, Republic of Tanzania.

Methods Household surveys were conducted in catchment areas around 18 primary schools in Dar es Salaam, Republic of Tanzania; 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 were. Based on these findings, a separate road safety engineering site analysis and consultation with the communities and other stakeholders, an injury-prevention programme was developed and implemented, consisting of infrastructure enhancements and a site-specific educational programme. The programme 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.

Results Data were collected on 12 957 school-aged children in the baseline period and 13 555 schoolaged 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.

Conclusion The programme demonstrated a significant reduction in paediatric RTI after its implementation, in very specific ways. This study demonstrates that for a reasonable investment, scientifically driven injuryprevention programmes are feasible in resource-limited settings with high paediatric RTI rates.

VII. SELECTING COST-EFFECTIVE MEASURES

a. Introduction

[2][31] 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. Van der Schuren et al [32] 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.

b. Illustrative example : Cost effective traffic enforcement in Uganda [33]

Background: In October 2004, the Ugandan Police department deployed enhanced traffic safety patrols on the four major roads to the capital Kampala.

Objective: To assess the costs and potential effectiveness of increasing traffic enforcement in Uganda.

Methods: 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 $US 2005. Cost offsets from savings to the health sector were not included.

Results: The annual cost of deploying the four squads of traffic patrols (20 officers, four vehicles, equipment, administration) is estimated at $72,000. Since deployment, the number of citations has increased substantially with a value of $327 311 annually. Monthly crash data pre- and post-intervention show 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).

Conclusion: 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.

VIII. LEGISLATION AND ENFORCEMENT

a. Introduction

In the context of legislation, at a strategic level, Target #2 [1] 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).

b. Illustrative example: The case of an helmet act in Thailand [34]

Objectives: 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.

Methods: 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.

Results: 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.

Conclusion: 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.

c. Illustrative example: Trends in motorcycle helmet use in Vietnam: results from a four-year study [35]

Objectives: Helmet use is a major risk factor for road traffic injuries and fatalities. This study sought to determine the state of helmet use in Ha Nam and Ninh Binh provinces in Vietnam, and ascertain knowledge, attitudes, and practices of helmet use over time. Study design: Observational helmet use studies, and roadside knowledge, attitudes, and practice surveys. Methods: Data were collected through observational helmet use studies at multiple sites in Ha Nam and Ninh Binh provinces over 14 rounds between June 2011 and December 2014. Six rounds of knowledge, attitude, and practice surveys were administered at gas stations between December 2011 and July 2014. Trend analysis and negative binomial regressions were used to analyze trend data.

Results: Between June 2011 and December 2014, 301,981 helmet-use observations were conducted in Ha Nam and Ninh Binh. Correct helmet use increased significantly ($P < 0.01$) in Ha Nam from 34.3% to 76.9% ($P < 0.01$), while use in Ninh Binh increased from 68.9% to 72.2% ($P > 0.05$).

Conclusion: Helmet use has improved statistically significantly in Ha Nam but not in Ninh Binh. Ceiling effects may have limited the scope of improvements in Ninh Binh province

Note: During the years legislation and enforcement have become more and more effective

There needs to be a continued focus on ensuring that consumers know not only the importance of helmets but also the importance of quality helmets that will be sufficiently protective in the event of a crash. Steps can be taken to: (1) increase consumer awareness of the harms of a substandard helmet; (2) educate consumers on how to recognize and purchase a quality helmet; (3) make quality helmets more widely available; and (4) continue regular and visible enforcement activities.

d. Illustrative example: The case of Guangzhou, China [36]

Stevenson et al (2008) report on a multifaceted intervention implemented in Guangzhou, China, to increase the prevalence of seat belt use. The intervention was modelled on the recommendations from a systematic review and comprised four components being (i) enhanced police training, (ii) enhanced enforcement, (iii) social marketing, and (iv) health education (with the latter two focused on raising public awareness). In terms of enforcement, police were given training in topics such as safe vehicle interception, safe checkpoint and road block operations, and targets were set for the issuance of infringement notices to unrestrained vehicle occupants. Results were considered positively with increased prevalence of seat belt use observed after the intervention.

IX. SPEED

a. Introduction

Speeding is to be considered as one of the most important causation factors of road unsafety. [36] gives an extensive background paper, describing how speed can be influenced through legislation, enforcement and roadway engineering measures. This Speed management Manual also give illustrative examples from LMICs. More recently arguments are presented to also consider the use of vehicle based solutions like intelligent speed adaptation.

b. Illustrative example: The case of Santo André, Brazil [37]

In Santo André, Brazil, the town council implemented a general road safety programme that included electronic enforcement using radar systems. Information on factors such as traffic flow, crash rates and road function were used to identify suitable camera locations. Installation of equipment was preceded by media publicity and the use of roadside banners to make the public aware of the safety benefits of speed management. Counter-campaigns were initiated by some driver and political groups in opposition to the programme. Despite such problems the campaign continued and expanded. The first year resulted in a reduction of 8.6% in crash fatalities (compared to the previous year) while the second and third years produced further reductions of 17.6 and 25.7% respectively. A similar programme conducted in Sumaré also resulted in significant crash and injury reductions.

c. Illustrativ example : An evaluation of speed management measures in Bangladesh based upon alternative accident recording, speed measurements, and DOCTOR traffic conflict observations [38][39]

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 Low and Middle Income Countries (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.

At the moment of writing this paper, at two out of the three intervention locations traffic conflicts were scored in the before and after period. The traffic conflict results of the third location in the after period will follow shortly. So far, 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%. 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.

	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 7 - Results from the Speed management measures in Bangladesh: 67% reduction in fatalities and 59% reduction in serious injuries [38]

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X. SUSTAINABLE SAFE ROADS

a. Introduction

Road design is generally considered as one of the most effective ways to traffic influence behaviour.

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. Star rating [40] 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. [41] gives an extensive overview of how safety may be implemented in road design.

b. Illustrative example : Road Safety Audit after the commissioning of the RN12 (from KP5 to KP49.8), the south-eastern bypass of Kairouan (from KP0 to KP6.8) and the north-eastern bypass of Kairouan (from KP0 to KP4.2) and of the RND1-RN12 interchange [42]

During the last five years, the Tunisian government, and with funding from the World Bank, has undertaken the detailed study, works and maintenance of the national highway road N12 between the major localities of Sousse and Kairouan. Over a 54km length, this road crosses different rural and urban areas and national roads and the Maghreb motorway. It was upgraded into 2x2 lanes with a physical median with concrete barriers (see Figure 8).

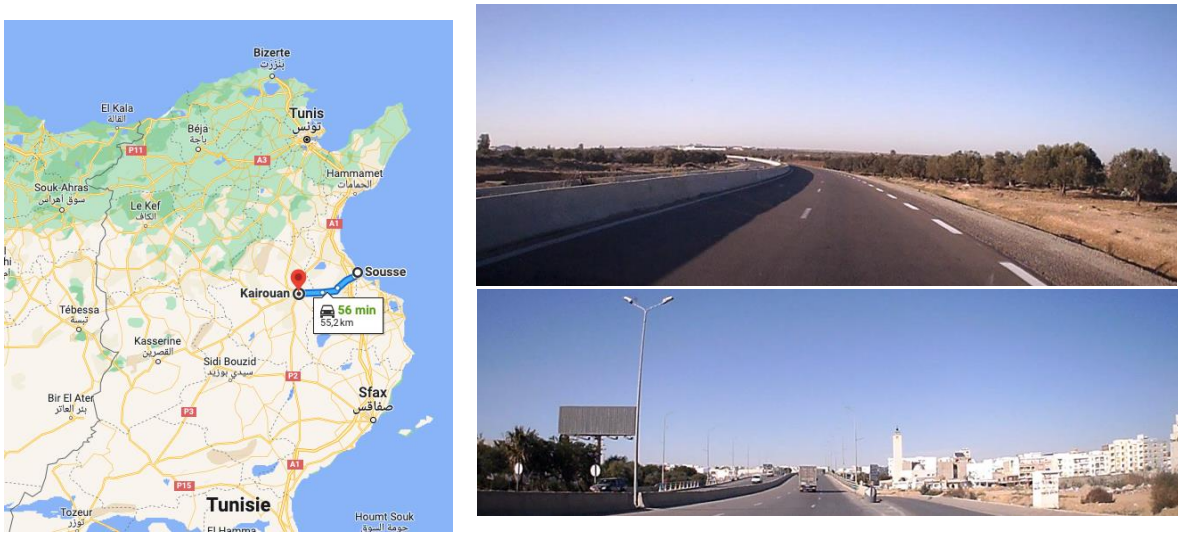

Figure 8 - Left: N12 road between Sousse and Kairouan, right: cross sections after works

From the preliminary studies, road safety audits were undertaken to ensure that the safety aspects of all users are taken into account in the design. This audit was carried out continuously in the preliminary and detailed design phases until the award of the contract to the companies in charge of the works. Checklists were used to ensure this control. Traceability of the decisions and discussions undertaken in the design phases was ensured for the supervision and control team, the design offices responsible for drawing up the detailed plans and the administration that manages the road network. This is to enable them to maintain the necessary requirements for road safety. These audits allowed checking the safety of engineering facilities by identifying risky configurations (horizontal curves succession, spiral curves length, intersection quality and signage, sidewalks, pedestrian crossing facilities , roadside hazards and clear zone, safety barrier design, etc.) and by proposing effective countermeasures based on scientific evidence (revision of certain junctions not compatible with the operating speeds, correction of the visibility conditions for certain sections, implementation of traffic calming layouts in urban areas such as narrowing the lanes, speed bumps, sound warning devices, the implementation of roundabouts at the entrance to major cities such in figure 9, the treatment of lateral hazards by safety barriers optimized for the road and for interchanges, etc.)

Figure 9 - Implementation of roundabouts at city entrances to moderate speeds and change the typical cross section from rural to urban areas

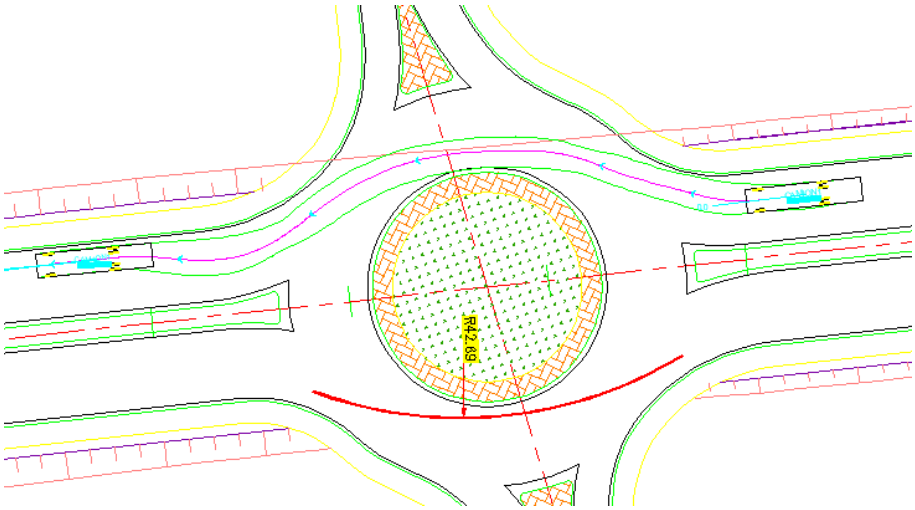

Figure 10 - Checking the heavy tracks vehicles movement and the deflection of the trajectory of vehicles to ensure a speed of less than 30km/h

After two years of service, a road safety audit was conducted to assess the level of safety of the asset. On the basis of crash data, crash reports, speed measurements and star ratings of the entire road, it was noted that a significant reduction in the number of accidents was possible through the countermeasures and the controls which were carried out during the design and work phases. Figure 11 shows a decrease in the risk expressed in terms of the number of fatal and serious crashes per year per km per million kilometres travelled from 2016 to 2021. Table 2 also shows the decrease in accident density between 2016 (works launch) and 2021 (after two years of service). The density is expressed as the number of serious and fatal crashes per year per km.

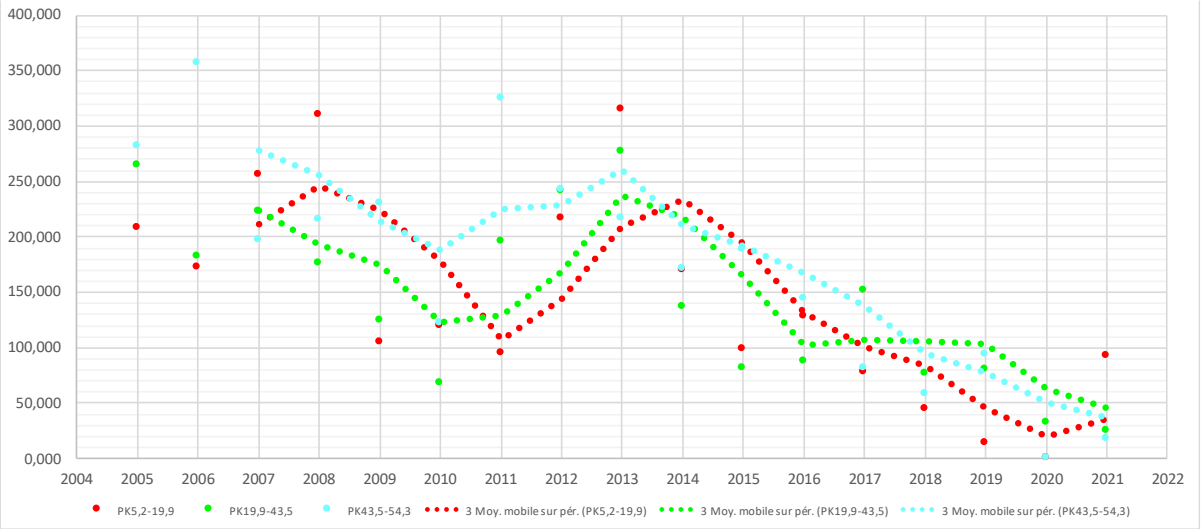

Figure 11 - Collective risk on the RN12 from 2007 to 2021 for different sections of the road

Table 2: density of crashes on the RN12 between 2005 and 2021 for different sections of the road

year	Station 5.2 km-19.9km	Station 19.9 km-43.5km	Station 43.5 km-54.3km
2005	0,544	1,059	0,833
2006	0,476	0,763	1,111
2007	0,748	0,975	0,648
2008	0,952	0,805	0,741
2009	0,340	0,593	0,833
2010	0,408	0,339	0,463
2011	0,340	1,017	1,296
2012	0,816	1,314	1,019
2013	1,224	1,525	0,926
2014	0,680	0,763	0,741
2015	0,408	0,466	0,833
2016	0,544	0,508	0,648
2017	0,340	0,890	0,370
2018	0,204	0,466	0,278

2019	0,068	0,508	0,463
2020	0,000	0,212	0,000
2021	0,476	0,169	0,093

Due to the pandemic, the reduction in the number of accidents may be due to periods of confinement in 2020 and 2021. For this reason, an additional evaluation according to the iRAP approach was conducted to assess the star rating score. More than 80% of the asset has been rated 3 stars or better. Speed control have been enforced to ensure the durability of these safety conditions.

c. Illustrative example: Assessment and treatment of high risk roads in Bangladesh [43][37]

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 of the most significant factors attributable to predominant crash types. Crashes are so clustered that 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 Highways and Britain's most persistently high risk roads. The safety problems especially for vulnerable road users are greatly compounded by the lack of appropriate facilities. Concerningly the majority of the highway sections are rated as 2-star or less (out of possible 5-star) as revealed from the results of the iRAP risk assessment of around 1400 kilometres of highways. Significant safety gains can be achieved by implementing affordable road infrastructure measures targeting priority crash types on such high risk highway sections. Bangladesh is committed to achieving the 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 specific infrastructure improvements through modification of alignments, curvatures, roadside hazards removal and delineation treatments have resulted in marked reduction in crashes and casualties, up to 70%. This paper has discussed the latest developments in investigating and assessing the high risk road network characteristics using iRAP 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.

d. Illustrative example : Multivariate Analysis of Motorcycle Accidents and the Effects of Exclusive Motorcycle Lanes in Malaysia [44]

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.

XI. SAFE VEHICLES

a. Introduction

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 1970ties 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 and Gleason [45] (2020) analyzed the potential life-saving effects of nine proven vehicle technologies for the Latin American (LAC) region.

b. Illustrative example : Effects of vehicle safety design on road traffic deaths, injuries, and public health burden in the Latin American region: a modelling study The case of vehicle safety design in Latin America [45]

Background: The Sustainable Development Goals (SDGs), which aim to halve global traffic deaths by 2020, will not be met by most low-income 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.

Methods: In our study done in October, 2018, we 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.

Interpretation: 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

c. Illustrative example : Comparing ASEAN NCAP Ratings between Editions of the Same Models [46]

Starting from 2011, ASEAN NCAP has been mandated to carry out crash tests on new cars in the ESCAP region, particularly Southeast Asia. With a total population of over 630 million, the 10 countries comprising ASEAN have seen passenger vehicle sales reach over three million units. To date, 90 percent of the vehicles sold in ASEAN market have been tested by ASEAN NCAP. Their safety aspects have been greatly improved over time. But aside from the safety of car occupants, ASEAN NCAP is also concerned with the safety of vulnerable road users. In November 2018, ASEAN NCAP announced its latest road map which focuses on the safety of motorcyclists in the region. ASEAN NCAP's efforts have also been recognized by the Malaysian government, as of next year, all car dealers are to showcase the star rating issued by ASEAN NCAP on the car's front windshield and side mirror in all showroom and sales centres in Malaysia. This is to educate buyers to choose the models that give priority to the best rating. The current paper shall provide an overview of the results produced by ASEAN NCAP, including its success and challenges to elevate the safety standards of passenger vehicles in the Southeast Asian market. In addition, the last section will describe ASEAN NCAP road map which guides its journey toward achieving SDG targets 3.6 and 11.2.

XII. POST CRASH HEALTH CARE

a. Introduction

[47] 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 limited or delayed access to care, protocols for mobile phone notification of community-based lay responders have been shown effective as a bridge to formal prehospital care. In the many countries without any ambulances or certified prehospital providers, organized systems for training and dispatching trained lay providers have been shown to improve care.

b. Illustrative example : Dispatching rapid emergency care for crash victims in Viet Nam [47][48]

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.

4. DISCUSSION AND CONCLUSIONS

During the first decade of action 2011 – 2020 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 a series of 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 report gives some examples of evidence based road safety measures. As such they serve as an illustration of the specific road safety issues for LMICs as presented in [2]. Our search for evidence based LMIC cases confirmed the findings from recent overview articles indicating the lack of LMIC related road safety research. As stated in **Erreur ! Source du renvoi introuvable.** ***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, [49]) studied the effectiveness of interventions in Low and Middle-Income Countries looking for evidence based measures during the period of the 1st Decade of Action. Their conclusion is similar to that in **Erreur ! Source du renvoi introuvable.**: *many interventions remain understudied and more holistic approaches capturing the complexity of road transport systems seem desirable.*

As argued in [2] a robust road safety policy requires an integrated set of measures at the strategical, tactical and operational. The safe system principles have to be translated to the local and regional context, i.e. considering local safety culture and traffic and transport characteristics.

At the strategical level a more widespread implementation of effective road safety measures in LMICs therefore 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. The lack of such a structure in many LMICs seems one of the important reasons for the limited level of road safety improvements until now. Given that background – and despite existing capacity building programs - countries need strong(er) university programs and a national road safety research organization. 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.* Knowledge about the effective local use of the tactical and operational issues described in [2] will then become part of the national knowledge base. 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.

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