UNECE

UN Vehicle Regulations for road safety Cost-benefit methodology

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United Nations Economic Commission for Europe

The United Nations Economic Commission for Europe (UNECE) is one of the five United Nations regional commissions, administered by the Economic and Social Council (ECOSOC). It was established in 1947 with the mandate to help rebuild post-war Europe, develop economic activity and strengthen economic relations among European countries, and between Europe and the rest of the world. During the Cold War era, UNECE served as a unique forum for economic dialogue and cooperation between East and West. Despite the complexity of this period, significant achievements were made, with consensus reached on numerous harmonization and standardization agreements.

In the post-Cold War era, UNECE acquired not only many new member States, but also new functions. Since the early 1990s the organization has focused on assisting the countries of Central and Eastern Europe, Caucasus and Central Asia with their transition process and their integration into the global economy.

Today, UNECE supports its 56 member States in Europe, Central Asia and North America in the implementation of the 2030 Agenda for Sustainable Development with its Sustainable Development Goals (SDGs). UNECE provides a multilateral platform for policy dialogue, the development of international legal instruments, norms and standards, the exchange of best practices and economic and technical expertise, as well as technical cooperation for countries with economies in transition.

Offering practical tools to improve people's everyday lives in the areas of environment, transport, trade, statistics, energy, forestry, housing, and land management, many of the norms, standards and conventions developed in UNECE are used worldwide, and a number of countries from outside the region participate in UNECE's work.

UNECE's multisectoral approach helps countries to tackle the interconnected challenges of sustainable development in an integrated manner, with a transboundary focus that helps devise solutions to shared challenges. With its unique convening power, UNECE fosters cooperation among all stakeholders at the country and regional levels.

Transport in the Economic Commission for Europe

The UNECE Sustainable Transport Division is the secretariat of the Inland Transport Committee (ITC) and the ECOSOC Committee of Experts on the Transport of Dangerous Goods and on the Globally Harmonized System of Classification and Labelling of Chemicals. The ITC and its 17 working parties, as well as the ECOSOC Committee and its sub-committees are intergovernmental decision-making bodies that work to improve the daily lives of people and businesses around the world, in measurable ways and with concrete actions, to enhance traffic safety, environmental performance, energy efficiency and the competitiveness of the transport sector.

ITC is a unique intergovernmental forum that was set up in 1947 to support the reconstruction of transport connections in post-war Europe. Over the years, it has specialized in facilitating the harmonized and sustainable development of inland modes of transport. The main results of this persevering and ongoing work are reflected, among other things, (i) in 58 United Nations conventions and many more technical regulations, which are updated on a regular basis and provide an international legal framework for the sustainable development of national and international road, rail, inland water and intermodal transport, including the transport of dangerous goods, as well as the construction and inspection of road motor vehicles; (ii) in the Trans-European North-south Motorway, Trans-European Railway and the Euro-Asia transport Links projects, that facilitate multi-country coordination of transport infrastructure investment programmes; (iii) in the TIR system, which is a global customs transit facilitation solution; (iv) in the tool called For Future Inland Transport Systems (ForFITS), which can assist national and local governments to monitor carbon dioxide (CO2) emissions coming from inland transport modes and to select and design climate change mitigation policies, based on their impact and adapted to local conditions; (v) in transport statistics – methods and data – that are internationally agreed on; (vi) in studies and reports that help transport policy development by addressing timely issues, based on cutting-edge research and analysis. ITC also devotes special attention to Intelligent Transport Services (ITS), sustainable urban mobility and city logistics, as well as to increasing the resilience of transport networks and services in response to climate change adaptation and security challenges.

The UNECE Sustainable Transport and Environment Divisions, together with the World Health Organization (WHO) – Europe, co-service the Transport Health and Environment Pan-European Programme (THE PEP). As of 2015, the UNECE Sustainable Transport Division is providing the secretariat services for the Secretary General's Special Envoy for Road Safety Mr. Jean Todt, and as of 2018 to the Road Safety Trust Fund.

The UNECE World Forum for Harmonization of Vehicle Regulations (WP.29), a working party of the ITC, is the worldwide regulatory forum in which relevant stakeholders from the world are participating. Three UN Vehicle Agreements, adopted in 1958, 1997 and 1998, provide a legal framework allowing Contracting Parties to establish internationally harmonized regulatory instruments concerning the certification of motor vehicles, their equipment and parts, and rules for technical inspections of vehicles in use. The regulatory framework developed by the World Forum allows the mass market introduction of innovative vehicle technologies, while continuously improving global vehicle safety, energy efficiency and environmental performance.

Preface

Well-developed, efficient, clean, safe and secure inland transport systems offer important access to markets, employment, education and basic services that are critical to poverty alleviation. Transportation, and road transport in particular, is simultaneously a major driving force behind a growing global demand for energy, it has a significant environmental footprint, and its impacts on public health are of major concern due to the worldwide death, injury rates and illness resulting from road traffic crashes and air pollution. Growing global demand for goods transport and personal mobility is driving a historically unprecedented increase in road motorization rates and traffic volumes worldwide, in urban and non-urban settings alike. The deployment of motorcycles, cars, buses and trucks on streets and roads is projected to increase in the coming decades, most significantly in developing countries with strong population growth rates, particularly in Africa and South-East Asia.

Annually, 1.35 million lives are lost in road traffic and a similar number of premature deaths can be attributed to air pollution from transport. Fossil fuels account for 96 per cent of energy consumption in road transport and the sector is responsible for 18 per cent of global GHG emissions. A business as usual trajectory will fail to mitigate these existing negative externalities of road vehicles and compound an even greater impact in the future due to the expected growth of demand for road transport worldwide. Making sure that the vehicles deployed on roads are safe, energy efficient and environmentally friendly will be vital for achieving many of the 2030 Agenda's 17 Sustainable Development Goals (SDGs) and their targets. Directly linked 2030 Agenda items include targets 3.6 on reducing road traffic fatality rates and 3.9 on reducing air pollution related deaths, 7.2 and 7.3 on increasing the share of renewables in the global energy mix and improving energy efficiency, targets of SDG 9 on infrastructure, industrialization and innovation, target 11.2 on ensuring safe, environmentally sound and sustainable urban transport systems for all, and SDG 13's actions to combat climate change and its impacts.

Efforts in research, development and innovation are continuously bringing to market new technologies that incrementally improve the safety performance, and reduce energy consumption and environmental impact of road vehicles. More efficient engines, alternative fuel technologies, active and passive safety systems and automation in vehicles are promising avenues for improving the sustainability of road transport and road vehicles. However, technology represents only part of the solution and should be widespread to have a lasting impact.

The World Forum for Harmonization of Vehicle Regulations (WP.29) is a unique global forum for harmonizing vehicle regulations and rules on vehicle performance and on vehicle parts and equipment, vehicle safety, environmental pollution, energy efficiency, anti-theft and security. The participation of all stakeholders, those from governments, the industry and representatives of consumers, in such a worldwide regulatory platform addressing road vehicles is a key link in ensuring sectorial sustainability, including its improved safety record, for the future.

This publication - UN vehicle regulations for road safety: cost-benefit methodology – showcases the impact of some UN Vehicle Regulations developed by WP.29 on the improvement of national and global road safety. It introduces methodologies and provides an in-depth analysis of the key criteria to be used in cost benefit analysis. One of the described cost-benefit methodologies is applied in three country cases, with satisfactory data availability, to assess the socioeconomic impacts of purposely developed policy scenarios for applying vehicle regulations to improve road safety.

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List of Acronyms and Abbreviations

Acronym/Abbreviation	Definition
ABS	Anti-lock brakes
AC.2	Administrative Committee of the World Forum for Harmonization of Vehicle Regulations
AEBS	Automatic Emergency Breaking System
AFS	Adaptive front lighting systems
AIS	Abbreviated injury scale
BAAC	Base de données accidents corporels de la circulation
BAS	Brake Assist System
BCR	Benefit cost ratio
CARE	Community Road Accident Database (EU)
CBS	Combined Braking Systems
CITA	International Motor Vehicle Inspection Committee
COP	Conformity of Production
CRS	Child restraint system
ECOSOC	UN Economic and Social Council
ESC	Electronic stability control
FARS	Fatality Analysis Reporting System
GIDAS	German In-Depth Accident Study
GDP	Gross domestic product
GHG	Greenhouse gas
GNI	Gross National Income
GTR	United Nations Global Technical Regulation
HC	Human capital
HGV	Heavy goods vehicles
HIC	High income countries
HID	High-Intensity Discharge
ITC	Inland Transport Committee
ITF	International Transport Forum
ITS	Intelligent Transport Systems
IWVTA	International Whole Vehicle Type Approval
LCV	Light passenger vehicle
LIC	Low income countries
LMIC	Low-middle income countries
LPV	Light commercial vehicle

MVSA	Motor Vehicle Standards Act (Australia)
NGO	Nongovernmental Organizations
NHTSA	National Highway Transport Safety Administration (USA)
OECD	Organization for Economic Cooperation and Development
OICA	International Automobile Manufacturers Association
PKM	Passenger kilometres
PSI	Pole side impact
PTI	Periodic technical inspection
PTW	Powered two-wheelers
R.E.6	Resolution on test-equipment, skills and training of inspectors, supervision
REIO	Regional Economic Integration Organization
RID	Road Illumination Devices
RIS	Regulation impact statement
SDG	Sustainable Development Goals
STATS 19	UK Road traffic crash database
STRADA	Swedish Traffic Accident Data Acquisition
TAA	Type Approval Authority
TBI	Traumatic brain injuries
TDC	Total distance covered
TPC	Total passengers carried
UK TRL	United Kingdom Transport Research Laboratory
UMIC	Upper-middle income countries
UNECA	United Nations Economic Commission for Africa
UNECE	United Nations Economic Commission for Europe
UNECLAC	United Nations Economic Commission for Latin America and the Caribbean
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
UNESCWA	United Nations Economic Commission for Western Asia
VRU	Vulnerable road user
VSL	Value of statistical life
WHO	World Health Organization
WP.29	World Forum for Harmonization of Vehicle Regulations (UNECE)
WTP	Willingness-to-pay

Executive Summary

Road traffic crashes and consequential fatalities and injuries are a major social, economic, developmental and public health challenge for every country in the world. Globally, well over a million people are killed annually in road traffic crashes resulting in, in addition to human loss and suffering, billions in associated costs which, in some countries, amount to up to 5 per cent of GDP. While many industrialized countries have significantly improved their road-safety records during the past three decades, developing countries and economies in transition bare a disproportional share of this global burden. As such, road traffic crashes are a development issue that strongly affects low and middle-income countries, especially the most economically vulnerable segments of the population.

This publication focuses on the role of road vehicles in the road traffic safety equation, namely the impact of UN Vehicle Regulations on improving the safety performance of national road vehicle fleets. It provides an overview of the international process for developing and harmonizing vehicle regulations within the UNECE World Forum for Harmonization of Vehicle Regulations, the UN Vehicle Agreements and their annexed UN Regulations, UN GTRs and UN Rules. Its ultimate purpose is to introduce methodologies for carrying out cost-benefit analyses for estimating socio-economic gains that may be expected as a result of applying UN Vehicle Regulations which are developed in order to enhance the safety performance of road vehicles. Three country case studies have been developed to illustrate how cost benefit analyses of applying UN Regulations for road safety may be performed, including detailed steps, data requirements and outcome interpretations.

The first chapter introduces global road safety statistics, focusing on vehicle fleet and safety performance data which are fundamental inputs for cost-benefit analysis calculations. It also introduces road safety science terminology, traffic risk and exposure measures, the prevailing relationship between economic development and traffic risk, factors that contribute to road crashes, and the UN frameworks that address road safety.

Chapter two provides an overview of WP.29, its structure, the UN Vehicle Agreements under its purview, and how governments and non-state actors can play a part in its work. WP.29 was established by the ECE Inland Transport Committee (ITC) in 1952 to mitigate safety and environmental externalities of road vehicles, and to facilitate international trade by eliminating technical barriers to trade of vehicles. Since the end of the past century it opened its geographical coverage to allow the participation of any country or region of the UN system. Three UN Agreements, adopted in 1958, 1997 and 1998, provide a legal framework for Contracting Parties to establish internationally harmonized regulatory instruments concerning the certification of motor vehicles, their equipment and parts, and rules for technical inspections of vehicles in use. The regulatory framework developed by the World Forum allows the mass market introduction of innovative vehicle technologies, while continuously improving global vehicle safety, energy efficiency and environmental performance.

A literature review of studies documenting passive and active vehicle safety technologies' contribution to the improvement of road safety is presented in chapter three. It illustrates how safety-belts, airbags, ESC, frontal impact and side impact protection and other safety measures for the construction of vehicles and the instruments regulating them save thousands of lives on roads worldwide each year. Road transport stakeholders, such as national regulators, public health promoters and research institutes quantify the benefits of these devices and regulations by estimating the number of people saved by each device, the number of victims would have survived if more occupants were protected by these devices, and the corresponding expressions of the savings and loss in financial terms. This information is then used to perform cost benefit analyses of proposed regulations, and to obtain estimated benefit-cost ratios of their application.

An impact assessment of adopting and applying vehicle safety regulations is carried out in many countries in the world as part of the decision-making process in the lead up to proposing legislation. In many cases it is a mandatory step in the regulatory process, as an ex-ante effectiveness evaluation. The goal is to determine the socio-economic efficiency of a proposed regulatory measure. Chapter four introduces the elements and steps in vehicle regulation impact assessments and cost benefit analysis models performed towards this end. Those depart from the definition of crashes that a particular technology is designed to avoid or mitigate and the assessment of the technology's effectiveness in its designed purpose, continue with an estimation of the costs and benefits of applying a regulation that mandates a technology that complies with specific legislated performance requirements and end with a cost-benefit analysis itself.

Chapter five presents three national case study examples of a cost-benefit analysis. The model, developed and described in the chapter, calculates the benefit-cost ratios of regulating ESC, an active safety measure addressing for car occupants, through performance conforming to UN Regulation 140 and UN GTR No.9. The model also calculates benefit-cost ratios for regulating an Automatic Emergency Breaking System AEBS, a collision avoidance active safety measure, with performance conforming to UN Regulation No. 152, and pedestrian protection passive safety measures in conformance with UN Regulation No. 127 and UN GTR No.9, estimating the combined impact of these systems on preventing vulnerable road user fatalities and serious injuries. The timeframe for which the model is applied is 2020-2030. The countries included in the analysis, Bolivia, the Kyrgyz Republic and Serbia, were selected so as to provide diverse geographic, economic development and the road safety performance sample from different continents, and on the basis of the current implementation status of the UN Vehicle Regulations in those countries, in particular those regulations that are included in the model.

The concluding chapter summarizes the results of the analysis and elaborates on the strengths and weaknesses of the applied methodology in light of the relevant vehicle fleet and road safety data that was available for the three countries from online sources. The model, within the best estimate scenario, indicates that the fitting of all first time registered (Serbia) or all newly registered (Bolivia and Kyrgyz Republic) vehicles, as of 2020, with systems that comply with requirements set out through UN Regulations Nos. 127, 140 and 152, would result in 867 lives saved and 6,662 serious injuries prevented in Bolivia, 2,035 lives saved and 15,845 serious injuries prevented in the Kyrgyz Republic, and 522 lives saved and 3,075 serious injuries prevented in Serbia by 2030, as compared to a no action scenario. In terms of economic performance of the regulatory measures, the models best estimate scenario indicates that the combined impact of the application, as of 2020, of the assessed UN Regulations directed at car occupant and vulnerable road users safety would become cost-beneficial before the end the 2020s in all three countries – by the end of 2023 in Bolivia, and during 2029 in both the Kyrgyz Republic and Serbia.

As there is inherent uncertainty in all predictions that were made, resulting in figures obtained as best-estimates, the impact of changing model input parameters (i.e. fleet evolution, technology prices, casualty rates, etc.) on calculated benefit-cost ratios was explored to improve the robustness of the results over the timeline under observation. The alternative scenarios and respective results that were obtained through this sensitivity analysis are presented in Annex I to this report.

CHAPTER I

Road safety – the global record, key statistics and factors

Road traffic crashes and consequential injuries are the tenth most common cause of death. Road traffic deaths have increased by about 13 per cent globally since the year 2000. Crashes lead to 1.35 million deaths worldwide in 2016, equal to a global rate of 18.2 per 100,000 population. To further place these numbers in perspective, more than 3,700 people die each day because of road traffic crashes. Road traffic injuries are now the leading killer of people between the age of 5 to 29. Low-income countries had the highest mortality rate due to road traffic injuries with 27.5 deaths per 100,000 population. Road injuries were also among the ten leading causes of death in both lower-middle- and upper-middle-income countries, with rates of 19.1 and 19.5 deaths per 100,000 population respectively.

On top of the fatalities, between 20 and 50 million people suffer serious injuries in road traffic crashes every year. In many cases, injuries result in permanent disabilities affecting the victims for the rest of their lives. Traffic deaths and injuries therefore have devastating effects on individuals, families, and on society as a whole. They also cause enormous economic losses, estimated at between 2 to 5 per cent of national Gross Domestic Product (GDP) (ITF, 2018). Such levels of road traffic deaths and serious injuries are unacceptable in terms of human suffering as well as of societal and economic costs and are not sustainable.

International efforts for addressing the global road safety crisis have been picking up pace during the past twenty years and the international community has strongly mobilized to address global traffic safety crisis. As of 1 January 2016, the United Nations and its Member States committed to an unprecedented effort to promote road safety. A global target was developed to halve the number of deaths and injuries caused by road crashes by 2020. This target is included in the UN's framework of Sustainable Development Goals (SDGs) in which road safety appears in the targets of SDG 3 "Good health and well-being" and SDG 11 "Sustainable cities and communities". This reflects the contribution that the UN expects road injury prevention to make towards a paradigm shift in favour of healthy lifestyles and sustainable urban development. The SDGs are universal in scope, and therefor apply to all UN Member States. The highly ambitious target for reductions in both road crash fatalities and injuries poses a significant challenge to all governments to reinvigorate their national road safety policies and plans.

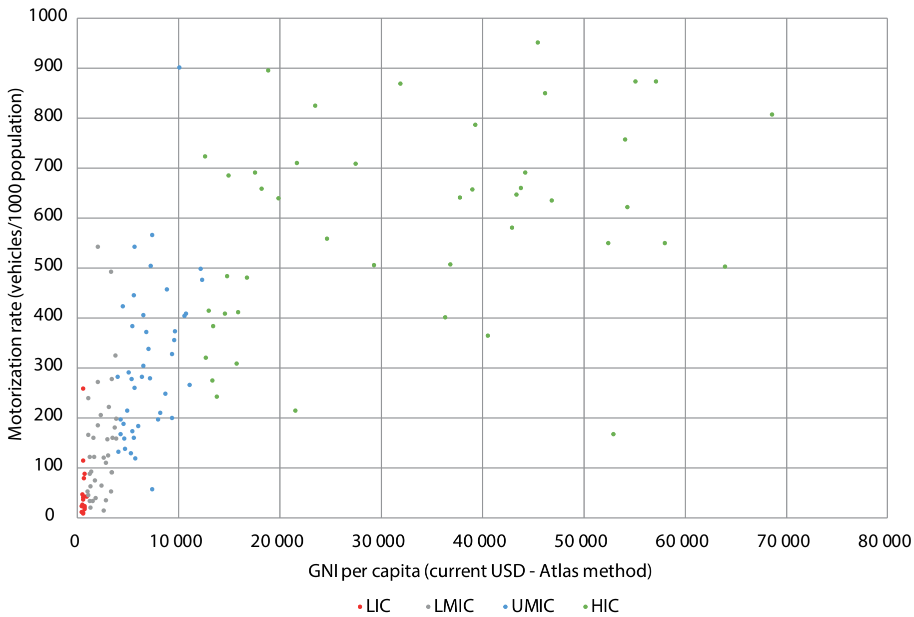
This publication focuses on the role of road vehicles in the road traffic safety equation, namely the impact of UN Vehicle Regulations on improving the safety performance of national road vehicle fleets, their crashworthiness and crash avoidance capabilities. The report introduces the international process for the development and harmonization of vehicle regulations within the framework of the UNECE World Forum for Harmonization of Vehicle Regulations (WP.29), the UN Vehicle Agreements and their annexed UN Regulations. The national application of UN Vehicle Regulations is recommended both through the UN Global Plan for the Decade of Action on Road Safety and the 2030 Sustainable Development Agenda because evidence strongly suggests that their implementation leads to the improvement of national road safety performance records. In that context, the principle purpose of this report is to provide an overview of cost-benefit analysis methodologies that are used to estimate countries' socio-economic gains derived from applying UN Vehicle Regulations which are applied to secure the enhanced safety performance of road vehicles. Three country case studies are performed towards this end. To begin with, road safety science terminology and worldwide statistics relevant for measuring road safety performance are introduced.

Traffic risk

The term road safety, or traffic safety as sometimes synonymously used, is widely employed by experts and by the public. The science of road safety has evolved in parallel with the historic developments in road transport, growth in transport volumes, expansion of road networks, increase in national and global numbers of vehicles per capita and kilometres travelled, as well as with advances in road vehicle technologies. In order to paint a clear picture of the aims and the state of the art in the science of road safety, at the outset it is necessary to outline a number of key concepts and definitions under its umbrella.

The general concept of safety is the absence of unintended harm to living creatures or inanimate objects. Quantitative safety measures nearly always focus on magnitudes of departure from a total absence of some type of harm, rather than directly on safety as such. Depending on the specific subject, road transport in our case, and on the data available, many measures are used. Traffic safety, defined as such, is a function of traffic fatality and injury risk. They are in turn the product of vehicles per person and fatalities (injuries) per vehicle and/or fatalities (injuries) per passenger-kilometre[1]. How rapidly fatality risk grows depends, by definition, on the rate of growth in motorization and the rate of change in fatalities per vehicle. In most developing countries over the past 35 years, vehicle ownership grew more rapidly than fatalities per vehicle fell. The experience in developed countries was the opposite however, as vehicles per person rates grew more slowly than fatalities per vehicle rates fell.

Figure 1.1 - Motorization rate vs. income – all countries (2016)



The motorization rate of a country is typically closely related to the purchasing power of its population. High income countries tend to have more vehicles per capita than lower income countries, but there are exceptions (Figure 1.1). Lower than average motorization rates for the highest income category are observed in Singapore and the United Arab Emirates. Otherwise, the motorization rates observed in countries with a Gross National Income (GNI[2]) per capita higher than 20,000 USD generally fall between 500 and 800 motor vehicles per 1,000 persons. Another clear correlation is observed at the GNI per capita of 4,000 USD threshold, under which almost no country has a motorization rate greater than 300 vehicles per 1,000 inhabitants.

In comparing motorization and road fatality levels, it appears that whereas several UNECE member States have been able to fully decouple motorization levels (passenger cars per 1,000 inhabitants) from road fatalities over the past two decades, numerous middle-income countries in Eastern/South-Eastern Europe and Central Asia have not (Figure 1.2).

The countries and regions between the red 45° line and the red horizontal line in Figures 1.2(a) and 1.2(b) have relatively decoupled motorization and road fatalities: road fatalities have increased less than motorization levels. UNECE is the only region in which absolute decoupling (i.e. the reduction of fatalities despite increases in levels of motorization) has been achieved. However, this may result from significant reductions in road fatalities in Western and Northern European Countries, whereas Central and Eastern Europe, the Caucuses and Central Asia have on average so far managed to relatively decouple motorization and fatality levels. Nevertheless, the trend is quite positive in these countries. Year after year the relationship between motorization levels and road fatalities is improving.

Relative decoupling between motorization rates and number of fatalities has been achieved in the UNECLAC and UNESCWA regions for an observed time period, however, some countries such as Bolivia and Mexico still have very high annual road fatality

1 Passenger Kilometre (PKM) is a measure of movement of passengers by a mode of transport (roads, railways, waterways, etc.). It is calculated as: PKM = TPC x TDC. Where, TPC is Total Passengers Carried measured in terms of number of passengers and, TDC is the Total Distance Covered measured in kilometers.

2 The World Bank assigns the world's economies to four income groups—low, lower-middle, upper-middle, and high-income countries. The classifications are updated each year on July 1 and are based on GNI per capita in current USD.

rate increases. The most critical countries in terms of road fatality levels are from UNECA and UNESCAP. This may be explained by the high economic growth rates and increased transport demand in these countries that resulted in rapid increases in private motorization levels and backlogs in road safety policies.

Figure 1.2(a) - Change in Motorization levels and road fatalities – all regions 1996 – 2016

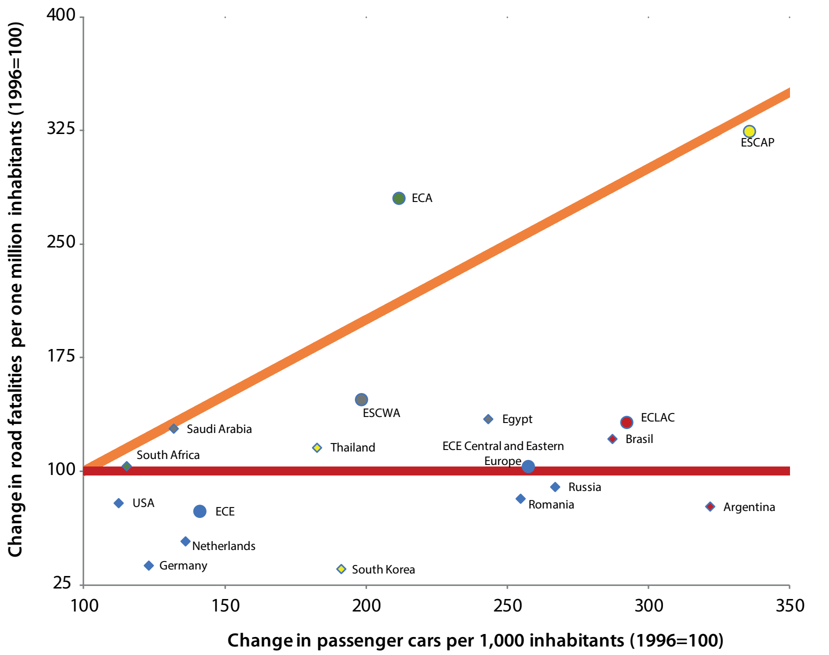
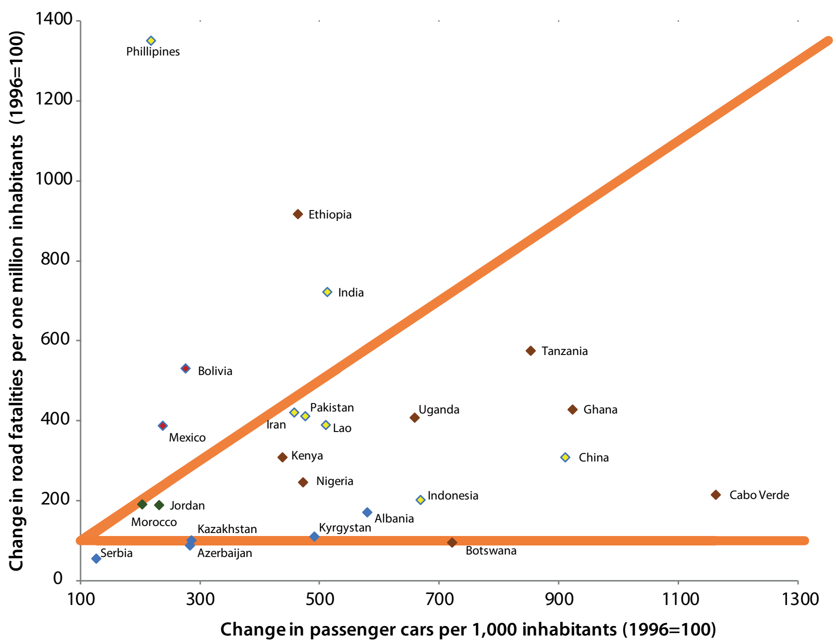


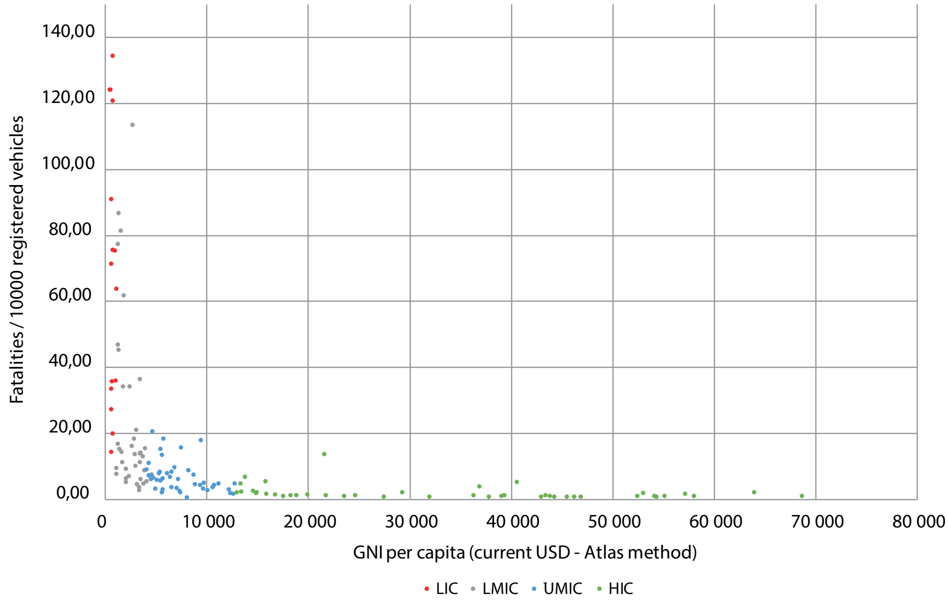
Figure 1.2(b) - Country comparisons and examples of notable dimensional shifts 1996 – 2016



Nevertheless, the prevailing constant is still evident as a largely disproportional fatality rate in developing countries. The vast majority of countries above the 10,000 USD GNI per capita mark do not exceed the five fatalities per 10,000 registered vehicles threshold. In the income categories between 4,000 and 10,000 USD GNI per capita nearly all countries remain below 20 fatalities per 10,000 registered vehicles, while many countries with per capita GNI below 4,000 USD are registering much higher fatality rates, even exceeding 100 fatalities per 10,000 registered vehicles (Figure 1.3).

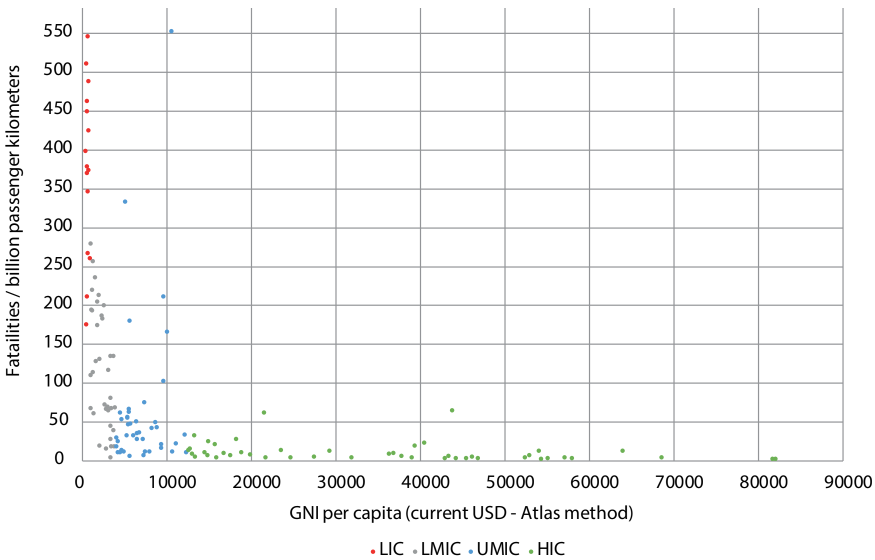
Figure 1.3 - Fatalities/vehicle registered vs. income - all countries (2016)

Fatalities per distance travelled per person paint an even clearer picture of the prevailing relationship between national per capita



income levels impact on traffic risk (Figure 1.4). Only in one national case do countries with a GNI per capita of more than 10,000 USD register a rate greater than 40 fatalities per billion passenger kilometres travelled annually. As GNI grows above 20,000 USD per capita, the fatality rates as a rule remain below 20 per billion passenger kilometres travelled, while the more than 60 per cent of countries taken into account in this per capita income category have annual fatality rates lower than 5 per billion passenger kilometres travelled.

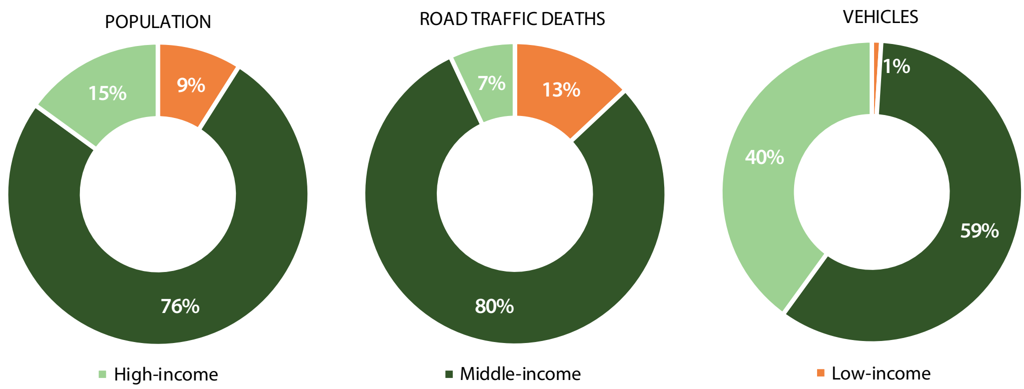
Figure 1.4 - Fatalities/passenger kilometre vs. income - all countries (2016)



Conversely, as GNI drops below 10,000 USD per capita, the national fatality rates per billion kilometres travelled rise significantly, commonly exceeding 100 annual fatalities per billion passenger kilometres travelled, while in many cases the 200 mark.

The relationship between economic development and road traffic risk and safety can be summarized as sketched in Figure 1.5 below. Fatalities incurred as a result of traffic crashes in Low- and Middle-income countries are significantly disproportional to both the population and the number of registered vehicles in these countries as compared to high-income countries.

Figure 1.5 - Proportion of population, road traffic deaths, and registered motor vehicles by country and income category (WHO, 2018)



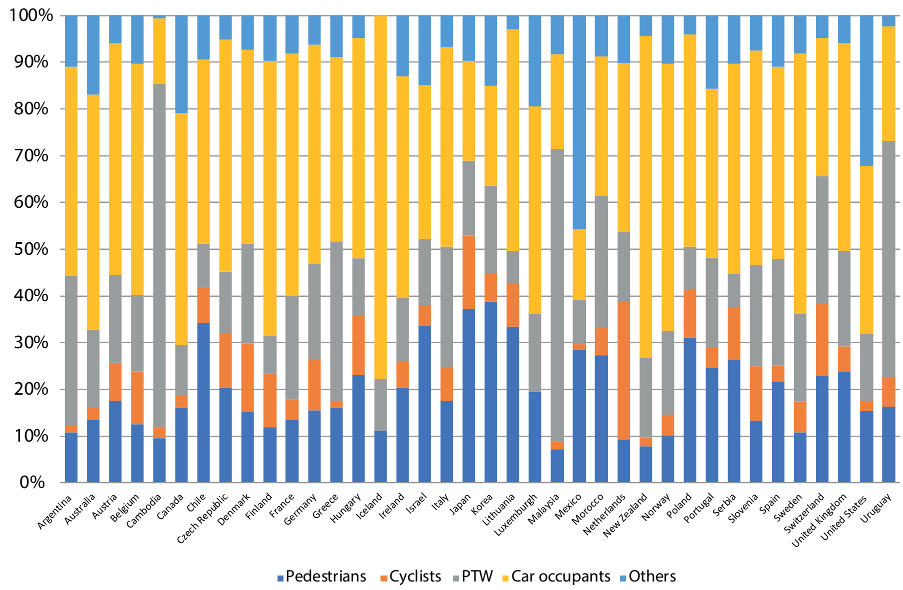
Between 1975 and 1998, road traffic deaths per capita increased by 44 per cent in Malaysia, and by over 200 per cent in Colombia and Botswana. The situation in high-income countries is quite different. Over the same period, traffic fatalities per person decreased by 60 per cent in Canada and Hong Kong, and by amounts ranging from 25 to 50 per cent in most European countries. This reflects a downward trend in fatality risk (deaths/population) that began in most OECD countries in the early 1970s and has continued to the present. The key issue for traffic safety analysis is to determine the cause of these patterns. Understanding them can help those who would try to introduce normative measures to try to reduce casualty rates.

Crashes rather than accidents and factors rather than causes

A vehicle striking anything is referred to as a crash. A traffic crash is defined as an incident that involved one or more motor vehicles where at least one vehicle was in transport and the crash originated on a public trafficway such as a road or highway (NHTSA, 2019). The term accident is considered unsuitable for technical use. Accident conveys a sense that losses are due exclusively to chance, or fate. Perhaps this is what gives accident its most potent appeal – the sense that it exonerates participants from responsibility. Accident also conveys a sense that losses are devoid of predictability. Yet the purpose of studying safety is to examine factors that influence the likelihood of occurrence and resulting harm from crashes. In 2001 the British Medical Journal prohibited the use of the term in its publications, and in 1999 the United States of America National Highway Traffic Safety Administration (NHTSA) renamed various data files, such as changing the name of the former Fatal Accident Reporting System to the present Fatality Analysis Reporting System (thus preserving the acronym FARS).

Similarly, the term cause is used cautiously because it can too easily invoke the inappropriate notion of a single use cause, such as is common in the physical sciences. Crashes result from many risk factors operating together. Although different road users have different exposure to risk, i.e. pedestrians, motorcycle riders, bicycle riders compared to four-wheel vehicle drivers and passenger, the road traffic risk factors are universal to all road users. The goal in safety analysis is to examine these risk factors associated with crashes with the aim of identifying those that can be changed by countermeasures (or interventions) to enhance future safety.

Figure 1.6 - Fatalities as a share of class of road user in ITF/OECD member countries in 2015 (based on data from ITF, 2017)



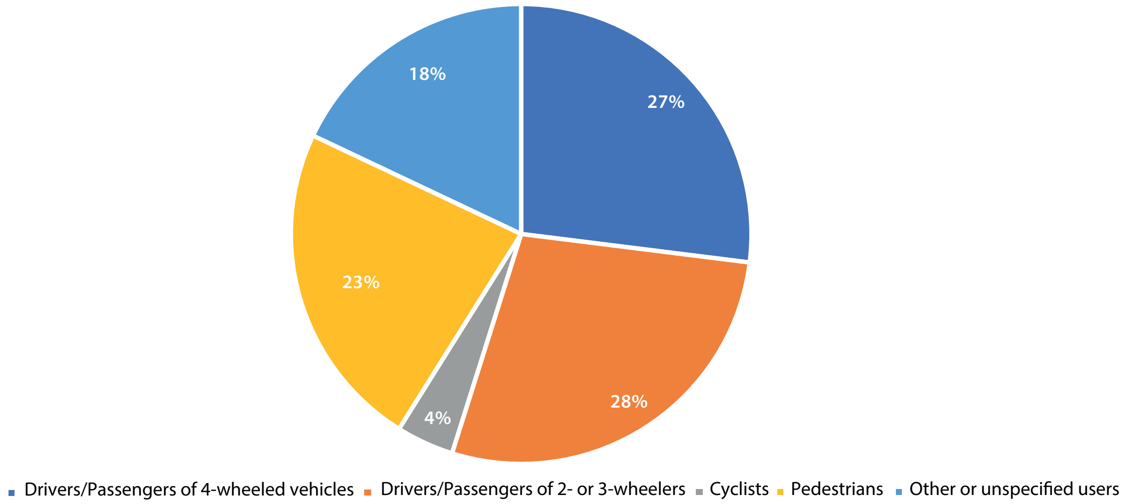
Different types of road users are exposed to varying risk levels across the globe (Figure 1.6). Vulnerable road users are disproportionally impacted. Pedestrians and cyclists comprise 26 per cent of road traffic fatalities while riders of two- or three-wheeled motor vehicles represent 28 per cent of fatalities. Occupants of four-wheelers are 29 per cent of all road traffic deaths, while the remaining 17 per cent are "unidentified road users". The latter characterization is an unfortunate consequence of the lack of data, unsatisfactory monitoring of road traffic safety and consequences of crashes that is observed in many countries across the world. Proper data collection and analysis is a basic condition conducting safety analysis and for improving the global and national road safety records.

The extent to which different categories of road users are exposed to risk in road traffic differs in across countries and regions. The relative exposure to risk of different types of road users depends on the composition and age of the road vehicle fleet and active and safety systems that are embedded in them, the behaviour of road users and their use of safety equipment (motorcycle helmets, child restraint system(CRS), safety-belts), the development and quality of road networks, both rural and urban, including existence of appropriate infrastructure for pedestrians and cyclists, and safety measures for vulnerable users, and effectiveness of post-crash response emergency services. In other words, relevant legislation, its enforcement, road user education and technologies are key components that impact the level of road traffic risk for different categories of road users.

As these elements of the road safety equation differ across world regions, so does the consequent vulnerability of all and of specific types of road users. In the UNESCAP region in total (Figure 1.7) and in South-East Asia and the Western Pacific in particular (including Australia and New Zealand), the most vulnerable group of road users are two- and three-wheel motor vehicle riders, representing respectively 43 and 36 per cent of all regional road traffic related fatalities. In Europe, although regionally it has the best record in comparison with the rest of the World at 9.3 deaths per 100,000 population, which is more than 50 per cent less road traffic fatalities then in the region with the second-best record, 48 per cent of road traffic fatalities are occupants of four-wheeled vehicles. In the Americas and the Middle East, a respective share of 34 and 39 per cent of all regional road traffic fatalities are also from this group of road users. Pedestrians are the most vulnerable in Africa, where they comprise 40 per cent of all road traffic fatalities on the continent, and in the Middle East where these road users comprise 34 per cent of regional fatalities. Regions where the bicycling culture is most developed are the regions where these vulnerable road users are most affected in traffic crashes. In Europe cyclists comprise 5 per cent, while in the Western Pacific 6 per cent of all traffic related fatalities[3].

3 Data on road user type fatalities was sourced from WHO, 2018.

Figure 1.7 - Fatalities by road user type in UNESCAP region in 2016 (data source: WHO, 2018)



United Nations Frameworks addressing road safety

In summary, factors controlling road crashes are a derivative of the elements that come together to define road traffic, namely relevant laws and rules and their enforcement, the infrastructure quality and traffic management, the construction and condition of the vehicle and the behaviour of its operator and passengers. In recognition of this fact, UN Global Plan for the Decade of Action for Road Safety recommended that activities directed at improving road safety performance should take place at local, national, regional and global levels along the five pillars (Figure 1.8).

Figure 1.8 - UN Decade of Action Pillars

Pillar 1	Pillar 2	Pillar 3	Pillar 4	Pillar 5
Road safety management	Safer roads and mobility	Safer Vehicle	Safer road users	Post-crash response

The UN Global Plan encourages universal deployment of improved vehicle safety technologies for both passive and active safety through a combination of harmonization of relevant global standards, consumer information schemes and incentives to accelerate the uptake of new technologies. Some of the recommended paths towards this end include:

- Encouraging UN Member States to apply and promulgate motor vehicle safety regulations as developed by the United Nation's World Forum for the Harmonization of Vehicle Regulations (WP 29).
- Ensuring that all new motor vehicles are equipped with safety-belts and anchorages that meet regulatory requirements and pass applicable crash test standards (as minimum safety features).
- Securing universal deployment of crash avoidance technologies with proven effectiveness such as Electronic Stability Control and Anti-Lock Braking Systems in motorcycles.

The UN Sustainable Development Goal framework set specific targets for a global improvement in road safety, and indicators to monitor progress made towards achieving those targets. Target No. 3.6 is to halve the number of global deaths and injuries from road traffic crashes by 2020 while Target 11.2 stipulates providing by 2030 access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons.

To achieve these goals, from the perspective of improving vehicle design and performance for increased safety of occupants in the occurrence of a crash and active crash avoidance systems, the UN Road Safety Collaboration has recommended national adoption and application of a minimum set of priority UN Vehicle Regulations, as follows:

- UN Regulations Nos. 14 and 16, which ensure that safety-belts are fitted in vehicles when they are manufactured and assembles and that the safety-belt anchoring points can withstand the impact incurred during a crash, to minimize the risk of belt spillage, and ensure that occupants can safely be removed from their seats post-crash.
- UN Regulation No. 78 on Motorcycle anti-lock braking systems, which help the rider maintain control during an emergency braking situation and reduce the likelihood of a road traffic crash and subsequent injury.
- UN Regulations Nos. 94 and 95 on frontal and side impact protection, which ensure that vehicles withstand impacts and protect occupants in cases of frontal and side impact crashes, in accordance with specific test parameters defined in these UN Regulations.
- UN Regulation No. 127 on Pedestrian front protection, which sets provisions for softer bumpers and modifications of front ends of vehicles to remove unnecessarily rigid structures therein enabling the reduction of pedestrian impact severity and consequences.
- UN Regulation No. 129 Enhanced Child Restraint Systems, which sets the design and performance requirements for CRS, ensures that the CRS is securely fitted and held in place in a vehicle with its safety-belts and/or embedded ISOFIX child restraint anchorage points.
- UN Regulation No. 140 on Electronic Stability Control (ESC), which sets performance requirements for a system that prevents skidding and loss of control in cases of oversteering and understeering. It is effective in avoiding single car and roll over crashes, at reducing crashes that may without ESC result in fatalities and serious injuries.

UN Vehicle Regulations are developed within the UNECE World Forum for Harmonization of Vehicle Regulations (WP.29). The WP.29 is a worldwide regulatory forum in which relevant stakeholders, including national government regulators, the automotive industry, vehicle and equipment manufacturers, specialized intergovernmental organizations, academia and consumer groups, participate to harmonize and develop state-of-the-art vehicle regulations. Three UN Vehicle Agreements, adopted in 1958, 1997 and 1998 (Box 1), provide a legal framework allowing Contracting Parties to these agreements to establish internationally harmonized regulatory instruments concerning the certification of motor vehicles, their equipment and parts, and rules for technical inspections of vehicles in use. The regulatory framework developed by the World Forum allows the mass market introduction of innovative technologies, while continuously improving global vehicle safety. Countries joining WP.29 benefit from a global platform where state-of-the-art technical regulations are discussed and adopted, reducing the administrative burden for contracting parties, and offering harmonized technical specifications for faster deployment of vehicle technologies aiming at achieving safer mobility.

Box 1 - United Nations Vehicle Agreements

- 1958 Agreement concerning the Adoption of Harmonized Technical United Nations Regulations for Wheeled Vehicles, Equipment and Parts which can be Fitted and/or be Used on Wheeled Vehicles and the Conditions for Reciprocal Recognition of Approvals Granted on the Basis of these United Nations Regulations (Revision 3)
- 1997 Agreement concerning the Adoption of Uniform Conditions for Periodical Technical Inspections of Wheeled Vehicles and the Reciprocal Recognition of Such Inspections
- 1998 Agreement concerning the Establishing of Global Technical Regulations for Wheeled Vehicles, Equipment and Parts which can be fitted and / or be used on Wheeled Vehicles

It is important to emphasize that the above list comprises only a limited number of safety related UN Vehicle Regulations. However, they are the minimum set of recommended UN Vehicle Regulations identified by the road safety and vehicle safety expert community, which are indispensable for reducing road traffic fatality and injury rates. A more comprehensive catalogue of UN Vehicle Regulations whose adoption and application secures enhanced safety of all classes of road traffic participants is listed in Table 1 below. An introduction to the UN World Forum for Harmonization of Vehicle Regulations, UN Vehicle Agreements and their annexed Regulations, the benefits that countries acceding to the Agreements and applying the Regulations can expect, follows in chapter 2.

TABLE 1

The most important UN Vehicle Regulations to make a change in road safety

Topic	Passenger cars UN Regulation	PTWs UN Regulation	Commercial vehicles UN Regulation
	Active safety		
Brakes	R13 H (incl. ABS)	R 78 (incl. ABS) GTR 3	R 13 (incl. ESC)
Electronic Stability Control	R 140 / GTR 8		
Steering	R 79		R 79
Tyres	R 30 / GTR 16	R75	R 54
Mechanical couplings			R 55
	Passive safety		
Helmets		R22	
Safety belts anchorages	R 14		R 14
Safety belts	R 16		R 16
Seats/ head restraints	R 17, R 25 / GTR 7		
Frontal collision	R 94		
Lateral collision/ pole side impact	R 95, R 135 / GTR 14		
Pedestrian safety	R 127 / GTR 9		
Child restraints	R 44		
Electric PTW safety		R 136	
Cabs strength			R 29
	General safety		
Buses and coaches			R 107
Safety glazing	R 43 / GTR 6		R 43
Devices for indirect vision			R 46
Underrun protection			R 58; R 93
	Lighting and light installation		
Installation of lighting	R 48	R 53, R 74	R 48

CHAPTER II

The World Forum and the United Nations Vehicle Agreements

The UNECE World Forum for Harmonization of Vehicle Regulations, also known as WP.29 is the worldwide regulatory forum in which relevant stakeholders from the world are participating. Three UN Agreements, adopted in 1958, 1997 and 1998, provide a legal framework allowing Contracting Parties to establish internationally harmonized regulatory instruments concerning the certification of motor vehicles, their equipment and parts, and rules for technical inspections of vehicles in use. The regulatory framework developed by the World Forum allows the mass market introduction of innovative vehicle technologies, while continuously improving global vehicle safety, energy efficiency and environmental performance[4].

Countries joining the World Forum benefit from a global platform were state-of-the-art technical regulations are discussed and adopted, reducing the administrative burden for contracting parties, and offering harmonized technical specifications for faster deployment of vehicle technologies aiming at achieving sustainable mobility.

This chapter contains an overview of WP.29, its structure, UN Vehicle Agreements under its purview, and the benefits of acceding to the Agreements and applying the annexed UN Regulations, UN Global Technical Regulations (GTRs) and UN Rules. It concludes with information on how governments and non-state actors can take part in the work of the World Forum, and with a list of references that interested parties can consult to learn more about WP.29, how it works and how to join it, the UN Vehicle Agreements and the annexed UN Regulations, UN GTRs and UN Rules.

Construction of Safer and more Environmentally Friendly Vehicles

WP.29 was established by the UNECE Inland Transport Committee (ITC) in 1952 to mitigate safety and environmental externalities of road vehicles, and to facilitate international trade by eliminating technical barriers to trade of vehicles. Since the end of the past century it opened its geographical coverage to include any country or region of the UN system that wants cooperate in improving the safety and environmental performance of road vehicles.

The World Forum WP.29 administers the following three UN Agreements:

(a) The agreement concerning the Adoption of Harmonized Technical United Nations Regulations for Wheeled Vehicles, Equipment and Parts which can be Fitted and/or be Used on Wheeled Vehicles and the Conditions for Reciprocal Recognition of Approvals Granted on the Basis of these United Nations Regulations (Revision 3). (The UN 1958 Agreement);

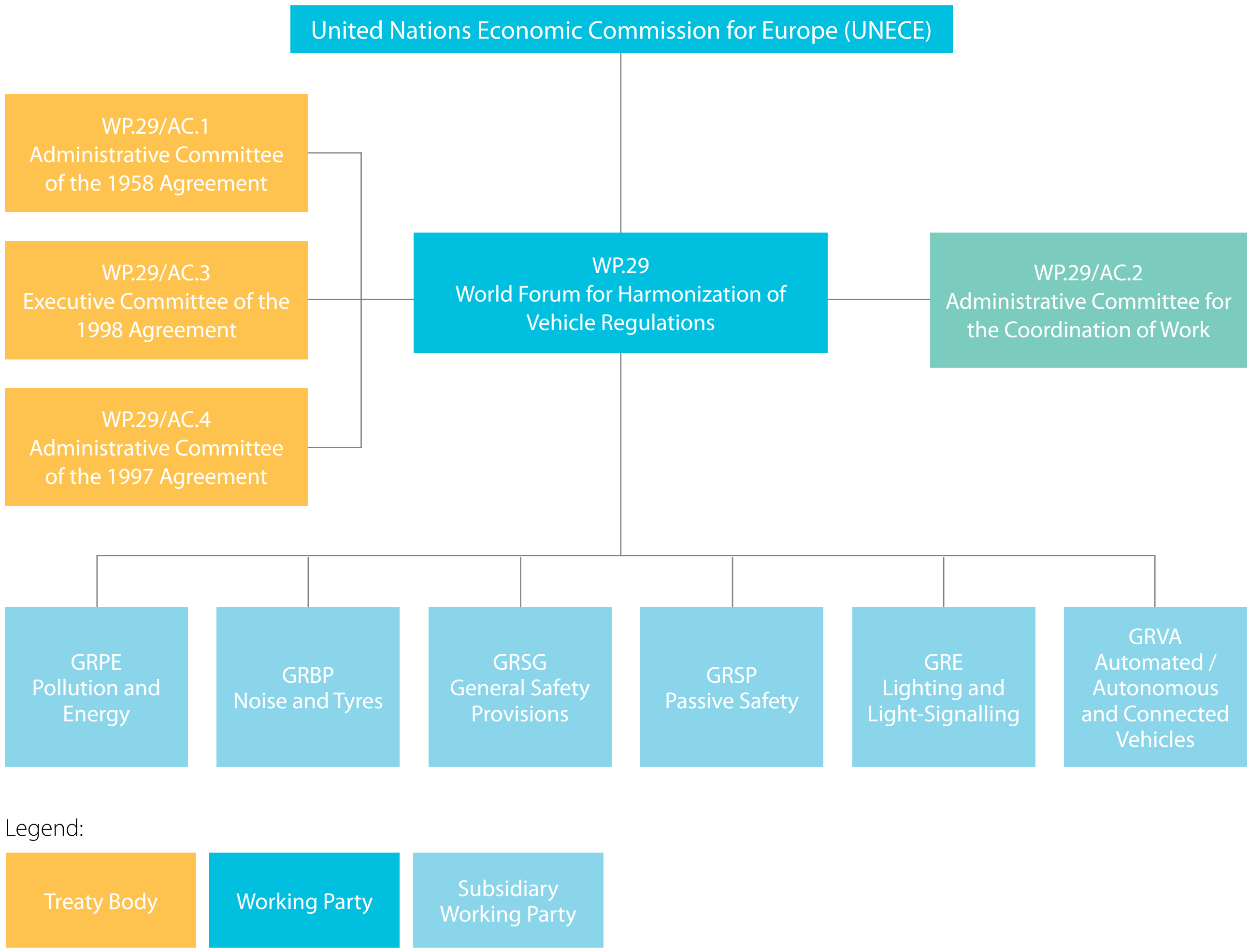
(b) The agreement concerning the Adoption of Uniform Conditions for Periodical Technical Inspections of Wheeled Vehicles and the Reciprocal Recognition of such Inspections, of 1997. (The UN 1997 Agreement);

(c) The agreement concerning the Establishing of Global Technical Regulations for Wheeled Vehicles, Equipment and Parts which can be fitted and/or be used on Wheeled Vehicles, of 1998 (The UN 1998 Agreement).

WP.29 ensures consistency between the UN Regulations, UN Rules and UN GTRs developed in the legal framework of these three UN Agreements. The day-to-day management of the activities of WP.29 is carried out by the UNECE Secretariat, namely its Sustainable Transport Division.

4 The text in this chapter is based on: 1. *World Forum for Harmonization of Vehicle Regulations (WP.29), How it works – How to join it, Fourth Edition* (United Nations, 2019); 2. Road Maps for accession to and implementation of the United Nations 1958 and 1997 Agreements (ECE/TRANS/WP.29/2018/163); 3. *Road Map for accession to and implementation of the United Nations 1998 Agreement* (ECE/TRANS/WP.29/2019/30).

Figure 2.1 - The structure of the World Forum WP.29



The World Forum's work is transparent: agendas, working documents, reports, informal documents as well as the agreements and their UN Regulations, UN Global Technical Regulations and UN Rules as well as all the documents of their Informal Working Groups are freely accessible on the WP.29 website:. Sessions of WP.29 are held three times a year. Those of the subsidiary Working Parties of Experts (GRs) are held twice a year. Sessions of WP.29's Administrative Committee for the Coordination of Work (AC.2) are held prior to each WP.29 session.

Regular sessions of WP.29 are held three times a year. The subsidiary Working Parties of experts (GRs) each hold two a year. WP.29/AC.2 meetings are held prior to each WP.29 session.

The primary areas of GRs concern are:

A. Active safety of vehicles and their parts (crash avoidance)

The UN Regulations and UN GTRs seek to improve the behaviour, handling and equipment of vehicles so as to decrease the possibility of a road crash. Some of the regulations seek to increase the driver's ability to detect and avoid hazards. Others seek to increase the driver's ability of to maintain control of the vehicle. Specific examples of current UN regulations include lighting and light-signalling devices, braking and running gear, including steering, tyres and rollover stability where the technology changes rapidly.

B. Passive safety of vehicles and their parts (crashworthiness)

The UN Regulations and UN GTRs aim to minimize the risk and severity of injury to the occupants of a vehicle or to other road users in the event of a crash. Extensive analyses of crash statistics can identify safety problems which may develop into a UN Regulation, a UN GTR or an amendment to existing ones. The statistics can also structure a cost-effective approach to improve performance requirements. This is significant on the overall impact of new requirements on vehicle construction, design and cost. Specific examples of current UN vehicle regulations address the structure the vehicle to manage crash energy and resist intrusion into the passenger compartment, occupant restraint and protection systems for children and adults, seat structure, glazing, door latches and door retention, pedestrian protection, and for mopeds/motorcycles, the quality of the protective helmet for the rider. These technologies also change rapidly and are becoming more complex, such as with the advanced protection devices that adjust their performance in response to the specific circumstances of each crash. In addition, changes in the vehicle population are raising issues of vehicle compatibility.

C. Environmental considerations

Specific UN Regulations and UN GTRs have been established to address the environmental performance (e.g. emissions of gaseous pollutants, particulates and CO2, noise level) of vehicles with conventional propulsion engines, hydrogen and fuel-cell vehicles, hybrid-electric vehicles and electric vehicles. These UN Regulations and UN GTRs have been adapted, and will be whenever appropriate, to take into account new propulsion technologies for cleaner and environmentally friendly vehicles.

D. General safety considerations

The UN Regulations and UN GTRs in this area address vehicle and component features which are not directly linked to the above-mentioned subject areas, such as windshield wipers and washers, controls and displays, devices for indirect vision and glazing. Others include theft prevention, automatic emergency call systems as well as the considerations of gas-fuelled vehicles and public transport vehicles for which special expertise is needed in establishing their performance requirements.

E. Automated/Autonomous and connected vehicles

Technical provisions and are being drafted to address the specificities of vehicle connectivity and automation. This work is needed to integrate innovative technologies into the existing transport system and to ensure that the benefits of these new technologies can be captured: to better road safety, the environmental performance of road vehicles, to reduce congestions and to potentially enable new kinds of mobility services.

In some cases, a specific problem needs to be solved urgently or needs to be addressed by persons with a special expertise. In such situations, a special informal working group may be entrusted with the analysis of the problem and invited to prepare a proposal for a new UN Regulation, UN GTR or UN Rule. Although such cases have traditionally been kept to a minimum, the rapid development of complex new technologies is increasing the necessity for this special approach.

Proposals to WP.29 for new UN Regulations, UN GTRs and UN Rules and amendments to existing ones are referred by WP.29 to its subsidiary bodies which prepare the technical recommendations (see Figure 2.1). Each subsidiary body consists of specialized experts. The current allocation of subject responsibility between the subsidiary bodies was originally developed in the "Groupes des Rapporteurs", some of which were later merged to form the "Meetings of Experts". The work of the subsidiary bodies has proven to be so useful and indispensable that they have been given permanent status under UNECE and, in turn, have been renamed 'Working Parties. See Chart 1 for the six current Working Parties. The traditional titles of the subsidiary bodies used the acronym "GR" (Groupes des Rapporteurs from the French language) that is still in the acronyms of the Working Parties and in the symbols of their working documents today

The 1958 Agreement

The 1958 Agreement was done on 20 March 1958, entered into force on 20 June 1959, was amended on 10 November 1967, revised on 16 October 1995 and on 17 September 2017. The Agreement provides harmonized technical UN Regulations for the approval/certification of new wheeled vehicles, their equipment and parts, including provisions for the reciprocal acceptance of approvals issued under UN Regulations annexed to this Agreement. UN Regulations adopted by Contracting Parties to the 1958 Agreement pursuant to the Agreement govern the approval of road vehicles, their equipment and parts for sale in those countries. The agreement addresses safety requirements for vehicles, their environmental performance (air and noise pollution), energy-efficiency and security.

The 1958 Agreement has 57 contracting parties, of which 45 are UNECE member countries. Other contracting parties are the European Union (Regional Economic Integration Organization – REIO), Australia, New Zealand, Japan, Republic of Korea, Malaysia, Thailand, South Africa, Tunisia, Egypt, Nigeria and Pakistan.

The Agreement had 157 UN Regulations annexed to it in 2020. These UN Regulations govern all categories of road vehicles, and non-road mobile machinery and their equipment and parts, and have been adopted in varying degrees by the Contracting Parties. The reciprocal recognition of type approvals between Contracting Parties applying the UN Regulations has facilitated trade in motor vehicles and equipment across Europe first and worldwide today.

In recent years, the European Union decided to replace as many European Union directives as possible by the 1958 Agreement UN Regulations, and to make direct reference to these UN Regulations in the European Union legislation. On 14 September 2017, Revision 3 of the 1958 Agreement entered into force.

In the past, reciprocal recognition under the Agreement applied to vehicle systems, parts and equipment, but not to the entire vehicle. In July 2018, UN Regulation No. 0 on the International Whole Vehicle Type Approval (IWVTA) entered into force. This UN Regulation allows the reciprocal recognition of the entire vehicle approval.

Benefits of acceding to the 1958 Agreement

UN Regulations are developed with the most stringent provisions for safety and environmental performance of vehicles. Acceding to the agreements and mandatory application of the UN Regulations for the registration of vehicles will result in safer and more environmentally friendly vehicles. Accession to the Agreement and application of its annexed regulations is recommended by the UN Plan of Action for the Decade of Road Safety. The third pillar of the UN Global Plan of Action for the Decade of Road Safety is dedicated to safer vehicles and recommends the application of UN Regulations, UN GTR's and UN Rules developed by the World Forum.

A contracting party that has decided to apply a UN Regulation annexed to the agreement can grant type approvals for motor vehicle equipment and parts covered by that UN Regulation. Such a contracting party is required to accept the type approval of any other contracting party that applies the same UN Regulation. This is one of the key elements of the 1958 Agreement. Through the mutual recognition system of the type approvals granted it eliminates technical barriers to trade.

The Agreement facilitates the elaboration of national vehicle regulations. The elaboration of new vehicle regulation is a complex, time consuming and very expensive process. By the application of UN Regulations, which have demonstrated their efficiency, countries have prompt and free access to a set of technical performance requirements for vehicles.

The Agreement provides flexibility in the application of the UN Regulations. When acceding to the agreement, the contracting party is free to select which UN Regulations will apply, if any. The contracting party can, at any moment decide to apply any other UN Regulation. Any contracting party can decide to cease the application of any UN Regulation. UN Regulations can also be optional to national regulations as contracting parties applying a UN Regulation can keep or derogate their national regulations;

By the application of UN Regulations, national industry can upgrade its technological knowhow to adapt the manufacturing process of vehicles, equipment and parts to the most developed technologies in practice. The adaptation of national regulations in parallel with the UN Regulations can facilitate the smooth integration of technological innovations. It also supports the technological development of the services of the administration through the establishment of a competent Type Approval Authority (TAA) and its designated technical services for the verification and testing of the performances;

The participation in the elaboration of UN Regulations is open to all the member States of the United Nations. Nevertheless, only the contracting parties to the agreement can vote when establishing a new UN Regulation, or when amending a UN Regulation.

Therefore, becoming a contracting party allows UN member States the possibility of participating in the global regulatory process for wheeled vehicles. National Authorities of contracting parties can grant in their own countries type approvals to vehicle manufacturers and their suppliers for those UN Regulations that the country applies and countries that are CPs to the agreement and are applying a UN Regulation can reject the registration of sub-standard vehicles in their own territory.

The 1998 Agreement on UN Global Technical Regulations

The official name of the 1998 Agreement is the Agreement Concerning the Establishing of Global Technical Regulations for Wheeled Vehicles, Equipment and Parts Which Can Be Fitted and/or Be Used on Wheeled Vehicles – also informally known as the Global Agreement of 1998.

The 1998 Agreement was negotiated and concluded under the auspices of ECE and opened for signature on 25 June 1998. The United States of America became the first signatory. The Agreement entered into force on 25 August 2000 for eight Contracting Parties. In 2020 the Agreement had 38 Contracting Parties. To date, 20 UN GTRs have been established under this Agreement.

The goal of the 1998 Agreement is to continuously improve global safety, decrease environmental pollution and consumption of energy and improve anti-theft performance of vehicles and related components and equipment through globally uniform technical regulations. This is achieved in a predictable regulatory framework for the global automotive industry, the consumers and their associations. Unlike the 1958 Agreement, the 1998 Agreement does not provide for mutual recognition of approvals, thus, allowing countries which are not ready or are unable to assume the obligations of reciprocal recognition to effectively engage in developing UN GTRs, regardless of these countries type of compliance or enforcement procedures.

The 1998 Agreement establishes a process by which countries from all regions of the world can develop UN GTRs jointly on safety, environmental protection systems, energy sources and theft prevention of wheeled vehicles, equipment and parts and to implement these regulations in line with the uniform provisions of UN Regulations. The equipment and parts cover, but are not limited to, vehicle construction, exhaust systems, tyres, engines, acoustic shields, anti-theft alarms, warning devices and child restraint systems.

The 1998 Agreement takes into consideration those nations that are employing a "self-certification system," in which manufacturers guarantee the conformity of their vehicles to relevant safety standards and the governments confirm the conformity of vehicles after they are placed on the market. UN GTRs under the 1998 Agreement and UN Regulations under the 1958 Agreement are expected to incorporate newly established provisions of each other into its own provisions. This makes it possible to harmonize regulations with countries employing the self-certification system. However, the type-approval system prescribed in the UN Regulations, is not included in UN GTRs

For the preparation of new UN GTRs, the agreement provides for two different approaches. The first consists in harmonising existing regulations or standards applied by contracting parties, while the second involves drawing up new global technical regulations where there have not previously been any.

The agreement provides for existing regulations of the contracting parties that could be harmonised to be listed in a Compendium of Candidate Global Technical Regulations in order to make it easier to transform them into global regulations. A regulation is added to the compendium if it is supported by at least one third of the votes cast by the contracting parties present, including a vote of the European Union, Japan and the United States of America.

Benefits of acceding to the 1998 Agreement

The advantage of international harmonization of regulations is that design specifications of vehicles do not have to be changed to meet country-specific regulations. Common specifications of vehicle parts will reduce the cost of development and production and the retail price of vehicles. It will also make homologation of certification procedures easier, make the market larger, and give the consumers a wider range of choices.

UN GTRs are developed with the most stringent provisions for safety and environmental performance of vehicles. Acceding to the agreements and mandatory application of the UN GTRs for the registration of vehicles will result in safer and more environmentally friendly vehicles.

The Agreement facilitates the elaboration of national vehicle regulations - a complex, time consuming and very expensive process. By the application of UN GTRs, which have demonstrated their efficiency, countries have prompt and free access to a set of technical performance requirements for vehicles.

By the application of UN GTRs, national industry can upgrade its technological knowhow to adapt the manufacturing process of vehicles, equipment and parts to the most developed technologies in practice. The adaptation of national regulations in parallel with the UN GTRs can facilitate the smooth integration of technological innovations.

The participation in the elaboration of UN GTRs is open to all the member states of the United Nations. Nevertheless, only the contracting parties to the agreement can vote when establishing a new UN GTR, or when amending a UN GTR. Countries, being CPs to the agreement and mandatory applying a UN GTRs, can reject the registration in their own territory, of sub-standard vehicles.

For many countries the 1998 Agreement is the most inclusive approach to work collectively to develop harmonized technical provisions. Especially, concerning new technologies, it is likely that new CP's and other stakeholder will engage in this effort to a greater extent than the past and should be given ample opportunity to make important contributions. As a matter of fact, it is easier to harmonize technologies where a standard is not yet designed to assess their liability rather than already existing standards (e.g. Frontal crashes). Since its entering into force, the Agreement has reduced regulatory divergences between countries applying self-certification vs. type approval regimes providing a level playing field for manufacturers, facilitating trade in vehicles throughout the global market.

Finally, the voting process provided by the Agreement allows any country to have the same weighing factor in the development and establishment of UN GTRs vis a vis Regional Economic Integration Organizations.

Box 2 - The 1958 and 1998 Agreement

UN Regulations annexed to the 1958 Agreement and UN GTRs under the 1998 Agreement aim to improve the safety, security and environmental performance of wheeled vehicles. UN Regulations and UN GTRs address performance requirements for new vehicles, their equipment and parts, including Electronic Stability Control (UN Reg. No. 140 / UN GTR No. 8), Pole-side impact protection (UN Reg. No. 135 / UN GTR No. 14), Pedestrian safety (UN Reg. No. 127 / UN GTR No. 9) and many others. In most cases UN Regulations and UN GTRs that address the same vehicle equipment and/or parts are harmonized.

The main reason of there being two, sometimes called, parallel agreements, is because some countries apply the type-approval system while others have a self-certification system in place. The 1958 Agreement stipulates the type-approval system and provides for the system of mutual recognition of type approvals between countries that are parties to the Agreement and applying its annexed UN Regulations. The 1998 Agreement on the other hand provides for the development and international application of UN GTRs for vehicles, their equipment and parts, where their compliance with regulations can be surveyed under the self-certification system. The development of harmonized regulations governing the construction of vehicles, their equipment and parts under these two Agreements ensures that vehicles will meet the technical performance requirements in countries that are parties to one or the other, regardless of which of the two Agreements they are parties to and regardless whether they apply the type-approval or self-certification system as the preferred system to ensure regulatory compliance. Nevertheless, when transposed into national legislation, the provisions of UN Regulations and those of UN GTRs can be applied under both the type-approval and/or the self-certification system. There are no limitations for UN member States to be contracting parties to both agreements. Several countries, in fact, are.

The type approval system requires that wheeled vehicles, their equipment and parts are, before market roll-out, "type approved" by a designated national authority (Type Approval Authority - TAA) upon testing carried out by designated Technical Services (entities that are delegated by Type Approval Authorities to carry out tests on vehicles, their equipment and parts, in accordance with the provisions of applicable UN Regulations). In addition, the 1958 agreement stipulates a "conformity of production" procedure to ensure that each produced and marketed wheeled vehicle, equipment or part is in conformity with the type that was tested and granted approval. It sets the TAAs responsibilities for screening manufacturer's quality management processes ("initial assessment"), for verifying the existence of adequate arrangements and control plans to ensure a product's conformity ("product conformity"), and for continuous verification processes to monitor the continued effectiveness of quality management and product conformity systems and processes.

The self-certification system on the other hand requires manufacturers to test and guarantee that the vehicle equipment and parts in models that are taken to market are in accordance with the provisions of all applicable regulations for the vehicle equipment and parts that are imbedded in its construction. Models that are taken to market are then subject to random testing by licensed agents to verify compliance with relevant regulations. In the self-certification system, in cases where non-compliance is determined manufacturers may face severe fines and be compelled to initiate recalls of the models in question.

The 1997 Agreement

The 1997 Agreement on Periodical Technical Inspections was done at Vienna on 13 November 1997 at the ECE Regional Conference on Transport and Environment. The Agreement provides the legal framework and procedures for the adoption of uniform UN Rules for carrying out technical inspections of vehicles that are in use and for delivering international inspection certificates. By 2020, the 1997 Agreement had sixteen contracting parties, while four UN Rules had been established under its umbrella.

The UN Rules for vehicle inspection that are annexed to the Agreement have been developed with the technical expertise of WP.29 participants and, in particular, of the International Motor Vehicle Inspection Committee (CITA). Initially designed for heavy duty vehicles, the scope of these rules has been extended to cover passenger cars and light duty vehicles. The related Resolution R.E.6 (see Annex VII) provides guidelines for testing facilities and equipment, training and certification of inspectors as well as quality control for the supervision of authorized test centres. These UN Rules and R.E.6 may be useful for countries aiming to introduce or strengthen, in their national legislation, a periodic inspection system based on international expertise.

CITA with its broad international membership has cooperated in and supported the development and updating of the technical UN Rules annexed to the Agreement on a regular basis.

Main benefits for the contracting parties applying the Rules

Application of the 1997 Agreement and its UN Rules increase fleet vehicle's safety and their environmental performance: UN Rules are developed to ensure a considerable level of performance regarding both their safety and environmental conditions during the overall lifetime of vehicles. It also contributes to the accomplishment of the recommendations of the UN Plan of Action for the Decade Road Safety, the third pillar of which is dedicated to safer vehicles and recommends the application of vehicle UN Rules developed by the WP.29.

The 1997 Agreement facilitates the Mutual Recognition of the Periodic Technical Inspection (PTI) certificates and supports the elaboration of national vehicle regulations. A contracting party that has decided to apply a Rule annexed to the agreement has the advantage that its PTI certificate is accepted by the others contracting parties applying the same Rule for cross border circulation of vehicles, and through the application of Rules, which have demonstrated their efficiency, countries have access to a set of rules for PTI at no cost and as soon as they need.

The 1997 Agreement allows flexibility in the application of the Rules, as when acceding to the agreement, a contracting party is free to select which Rules will apply. The contracting party can, at any moment, decide to apply any other Rules. Similarly, any contracting party can decide to cease the application of any Rule. Furthermore, contracting parties can establish their own priority areas of safety and environmental performance of vehicles by selecting the order on the application of Rules;

Participation on the decision-making process for the elaboration of Rules is open to all the Member States of the United Nations. Nevertheless, only the contracting parties to the agreement can vote when establishing new Rules, or for the adaptation to the technical progress of the Rules the Member State applies.

How to join the World Forum

Participation in WP.29 activities is worldwide, and further encouraged by the cooperation between countries and regional economic integration organizations on technical matters that come before it or its Working Parties. WP.29 also encourages open, transparent dialogues between government officials, technical vehicle experts and the general public to ensure that the best safety and environmental practices are adopted, and that cost-efficiency is considered in developing UN vehicle regulations. The sessions of WP.29 are public. Any government or other interested party may attend and observe the proceedings of the meetings.

Participation of Governments

Rule 1 of the Terms of Reference and Rules of Procedure of WP.29 states that any country, member of the United Nations, and any regional economic integration organization set up by countries members of the United Nations, may participate fully or in a consultative capacity in the activities of WP.29 and become a Contracting Party to the Agreements administered by WP.29.

The official process to become a participant is to simply send a letter signed by the authorized official of an interested country or REIO notifying the secretariat of WP.29 of the desire of that country or REIO to send representative(s) to the sessions and to participate in the activities of WP.29.

Participation of Non-Governmental Organizations

Rule 1 of the Terms of Reference and Rules of Procedure states that Nongovernmental Organizations (NGOs) may participate in a consultative capacity in WP.29. An NGO must first be accredited with consultative status to ECOSOC - the Economic and Social Council of the United Nations. Consultative status with ECOSOC allows NGOs to contribute to the work programmes and goals of WP.29 by serving as technical experts or advisers and consultants to governments and the secretariat. The number of NGOs participating in any session of WP.29 or its subsidiary bodies typically varies between six and fifteen, depending on the topic. A smaller number attend the sessions of the subsidiary Working Parties and informal working groups.

NGOs contribute substantially to the process of developing UN vehicle regulations on vehicle safety, energy-efficiency and environmental and anti-theft performances. They are often contributing technical data and advice. In special cases, they invest resources in tests and analyses, and make the results available to the experts developing the UN vehicle regulations. At times, NGOs have responded to the requests of technical experts by providing proposals for UN vehicle regulations and amendments to existing UN regulations. NGOs may also advocate policy positions and provide testimony to the legislative bodies of participating governments. NGOs not in consultative status with ECOSOC may participate in a consultative capacity, subject to prior approval of W.29/AC.2.

How to become a Contracting Party

Only a country or an REIO can become a Contracting Party. A Contracting Party to an Agreement administered by WP.29 is bound by consent to that Agreement in accordance with the provisions of that Agreement. The provisions include signature, notification of ratification, acceptance, approval or accession. See Article 6 of the 1958 Agreement, Article 9 of the 1998 Global Agreement and Article 4 of the 1997 Agreement on Periodical Technical Inspections in Annexes II, III and IV, respectively.

While an Agreement is open for signature and a country or REIO expresses its consent to be bound by an Agreement by signature, the signing must be:

- Done by the Head of State, the Head of Government or the Minister for Foreign Affairs of that country, or
- By a person in possession of a valid instrument of Full Powers signed by one of the afore-mentioned representatives of a country or REIO, indicating clearly the title of the Agreement and the name and function of the official authorized to sign.

At the time of signing, or in the text of Full Powers, it shall be clearly indicated if the signature is definitive, or only a signature which is subject to ratification.

If the period of signature had been closed, a country or REIO may express its consent to be bound by an Agreement by depositing an instrument of accession with the Secretary-General of the United Nations.

Resources for accession to and implementation of the UN Vehicle Agreements

The secretariat of the World Forum has issued several publications that provide detailed guidance to interested stakeholders on all matters related to participation in WP.29 and accession to and implementation of international agreements and UN Regulations developed under its auspices.

The 2019 edition of the "Blue Book" – World Forum for Harmonization of Vehicle Regulations (WP.29) – How it Works, How to Join It (United Nations, 2019) – reflects the developments within WP.29 since 2012 (Adoption of the Revision 3 to the 1958 Agreement, Amendment to the Terms of Reference and Rules of Procedures, proposed amendment to the 1997 Agreement, the adoption of new Resolutions and the new structure of the subsidiary bodies of WP.29). It provides the foundation and methods of operation the World Forum. The principal intent of this document is to present the organizational structure and operational process of WP.29 and its subsidiary bodies and their relationship to specific multinational agreements under the United Nations. It also describes the three main UNECE agreements concerning vehicle regulations. The "Blue Book" is available on the WP.29 website - https://unece.org/transport/publications/world-forum-harmonization-vehicle-regulations-wp29-how-it-works-how-join-1.

Our "Road Maps" provide further in-depth information on how to prepare for accession and how to implement the Agreements. The Road Maps for accession to and implementation of the 1958 and 1997 Agreement (ECE/TRANS/WP.29/2018/163) and the 1998 Agreement (ECE/TRANS/WP.29/2019/30) aim to provide guidance to countries wishing to accede and implement the Agreement, and propose the implementation of main steps that, if pursued in a proper and timely manner, would result in the full application of the systems in their territories. The Road Maps are available on the WP.29 website - https://unece.org/roadmap-accession.

CHAPTER III

Vehicle safety impact for road safety

Specialists and the public use the term road traffic safety widely. Such use rarely generates serious misunderstanding even though there is no globally agreed upon precise or quantitative definition of traffic safety. The general concept is the absence of unintended harm to living creatures or inanimate objects. A vehicle striking anything is referred to as a crash. The consequences of crashes include fatalities, severe or slight injuries and property damage.

As laid out in chapter I, crashes result from many factors operating together. Instead of focusing on a single cause, we generally think of a list of factors, which, if different, would have led to a different outcome. The goal of safety analysis is to examine factors associated with crashes with the aim of identifying those that can be changed by countermeasures, interventions, which enhance future safety. Quantitative safety measures nearly always focus on the magnitudes of departure from a total absence of some type of harm, rather than directly on safety as such.

The Global Plan for the Decade of Action for Road Safety 2011-2020 provided an overall framework for activities, which may take place in the context of the Decade. The categories or "pillars" of activities are:

- Building road safety management capacity;
- Improving the safety of road infrastructure and broader transport networks;
- Further developing the safety of vehicles; enhancing the behaviour of road users;
- Improving post-crash response.

These pillars are meant to address and mitigate the various factors that contribute to road crashes. Indicators have been developed to measure progress in each of these areas. Governments, international agencies, civil society organizations, the private sector and other stakeholders make use of the Plan as a guiding document for the events and activities they will support as part of the Decade.

Pillar three of the UN Decade of Action is Safer Vehicles. Road vehicle safety performance is still a major issue across the globe, even though motor vehicles in high-income countries are much safer today than ever before. This is the result of a combined effort to use mandatory standards for the construction of vehicles, their equipment and parts, and consumer information to advance the safety performance of motor vehicles. Policy makers and the automotive industry assign top priority to developing and implementing measures to, on the one hand fully avoid crashes, and on the other to reduce their consequences. Vehicle design improvements introduced over the past decades have significantly reduced the risk of death in a crash. Occupant protection from wearing a safety-belt reduces fatality risk by 42 per cent (safety-belt plus airbag by 47 per cent), so a belted driver in a modern car is less than half as likely to die as a driver in a 1950s car of a similar mass in an identical crash. This is a major achievement and has saved many lives. Therefore, a set of UN Vehicle regulations have been identified within the UN Decade of Action as minimum set of recommended regulations that, if adopted and enforced, can contribute significantly to improving the road safety performance of countries (Table 1).

Passive and active safety

The greatest contributor to vehicle safety over the last fifty years has been improved occupant protection or crashworthiness. It is also referred to as passive safety (or secondary safety) and it signifies engineering features aimed at reducing losses when a specific crash occurs. Examples include padding the vehicle interior, making a structure that is not close to the occupant crumple during the crash while keeping the occupant compartment strong to prevent intrusion of struck objects, and devices such as airbags and collapsible steering columns. Reducing the risks of post-crash fires are also crashworthiness features.

Crash test standards and independent consumer rating programmes have helped to secure significant reductions in crash fatalities even as exposure to injury through rising vehicle use has increased substantially. This is especially true in markets in high-income and higher-middle income countries where a high number of passive safety features are mandatory equipment even in the least expensive vehicle models. In its 2015 report, NHTSA estimated that more than 600 thousand lives were saved in the USA between 1960 and 2012 as a result of automotive safety technologies required by Federal Motor Vehicle Safety Standards (Kahane, 2015). Countries of the European Union registered a 55 per cent reduction in car occupant fatalities between 2001 and 2012 (Jost et al., 2014). An analysis of vehicle-based crash rates in the Australian state of New South Wales estimates that occupant fatality risk of cars built in 2010 is 75 per cent lower than for those built in 1995 (Anderson and Searson, 2014). The gains derived from improved crashworthiness are now being supplemented by active safety systems which can reduce potential impact speeds or avoid a crash entirely and will sustain the positive contribution that vehicle technology made to reducing road fatalities.

In general terms, crash avoidance vehicle technologies refer to measures aimed at preventing a crash from occurring. Such engineering measures include enhancements to lighting and light-signalling, braking and running gears, steering and roll-over stability, as well as for example the introduction of proximity sensing technology applications in vehicles. The earliest crash avoidance, or active safety, technology was anti-lock brakes (ABS) and this has been followed more recently by electronic stability control (ESC), which prevents uncontrolled skidding incidents. ESC detects whether steering inputs of the driver are consistent with the vehicle's direction of travel. If this is not the case, ESC applies the break to one of the wheels (using ABS) to correct the slide.

A summary of nearly twenty ESC effectiveness studies undertaken in Europe, Japan and North America, between 2001 and 2009 indicates ESC to be highly effective (between 18 per cent and 73 per cent effectiveness depending on type of crash, conditions and casualty outcomes of the specific scenarios investigated) at reducing single-vehicle, run off road, opposing-traffic, loss of control and roll-over crashes as well as reducing the risk of fatal outcomes and serious injuries in cars and SUVs (see: Fitzharris et al., 2010, pp. 15-23). ESC is now mandatory in Australia, Canada, the European Union, Japan, New Zealand, South Korea, and the United States of America in all new vehicles. In 2014, ESC became a mandatory requirement in all new cars in the European Union, where it is estimated that it prevented at least 188,500 injury-crashes and saved more than 6,100 lives since 1995[5].

Impact of technologies of UN Vehicle Regulations recommended through the UN Decade of Action

The construction of vehicles, their equipment and parts are typically not regulated in emerging markets to the same extent as seen in industrialized regions. Casualty rates observed in developing countries are considerably higher and the lack of vehicle safety regulation is responsible for at least some of this difference. With rapid growth in passenger vehicle fleets, the number of road deaths has been rising and is projected to continue in a regulatory business-as-usual scenario. Vehicle safety technologies effect on prevention of fatalities and injuries has been broadly examined in scientific literature and sectoral governmental, intergovernmental and industry reports from all over the world. The purpose of technology assessment studies is to quantify the impact of vehicle safety technologies that are mandated through regulations or to estimate their potential impact, namely to project the future reduction of fatalities and injuries that can be expected as a result of vehicle technology standards mandated through regulations. Technology assessment is one of the steps in the complete impact assessment process for enacting vehicle safety regulations. The process will be described in detail in the next chapters. The section below presents an overview of impact assessment studies and their results carried out for a range of technologies that are addressed in UN Vehicle Regulations, including those that are identified in the UN Decade of Action as the minimum set of recommended vehicle safety regulations to improve road safety.

Before going into the examples of regulation impact assessment studies themselves, it is important to keep in mind what the regulations that are discussed here represent. Regulations under this review, such as the frontal-impact and side-impact regulations, are not deemed to impose the particularities of safety systems and their design but mandate specific performance requirements that will be verified through comprehensive test procedures which examine whether the tested vehicle can sustain a required level of passenger protection. To illustrate with an example, the different solutions used by car manufacturers to meet the requirements of UN Regulation No. 95, which include a test procedure in which a vehicle is struck by a mobile barrier traveling at 50 km/h, include: side paddings implemented in the trim of the doors, side thorax airbag implemented in the passenger seat or in the trim of the door, side curtain airbag implemented in the roof of the car, and various structural reinforcements implemented throughout the car body structure. Therefore, it is up to the car manufacturers what materials and designs they will implement to meet the requirements of for example UN Regulations Nos. 94 and 95. Similarly, lighting regulations mandate that headlights comply with certain photometric specifications, such as requirements on the amount, colour and intensity of light to be produced, but their designs are not restricted to a specific shape, such as round or square.

5 Information from: http://www.globalncap.org/electronic-stability-control-esc-must-become-standard-fit-worldwide-says-global-ncap/

It is also important to note that the number of lives saved, and the potential lives saved are, in calculations, not derived through a case by case examination of serious crashes. It would be difficult, highly subjective and speculative to conclude for a given crash that an occupant did not die because they used a belt, and/or an airbag deployed, or that they were killed because they did not use the restraint. Modelling is instead based on the number of fatalities, the restraints that they used and the effectiveness of these restraints in preventing fatalities. Effectiveness ratings of safety technologies or vehicles' structural elements are calculated based on historical crash data by applying statistical methods, such as logistic regression for example, for disaggregating the effects of safety systems in place or activated in a certain type of crash (frontal, lateral, etc.).

Side impact protection

The purpose of UN Regulations Nos. 95 and 135, and UN GTR No. 14 is to reduce the risk of serious and fatal injury of vehicle occupants in side impact crashes by limiting the forces, accelerations and deflections measured by anthropomorphic test devices in pole side impact crash tests and by other means. The passive safety countermeasures used in vehicles to meet the requirements of UN GTR No.14 reduce the injury risk in pole side impact crashes as well as other side impact crashes, including high severity vehicle-to-vehicle side impact crashes and/or crashes where head injury risks not simulated by previous regulatory barrier tests occur as a result of geometric incompatibility between vehicles. Benefits are also observed in mitigating the effects of roll-over crashes (ECE/TRANS/180/Add.14, pp. 5). It is reasonable to assume that a portion of rollover fatalities and injuries are avoided through the implementation of UN GTR No.14. The main benefit of the pole side impact countermeasures in protecting vehicle occupants in a rollover is by prevention of ejection through side windows. This may only be effective in a subset of crashes as it is necessary for sensors to detect rollovers without side impact (unless the rollover is initiated by a side impact) and for the deployed curtain to cover the window area and remain in place sufficiently long to prevent ejection (ECE/TRANS/180/Add.14, pp. 12).

The study on priorities for enhanced side impact protection in UN Regulation No. 95 compliant cars (Thomas et al., 2009) endeavours to estimate the effectiveness of UN Regulation No. 95 in preventing casualties resulting from car to car side impact crashes that took place in 2005. Authors carry out a comparative analysis of three national cases - France, Sweden and the United Kingdom - using data from the respective national crash databases (BAAC, STRADA and STATS 19). They analyse the impact of the regulation by comparing casualty rates in vehicles registered in each country before and as of 2003, when all newly sold vehicles in the countries were required to meet the side-impact regulatory requirements. The results show that side-impact casualty rates for occupants of post-2003 registered new vehicles were in France 26 per cent, in Sweden 61 per cent and in the UK 3 per cent lower as compared to earlier models. The data indicates that there had been improvements in safety in the period under consideration which resulted from the introduction of UN Regulation No 95, while the inconsistency in the range of casualty reduction observed (3 per cent to 61 per cent) is explained as being a consequence of different data sampling practices in the three case countries. The authors assert that the availability of representative crash data is fundamental to the development of relevant performance criteria to reduce the impact of crashes.

In a study prepared by Injury Research Institute Accident Research Centre of Monash University in Australia (Fitzharris & Stephan, 2013), authors find that considerable fatality and serious injury reductions would be realised through the implementation of the UN GTR No. 14 on Pole Side Impact (PSI). Between 2001 and 2006, a total of 898 occupants of M1 and N1 vehicles were killed in pole side impact crashes. These fatalities comprise 15.6 per cent of the total number of M1 and N1 vehicle fatalities, and 9.1 per cent of all road traffic fatalities in Australia during that six-year period. Throughout the first 30 years, the improved side impact safety requirements demanded by the pole-side impact GTR will translate to 761 fewer passenger car (M1) and light commercial vehicle (N1) occupant fatalities and a substantial reduction in the number of severe head injuries and other serious injuries. To put this estimate into perspective, it is important to note that front row occupants are expected to be the most affected vehicle occupants, in terms of lives saved and injuries prevented. Also, the introduction of the PSI GTR is highly cost effective for both the M1 and N1 vehicle segments and sensitivity analysis highlights the robust nature of the benefits across a range of benefit scenarios. The combined economic saving is approximately $AUD 3.47 billion for a cost of $AUD 0.726 billion, resulting in a benefit-cost ratio (BCR) of 4.77:1. The study concludes that the adoption of a requirement for vehicles to pass an oblique narrow object side impact performance-based standard will deliver significant benefit to the community.

Braking systems

The study carried out by Chouinard and Lécuyer (2011) is an effectiveness evaluation of Electronic Stability Control (ESC, UN Regulation No. 140) using crash data. The purpose of a Canadian evaluation study was to examine whether there was an issue with multi-vehicle crashes, and whether ESC is effective in Canadian weather conditions, i.e. on ice, snow and slush. Results show that ESC is effective for all ESC-sensitive crashes (41.1 per cent effectiveness) as well as ESC-sensitive injury only crashes

(54.8 per cent effectiveness). In particular, ESC is effective in the case of all multi-vehicle ESC-sensitive crashes (23.2 per cent effectiveness) and of multi-vehicle ESC-sensitive injury crashes (28.4 per cent effectiveness). ESC is also effective for single-vehicle ESC-sensitive crashes, both for all severities of crashes (18.6 per cent effectiveness) and injury crashes only (49.3 per cent effectiveness). The results of the study also show that ESC is effective in Canadian weather conditions (i.e. on ice, snow and slush). The effectiveness of ESC on roads covered with ice, snow and slush is 51.1 per cent for ESC-sensitive crashes of all severities and 71.1 per cent for ESC-sensitive injury crashes. ESC is also effective on dry roads (36.3 per cent effectiveness for ESC-sensitive crashes of all severities and 46.6 per cent effectiveness for ESC-sensitive injury crashes), wet roads (35.8 per cent effectiveness for ESC-sensitive crashes of all severities and 49.5 per cent effectiveness for ESC-sensitive injury crashes) and for both cars (28.5 per cent effectiveness for ESC-sensitive crashes of all severities and 43.7 per cent effectiveness for ESC-sensitive injury crashes) and light trucks (51.9 per cent effectiveness for ESC-sensitive crashes of all severities and 69.6 per cent effectiveness for ESC-sensitive injury crashes).

During the period 2000 to 2011, on average, 220 pedestrians and 36 cyclists were killed each year in Australia as a result of collisions with vehicles. The Australian Regulation Impact Statement (RIS) (DIRD, 2014) examined the case for Australian Government intervention in order to increase the fitment rate of BAS to the new light vehicle fleet in Australia. A total of six options, including both regulatory and non-regulatory were considered. The focus of the analysis was on benefits for pedestrians and cyclists. The results of a benefit-cost analysis showed that, even in the presence of the high fitment rates predicted by the Australian vehicle industry, there is a case for government action to increase the installation of BAS in passenger cars, sport utility vehicles (SUV) and light commercial vehicles (LCV). Non-regulatory options of running an information campaign and changing government fleet purchasing policies would both be expected to provide a small net benefit to the community. The implementation of a mandatory standard under the Motor Vehicle Standards Act (MVSA), known as an Australian Design Rule (ADR), would generate the highest net benefits of the options examined. Compared with the business as usual case, this option would provide net benefits of $30m, saving 10 lives and preventing over 200 serious injuries over a 15-year regulation period. It is also likely to be the option that results in the highest ongoing fitment rate of BAS in new vehicles, thereby maximising the benefits that BAS has to offer. Regulation through the MVSA is therefore the recommended option. The recommended requirements to be applied are those contained in the UN Regulation No. 13-H, as adopted by the WP.29. The proposed implementation timetable was 2015 for new models and 2016 for all models.

Restraint systems

Elvik et al. (2009) conducted a meta-analysis of 29 studies on the effectiveness of safety-belts developed in Australia, several European countries and the United States of America. Their findings state that, in passenger car and van traffic crashes, safety-belts prevent 50 per cent of driver, 45 per cent of front seat passenger and 25 per cent of rear seat passenger fatal injuries. In terms of serious injuries, results indicate a 45 per cent reduction for drivers and front seat passengers, and a 25 per cent reduction with regard to serious injuries suffered by rear seat passengers.

A study commissioned by the Australian Transport Safety Bureau (Fildes et al., 2003) sought to determine whether fitting a more aggressive safety-belt reminder system to new vehicles would be cost-beneficial for Australia. While safety-belt wearing rates have been observed around 95 per cent in the front seat, non-wearing rates in casualty crashes are as high as 33 per cent among persons killed and 19 per cent among seriously injured occupants. Benefits were computed for three device options (simple, simple-2 and complex) and three introduction scenarios (driver-only, front seat occupants and all occupants). Four levels of effectiveness were assumed, from 10 per cent to 40 per cent, depending on the type of device fitted. Unit benefits were computed assuming a 5 per cent discount rate and a 15-year fleet life. Various industry experts provided the costs. The findings showed that BCRs ranged from 4.0:1 at best (simple device for the driver only) to 0.9:1 for all seating positions.

The European Transport Safety Council (ETSC, 2003) also investigated the potential benefits of audible safety-belt reminders in car front seats. Taking into account injuries as well as fatalities it is shown that the present value of the benefits of requiring audible safety-belt reminders for the front seats of cars in the European Union amounts to 66,043 million Euro. The present value of the costs amounts to 11,146 million Euro, giving a benefit-cost ratio of 6:1, with the benefits of audible safety-belt reminders for front seats thus clearly exceeding estimated costs.

Child restraint systems (CRS) have had a significant safety impact as well. The Norwegian Traffic Safety Handbook (Høye, 2020) provides an example, in its chapter 4.13 "Securing children in a car", of a simplified utility cost analysis to approximate the number of child injuries avoided annually thanks to the use of approved child safety equipment, the costs incurred to achieve today's level of use of CRS equipment and the socio-economic benefit stemming from the harm-reducing effect of child safety equipment.

The effect is calculated under the following preconditions: In the years 2008-2012, an average of 10.4 of children aged 0-10 were killed, 8.2 were severely injured and 258.4 were slightly injured (applies only to children who were passengers in light vehicles). The applied model assumed that the statutory use of child safety equipment reduces the risk of fatalities by 40 per cent, the risk of severe injury by 35 per cent and the risk of minor injuries by 20 per cent. If in 95 per cent of the cases CRS were for transporting children in cars, according to the model, 6.4 deaths, 4.1 severe injury and 60.6 slight injuries would be avoided.

Lighting systems

The 2003 study carried out by the TÜV Rheinland Group for the European Commission (TÜV, 2004) investigated the effects of a mandatory introduction of UN Regulation No. 104 on "retro-reflective marking for heavy and long vehicles and their trailers" on crashes, and developed a cost-benefit analysis of the measure.

In addition to the standard signal lamps, the retro-reflective contour-marking is intended to increase the visibility (recognition) over a wide range of distances and for an easy identification of certain vehicles. As part of background research, the authors offer a number of assertions, including that the optimal colour of the retro-reflective material is "white" (colourless), that contour-marking can reduce the reaction time of drivers by a factor of more than 5 and can enlarge the recognition distances by 50 per cent to 500 per cent, and that in adverse weather conditions the recognition of retro-reflective contour-marking is better compared with that of signal lamps. The authors queried the CARE database to determine the number of crashes where contour-marking of Heavy Goods Vehicles (HGV) with retro-reflective material could have had an impact, identifying 4,531 personal damage crashes per year in the European Union-15 with 402 fatalities, 2,159 seriously injured and 4,904 slightly injured persons . The crash avoidance potential analysis - an estimate of how many of those relevant crashes would probably be avoided - of retro-reflective markings of HGV determined crashes leading to 165 fatalities, 857 seriously injured and 1,836 slightly injured persons could have been prevented had retro-reflective contour-markings been applied to vehicles involved in the sample.

In the cost-benefit analysis, the number of avoidable crashes and fatalities has been valued monetarily in order to determine the monetary benefits of the contour-marking of HGV. Alternative costs of contour-markings and various application scenarios had been taken into consideration, including which tonnage class of HGV (> 3.5; > 12) is considered for mandatory contour-marking, the assumed economic lifetime of the retro-reflective material, and the duration of the phase-in period for the fleet of HGVs. Sensitivity calculations supported the general conclusion of the cost-benefit analysis, which was that equipping HGVs with retro-reflective contour-marking in the European Union is cost-effective, with benefit-cost ratios ranging between 1.2 and 6.

The 2019 study by the University of Michigan Transport Research Institute (Leslie et al., 2019), commissioned by General Motors (GM), analysed the safety system content of over 3.7 million vehicles, across twenty different GM Model Year 2013-2017 vehicles provided by GM to UMTRI to examine the field effectiveness of fifteen active safety and advanced headlighting systems. These data were matched to police-report data from vehicles involved in crashes using ten US state crash databases. The analysis of lighting systems concluded that Intellibeam (automatic high beams) and High-Intensity Discharge (HID) headlight features provided 35 per cent and 21 per cent reductions, respectively, in night-time pedestrian/bicyclist/animal crashes relative to halogen headlights (with a 49 per cent reduction when both systems are present in a vehicle). The elements mentioned in the study (HID, articulating HID, Intellibeam, adaptive driving beam, etc.) are addressed by the following UN Regulations (terms could be different):

- No. 99 - Gas-discharge light sources
- No. 98 - Headlamps with gas-discharge light sources (being replaced by UN Reg. No.149)
- No. 112 - Headlamps emitting an asymmetrical passing-beam (being replaced by UN Reg. No.149)
- No. 123 - Adaptive front lighting systems (AFS) (being replaced by UN Reg. No.149)
- No. 149 - Road Illumination Devices (RID)

The report acknowledges that in the headlighting analysis it addresses animal, bicyclist and pedestrian crashes collectively as VRU crashes and that analysed occurrences are dominated by animal crashes, especially at night. The authors state that *"This allows us to estimate the benefits of headlamps, but these benefits primarily apply to night-time animal crashes. That said, we argue that the mechanisms for each of these three VRU crash types involve the driver's inability to see the VRU at night early enough to prevent a crash. Thus, a headlamp effect for animal crashes is likely to apply to pedestrian and bicyclist crashes as well since the underlying causal mechanism for the crash should be similar."* In addition, the report emphasizes that *"The rarity of front pedestrian crashes means that a substantially larger dataset would be required for a pedestrian only analysis to have sufficient power to detect effects of this magnitude."*

Tyres

Optimized friction coefficients between tyres and road surfaces reduce the braking distance of vehicles, thus reducing collision speed and incidences of fatal and serious injury road traffic crashes. Several literature sources analyse the relationship between tyre grip values, the performance of tyres on dry and wet surfaces, braking performance and these factors relationship with road traffic crashes and injury severity. A study by Otte et al. (2008), which analyses data from the German in Depth-Accident-Study (GIDAS), indicates that improved grip performance of tyres can reduce collision speeds of cars in 30 per cent of all traffic crashes that result in personal injuries. The analysis shows that a 10 per cent tyre grip value increase on dry roads and a 15 per cent tyre grip value increase on wet road surfaces would result in the reduction of fatalities by 2 per cent and severe injuries by 1.8 per cent. Conversely, the results of the study argue that a reduction of dry surface tyre grip by 10 and wet grip values by 15 percent may result in a 2 per cent increase in fatalities and a 7 per cent increase in the number of serious injury crashes. The authors emphasize that the most impacted road users according to the modelled changes in grip values are pedestrians and cyclists, in terms of VRUs injury severity in sampled crashes.

Safety in wet conditions can be improved by testing of worn tyres. Such tests are deemed necessary because the wet grip performance of a worn tyre cannot be predicted from the test results of a new tyre. An analysis by Biesse (2019) states that relevant test already exists, namely the vehicle wet braking test defined within UN Regulation No. 117 applied to worn tires. The author highlights that removing from the market tyres that are not performing sufficiently well when new, when their performance is at its maximum, would , increase the wet grip level during their lifetime, ensure a minimal performance when they are worn, altogether improving wet driving safety. The analysis concludes that such practices would improve the wet road safety and give drivers confidence to use their tyres up to the legal limit.

Motorcycle equipment and systems

The report of the Norwegian Centre for Transport Research, Institute of Transport Economics, (Høye, 2016) reported estimated crash mitigation effectiveness ratings for motorcycle helmets (UN Regulation No. 22), daytime running lamps (UN Regulation No. 53) and anti-lock braking systems (UN Regulation No. 78). The report states that other road users often fail to detect motorcycles and that motorcyclists are more vulnerable to injuries than other motor vehicle occupants. Based on a literature review of empirical studies, the report infers that sports bikes have higher risk than most other motorcycles, while engine volume or capacity were not found to be related to crash involvement. Daytime running lights on motorcycles and mopeds were found to reduce multi-vehicle crashes by about 40 per cent, while mandatory daytime running lights were found to reduce the total number of multi-vehicle crashes with motorcycles by about 10 per cent. The report indicates that motorcycles helmets reduce the risk of fatal head injuries by 60 per cent and brain injuries by 47 per cent (also on all-terrain vehicles), and that full-face helmets provide better protection than modular helmets, open face or half helmets. Concerning antilock brakes for motorcycles, results indicate that those systems reduce injury crashes by 30 per cent, with effects being greater in more serious crashes and on wet road crashes.

The Australian early assessment regulation impact statement of 2017 concerning Advanced Motorcycle Braking Systems for Safer Riding report (DIRD, 2017) found that the principal advanced braking system for motorcycles, ABS, could help in 93 per cent of crash situations. This in practice reduces motorcycle trauma crashes in Australia by 31 per cent overall, including a 36 per cent effectiveness in alleviating serious and fatal trauma crashes, which is in alignment with international effectiveness findings. Findings state that advanced braking systems are particularly effective against serious and fatal motorcycle trauma, which account for the overwhelming cost of motorcycle trauma (in Australia 97 per cent of all motorcycle trauma cost is from serious and fatal injuries). A total of six options, including both non-regulatory and regulatory, such as mandating Combined Braking Systems (CBS) or ABS, were explored for motorcycles with a capacity of 50cc and above. Tables 3.1, 3.2 and 3.3 below summarize the results of the analysis and the projected impacts of the measures under consideration.

TABLE 3.1

Summary of net benefits and gross benefits for each option

	Net benefits ($m)			Total benefits before costs($m)
	Best case	Likely case	Worst case	
Option 1: no intervention	-	-	-	-
Option 2a: targeted awareness	372	368	364	393
Option 2b: advertising	379	375	371	468
Option 6a: mandatory ABS	1465	1452	1439	1492
Option 6b: mandatory ABS/CBS	1633	1618	1604	1663

TABLE 3.2

Summary of costs and benefit-cost ratios for each option

	Costs ($m)			Benefit-cost ratios		
	Best case	Likely case	Worst case	Best case	Likely case	Worst case
Option 1: no intervention	-	-	-	-	-	-
Option 2a: targeted awareness	22	25	29	18.2	15.6	13.6
Option 2b: advertising	89	92	96	5.3	5.1	4.9
Option 6a: mandatory ABS	27	40	54	55.3	37.1	27.9
Option 6b: mandatory ABS/CBS	30	45	59	55.6	37.2	28.0

TABLE 3.3

Summary of number of lives saved and injuries avoided

	Lives saved	Severe TBI[6] avoided	Moderate TBI avoided
Option 1: no intervention	-	-	-
Option 2a: targeted awareness	97	1186	1353
Option 2b: advertising	190	2337	2666
Option 6a: mandatory ABS	534	7754	7484
Option 6b: mandatory ABS/CBS	587	8522	8225

The United Nations Motorcycle Helmets Study (United Nations, 2016) examines issues, progress and challenges in efforts to improve the safety and wellbeing of powered two-wheeler riders through the appropriate use of type-approved motorcycle helmets. It outlines that substantial benefits could be derived from implementing and enforcing helmet-wearing legislation in line with UN Regulation No. 22, estimating that 3.4 million deaths may have been caused by motorcycle crashes during the period 2008-2020, of which 1.4 million could have been prevented by the proper use of safety helmets.

The results of the study indicate that, globally, up to 676 billion US dollars could have been saved thanks to fatalities and serious injuries prevented in 2020 as a result of helmet wearing policies. Low and upper-middle income countries (UMIC) could have saved up to 2.1 and 3 per cent of GDP, respectively, in 2020 with enforcement of helmet wearing policies, high-income countries could have saved about half of one per cent, while low-middle income countries (LMIC) could have saved as much as 7 per cent of GDP in 2020. Although the potential savings projected for low-middle income countries seem exaggerated, they are justified by the fact that motorcycles constitute between 50 and 80 per cent of all registered vehicles in the largest countries of this income category included in the analysis.

Considering maximum purchases of high-end helmets, and the upper-end of the range of potential savings resulting from helmet-use avoided fatalities and serious injuries, a benefit-cost ratio of 2.2:1 is obtained for the group of low-income countries.

6 Traumatic brain injury

In other words, in the particular scenario, the benefits of purchasing such helmets outweigh the costs of not doing so by a factor of 2.2. Conversely, if all helmets used by riders are low-end products, and considering the lower end of the range of estimated savings stemming from avoided injuries and fatalities, a benefit-cost ratio of 1:1 is obtained, indicating that massive use of low-end helmets, apart from providing a dangerously false sense of safety, also delivers no monetary benefits whatsoever to society.

The benefit-cost analysis for LMIC and for UMIC computes ratios of 4:1 and 4.3:1 respectively, when considering maximum purchases of highest end helmets, and the upper end of the range of potential savings resulting from helmet-use avoided fatalities and serious injuries. These results indicate that it can potentially be four times more cost-effective for societies in LMIC and UMIC to dedicate resources to expensive helmets than to continue riding their motorcycles without head protection. The authors state that achieving economies of scale on the helmet market would improve the benefit-cost ratio of helmet expenditures. Adoption of type approval standards and enforcement of helmet wearing regulations would therefore, apart from contributing initially to decreasing fatalities and injuries (as well as consequent expenditures), also stimulate local production of approved helmets at a much broader scope, helping to decrease market prices of helmets and further improving the benefit-cost ratio calculated above, even if using modest projected savings figures within the obtained range.

High-income countries are the most advanced in adoption and enforcement of motorcycle helmet related rules and regulations. Nevertheless, according to the study, there is still room for improving the negative economic impact resulting from motorcycle crashes. The benefit-cost ratio of 1.2:1 is obtained when considering maximum purchases of highest-end, most expensive, helmets, in a scenario of lowest projected savings. This means that even when considering the most conservative projections, the social monetary savings potential associated with purchasing the most expensive helmets in high-income countries is 20 per cent higher than the expenses that may be incurred within those societies as a result of fatalities and serious injuries that are the consequence of motorcycle crashes in which riders are not wearing helmets.

Aggregated estimates of multiple regulatory interventions

A study carried out by Lloyd et al. (2015) offers an analysis of the combined impact of UN Decade of Action minimum recommended regulations (UN Regs. 14, 16, 94, 95 and 140; UN GTRs Nos. 8 and 9) on road safety in the UK for the period 2004-2013. When taking into account new vehicles registered as of 2004-05 in the UK, results indicate that 4.2 per cent fewer car drivers died between 2004 and 2013 due to the improvements in passive safety of vehicles stemming from applying the package of UN Regulations. Based on UK results, the authors apply a scenario-based model to quantify how many car user fatalities are likely to be prevented in Malaysia between 2014 and 2030, as a combined impact of adopting the minimum recommended regulations. Contingent on the change in motorization rates and the rate of uptake of new cars, the model concluded that between 1,200 and 4,300 car occupant fatalities are likely to be prevented on roads in Malaysia between 2014 and 2030 as a result of the adoption of UN Decade of Action minimum recommended UN Regulations. In a follow-up analysis, Cuerden et al. (2015) applied the same methodology to estimate the number of car occupant casualties that could be prevented in Brazil. It was estimated that 10,200 car occupants died as a result of a road collisions in Brazil in 2010. That was a higher death rate per unit of population than has ever been observed in Britain. With the number of cars predicted to increase over the next 15 years by an annual average rate between 0.7 per cent and 14.8 per cent, this death toll is expected to rise considerably unless road safety strategies and regulations can be effectively introduced. Assuming that similar regulations were introduced, and a similar impact of consumer testing was observed in Brazil between 2015 and 2030 as was seen in Great Britain between 2002 and 2017, it is predicted that between 12,500 and 34,200 fatalities could be prevented by 2030.

The UK TRL published a comprehensive study (Wallbank et al., 2019) that estimates the lives that could be saved and injuries that could be prevented by application of a set of vehicle safety regulations (UN Regs. 14, 16, 94, 95, 127 and 140; UN GTRs Nos. 8 and 9; AEB for VRUs) from 2020 to 2030 in Brazil, Argentina, Chile, and Mexico, and provides cost-benefit estimations of their application. Some progress has already been made towards implementation of these priority standards, as a result of efforts within the four countries to adopt minimum UN Decade of Action minimum recommended regulations for crashworthiness (UN Regs. 14, 16, 94 and 95). If these initiatives continue, this study estimated that these crashworthiness regulations will prevent 11,000 car occupant fatalities up to 2030. It also estimated that if regulations for ESC, secondary safety pedestrian protection and AEB for VRU are adopted, an additional 14,000 lives could be saved during the 2020 to 2030 period (12,000 of which would be VRUs). In total, if Argentina, Brazil, Chile, and Mexico adopted the set of priority vehicle safety standards from 2020, more than 25,000 lives could be saved and over 170,000 serious injuries prevented, by 2030. The results of a benefit-cost analysis of the combined application of ESC, AEB-VRU and pedestrian protection regulations in the individual countries indicates that measures would cumulatively become cost beneficial latest by 2026. As a best estimate, the payback time for Brazil and Mexico would be three years, for Chile two years, while for Argentina the monetary benefits would start to exceed the costs after four years (Table 3.4).

TABLE 3.4

Year in which the combined set of technologies becomes cost-beneficial in each country

Country	Payback time in years (2020 initial year of application)		
	Best estimate	Shorter estimate	Longer estimate
Argentina	4	6	3
Brazil	3	5	1
Chile	2	3	1
Mexico	3	5	1

Safety-belts, airbags, ESC, frontal impact and side impact protection and other safety measures for the construction of vehicles referenced in the UN Decade of Action and the instruments regulating them save thousands of lives on roads worldwide each year. Road transport stakeholders, such as national regulators, public health promoters and research institutes quantify the benefits of these devices and regulations by estimating the number of people saved by each device, the number of victims would have survived if more occupants were protected by these devices, and the corresponding expressions of the savings and loss in financial terms. This information is then used to perform cost benefit analyses of proposed regulations, and to obtain estimated benefit cost ratios of their application. The details of these topics are discussed in the next chapter. The research presented in this chapter is a limited selection of representative vehicle regulation impact assessment studies.

CHAPTER IV

Impact assessment and cost benefit analysis of vehicle safety regulations - elements in model

Vehicle regulations designed to improve road safety aim to reduce the risk of occupant injury and death and therein improve the utility, or benefit, of motorized road transport. An impact assessment of adopting and applying vehicle safety regulations is carried out in many countries in the world as part of the decision-making process in the lead up to proposing legislation. In many cases it is a mandatory step in the regulatory process, as an ex-ante effectiveness evaluation. The goal is to determine the socio-economic efficiency of the proposed regulatory measure(s). Impact assessments and cost benefit analysis are carried out as part of the development of some vehicle safety-related UN Regulations annexed to the 1958 Agreement and some vehicle safety related UN GTRs under 1998 agreement. Although there are differences in methodologies applied within the different stages of the process, it generally consists of the following steps:

I. Definition of relevant crashes

A safety measure that is promoted through a proposed regulation is designed to address a specific type or types of crashes. For example, for ESC systems only left roadway crashes are considered. For the BAS only rear end and head on collisions, merging and intersection collisions, vehicle-pedestrian collisions, collisions with obstacles and left roadway crashes are relevant. Pole-side impact safety systems address crashes against narrow objects such as poles and trees. Data on types of crashes, their number and severity of the injuries suffered are available in many countries in national traffic crash databases as well as in professional and academic literature. In numerous countries, though, data on specific types of crashes involving a concrete population of traffic participants is not available. In the case studies presented in chapter 5, factors from literature that estimate the ratio of specific types of traffic crashes and their impact on the total population of a certain segment of traffic participants, victims, under observation, such as drivers and occupants of four-wheeled light vehicles, or pedestrians struck by the fronts of four wheeled-light vehicles, are used to overcome such data gaps.

II. Technology assessment

Information on the effectiveness of the technologies under consideration can be found in literature, in studies that have been carried out. The benefits of implementing a certain safety technology can be in the form of reduced probability of the occurrence of the observed crash types (e.g. lateral collision, rear end collision, etc.) and/or severity of the consequence of the crash for vehicle occupants and/or other traffic participants, depending on the types of crashes and collisions that the technology is designed to address. In other words, the implementation of a certain technology reduces the risk of fatalities and injuries in certain types of crashes.

III. Structure of fleet

In order to estimate the impact of the introduction of certain regulatory measures and the vehicle safety technologies that they mandate, the structure of the existing fleet needs to be analysed. The prevalence of safety technologies in vehicle fleets will depend on existing policies, when they entered into force and as of when the technologies have become mandatory in new vehicles sold on the market, on the average age of the vehicle fleet and on the fleet turnover rate.

IV. Scenario for implementation

The scenario refers to the schedule for the diffusion of a safety technology within the vehicle fleet, or its segment, over time. Several scenarios can be developed to estimate the impact of the technology on road safety. The most common approach is to determine a reference scenario, sometimes called a do-nothing scenario, in which no actions/policies are put in place to promote (or further promote) the use of a safety technology, and to compare its road safety impact over time with the projected impacts of modelled do-something/full application scenarios. Such scenarios should consider projections based on a set of assumptions for the envisaged period, including on population growth, macroeconomic and oil price developments, technology improvements, and policies. Most importantly, a set of assumptions concerning safety measures should be included in the model. Those would include the impact of existing vehicle technology safety measures that are mandatory but still dispersing into the vehicle fleet at the pace of the location-specific vehicle fleet turnover rate. Furthermore, the extent of voluntary uptake of vehicle technology safety measures, gradual market penetration, should be factored into the baseline scenario, as a result of for example market competition between vehicle manufacturers and/or impact of the diffusion of information on vehicle safety ratings among consumers. The do-something/full application scenarios commonly define the scope of introduction of the technology under consideration in all new vehicles as of a specific point in time, whether it would be mandatory for all types of vehicles or only for specific types, and any variation of the two in time. Do-something/full application scenarios are technology specific as for some types of safety regulation, such as motorcycle helmets, child restraint seats or retrofitting measures (tyres, mirrors rear underrun protection), they are either made mandatory or not.

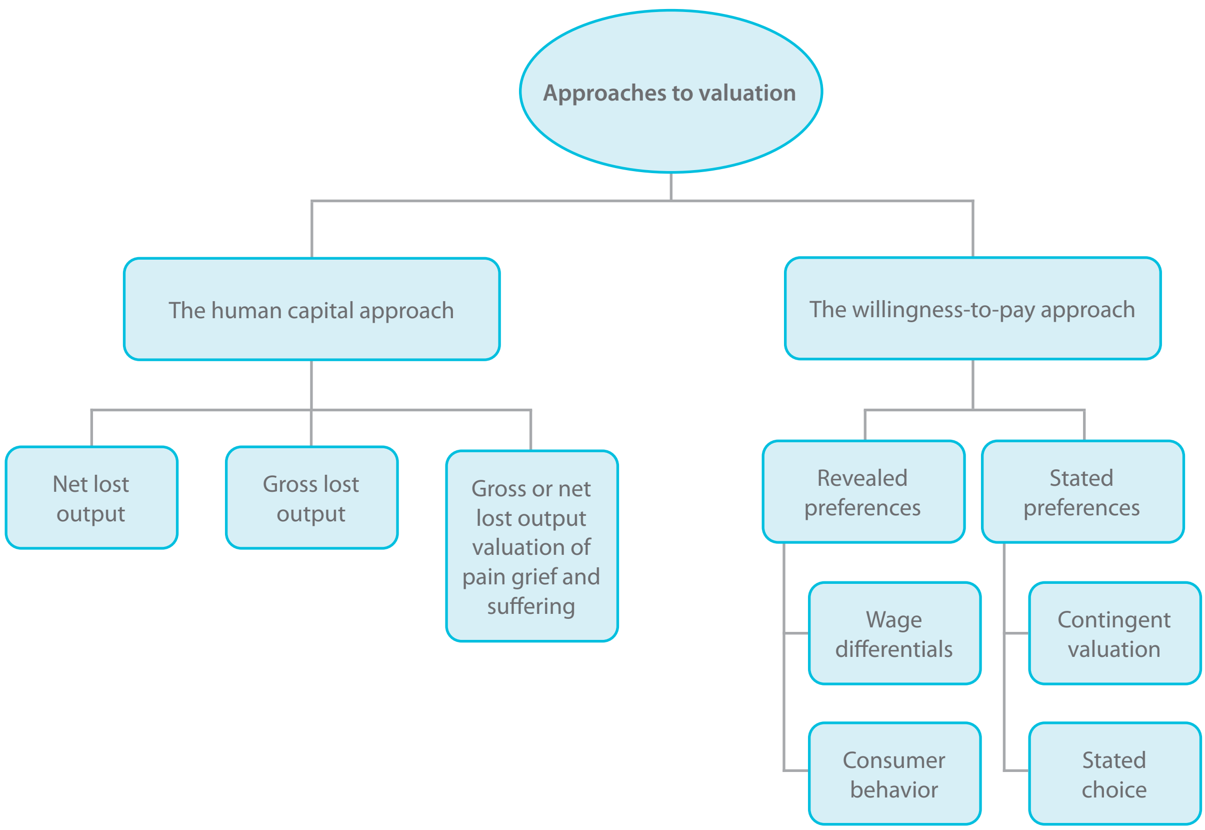
V. Effect of the technology, system and/or performance requirement on crashes

The effect on the number of fatalities, severe injuries and slight injuries of making the installation of the technology mandatory in all new vehicles is computed based on the effectiveness of the technologies (step II) and the scenario for their introduction in the vehicle fleet (steps III and IV).

VI. Net benefits - Approaches to the economic valuation of reduced risk of road traffic crashes

A calculation of economic benefits is thereafter made for each of the scenarios' effects. These are determined through the reduction in fatalities and serious and slight injuries, namely the reduced costs to society resulting from their prevention and avoidance. The net benefits are evaluated by calculating the estimated crash costs in the do-something scenario(s) and the crash costs in the do-nothing scenario. The applied unit values have a large impact on the estimated benefit-cost ratio. If higher values are used the benefit-cost ratio will increase, and vice-versa.

Figure 4.1 – Approaches to valuation (Elvik, 2017)



The purpose of assigning a monetary value to human life and health is simply to establish a projection concerning the amount of resources that can be saved through the prevention of fatalities and injuries that result from traffic crashes. These estimated savings are then pitted against the cost of measures that would lead to the prevention of fatalities and injuries in traffic crashes in order to derive estimated cost-benefit ratios. Assigning a monetary value to human health and life is an essential component of cost-benefit analysis. However, it by no means implies that human health and human life are commodities that can be traded for other goods, but rather internalizes the fact that resources at societies' disposal are limited and can be put to many alternative uses. Figure 4.1 gives an overview of the methods that have been used in studies and research to obtain a monetary valuation of reduced risk of death. The monetary valuation obtained through using the chosen methodology is the benefit side of the cost-benefit equation.

The two main approaches used to value the benefit of preventing a road crash fatality are the Human Capital (HC) and Willingness-to-pay (WTP) methods. The HC method works out the loss to the economy based on the cost of treating the person's injury, loss of income, and damage to property. It is an ex-post approach that discounts the present value of victims future forgone output due to death or injury (depending on severity). Some HC methods also include costs for pain and suffering caused by death or injury. Even when this is added into the calculation, it is still considered that the approach underestimates the true cost of a crash as it concentrates on economic costs.

The WTP approach consists of estimating the value that individuals attach to safety improvement by estimating the amount that they would be willing to pay to reduce the risk of loss of life. This ex-ante approach involves assessing risk and the preparedness of an individual to commit resources in return for reducing risk. The method is based on results of surveys that ask people how much they would pay to reduce specific types of risk. It is therefore measuring the value of prevention of road crashes, i.e. the amount that society is prepared to pay to prevent crashes. While this is considered a more theoretically sound approach than the HC method because it better reflects the full social and economic costs of death and injury, it also suffers from some methodological challenges (particularly the development of survey instruments, and cost of collecting appropriate data). There are two main methods for eliciting WTP: stated preference methods and revealed preference methods. Revealed preference studies examine actual choices in real markets, which in the case of road safety analysis might be the choice to purchase a new car. As cars differ with respect to safety features, if the relative importance of factors that influence the choice of car, such as price, size, engine power or safety features, can be determined, the implicit value placed on various key safety features can be estimated.

Most studies of the valuation of road safety have employed stated preference methods. There are two main versions of stated preference methods: the contingent valuation method and the stated choice method. In the contingent valuation method, a sample of the population is asked direct questions about how much they are willing to pay for a certain reduction of the risk of dying or getting injured in a road traffic crash. The question can be in an open ended format requiring a quote from the respondent, or by offering a pallet of different amounts which respondents are asked to choose, through simulating a bidding process starting with an initial value that if refused is then decreased until an amount is accepted, or if the initial amount is accepted it is increased until the first rejected amount, or finally by stating a bid that would require a final yes or no answer. The stated choice method asks people to make a choice between two options. The options are characterized by certain attributes, one of which is safety. Respondents do not state an amount they are willing to pay. They simply choose an option, and the valuation implicit in that choice is estimated by the analyst. The choices presented would typically be between two roads, two residential areas or two modes of transport.

Ideally, countries should carry out WTP surveys to obtain national estimates of fatality and serious injury valuations in road crashes prior to any investment in road safety. However, care must be taken as the approach is costly and requires sophisticated survey techniques in order to compute reliable estimates. Due to those considerations, as it was not technically feasible to apply the WTP approach, the HC approach was applied in case studies presented in chapter V of this publication. Therefore, for estimates of economic loss due to road traffic fatalities, we applied the value of statistical life (VSL) factors proposed in the 2019 TRL study (Wallbank et al., 2019). In addition, we used iRAP's (International Road Assessment Programme) economic appraisal model (Dahdah and McMahon, 2008) to derive the value of serious injury estimates. Serious injuries are defined as category 3 injuries or higher on the Abbreviate Injury Scale (AIS[7])[8].

7 AIS – Abbreviated Injury Scale categorizes casualties according to the most severe injury suffered. It is widely used to describe overall injury to a particular body region or overall injury to the whole body. The scale has a range from 1 to 6, where 1=Minor, and 6=Maximal (fatal).

8 The UNECE acknowledges that the AIS (in all its versions) is the property of the Association for the Advancement of Automotive Medicine (AAAM), owner of the Copyright. The so-called AIS is mentioned in this UNECE publication for information purposes only.

VII. Cost assessment

The cost of installing relevant technologies in all new vehicles are assessed in this step. The cost is expressed as an increase in the price of a vehicle because of the embedded technology. This figure will be multiplied by the number of vehicles projected in the scenarios that are being evaluated (step 3). In addition, another element on the cost side of the calculation is the cost of maintaining national type approval authorities that are required to be established by member states of the 1958 Agreement. This element will be discussed in more detail in the next chapter.

VIII. Economic cost-benefit assessment

The final step is to assess whether it is economically beneficial to implement a safety technology under consideration, namely, to derive benefit-cost ratios of applying a policy measure or a set of measures. The main reason for carrying out cost-benefit analysis of road safety measures is to help develop policies that make the most efficient use of limited resources, or in other words that produce the largest possible benefits for a given cost. To provide a comprehensive picture of the socio-economic benefit-cost ratio that can be expected from the introduction of new measure (safety-belt, airbag, ESC, etc.), it is crucial to form comparable dimensions. Therefore, costs and benefits are represented in monetary values. The net benefits of the system (step VI) are compared to the net costs of installing the system in a certain segment and proportion of the vehicle fleet, over time, along with other cost elements (step VII). If the net benefits outweigh the net costs, the introduction of the safety system will be beneficial to society. The robustness of the results and the values used for key parameters (e.g. unit cost per technology, effectiveness of the system) is evaluated through several sensitivity analysis. Finally, benefit-cost ratios are derived for the scenarios and for the sensitivity ranges.

CHAPTER V

Country Case Studies

The overall objective of this publication is to exhibit a model that countries can use in evaluating the socioeconomic impact of vehicle related policy options for improving road safety[9]. The model calculates benefit-cost ratios of regulating ESC, an active safety measure addressing for car occupants, through performance conforming to UN Regulation 140 and GTR No. 8. The model also, separately, calculates the cost-benefit of regulating an Automatic Emergency Breaking System (AEBS), a collision avoidance active safety measure, with performance conforming to UN Regulation No. 152, and pedestrian protection passive safety measures in conformance with UN Regulation No. 127 and UN GTR No.9, estimating the combined impact of these systems on preventing pedestrians and cyclist (hereinafter VRUs) fatalities and serious injuries. The timeframe for which the model is applied is 2020-2030.

The countries included in the analysis, Bolivia, the Kyrgyz Republic and Serbia, were selected so as to provide diverse geographic, economic development and the road safety performance sample from different continents, and on the basis of the current implementation status of the UN Vehicle Regulations in those countries, in particular those regulations that are included in the model. In addition, the selection of countries to be included in the case study was guided by the availability of reliable and relevant road crash victim data from publicly available sources that can be used as a basis for performing the regulation impact assessment exercise.

The regulation impact assessment and economic cost-benefit analysis applied in this study is based on elements of methods used in research that was presented in the literature review in chapter IV, most prominently on the 2018 Transport Research Laboratory (TRL) project to assess the potential for vehicle safety standards to prevent deaths and injuries in a number of Latin American countries (Wallbank et al., 2019), and on the "SafetyCube" project's economic assessment of road safety measures (Martin et al., 2017).

The aim of this analysis is to demonstrate the effectiveness of UN Vehicle Regulations in the prevention of road traffic deaths and serious injuries. As a first step, the number of deaths and serious injuries occurring in road traffic crashes among four-wheel light vehicle occupants, pedestrians and cyclists, based on past data, is projected for the 2020-2030 period, for the case study countries. Effectiveness estimates of the application of selected UN Vehicle Regulations are then applied to this data to estimate the number of fatalities and serious injuries that could be avoided within the target population. Finally, taking into account the applicable costs and benefits related to the policy interventions over the selected time period, benefit-cost ratios for the implementation of policies are derived.

In order to ultimately compute the economic benefit-cost ratios that may be achieved in the three countries through applying ESC related regulations, the following steps were carried out for the car occupant model:

- Estimate the number of car occupant casualties between 2020 and 2030 assuming past trends in vehicle fleet growth and car occupant fatality and serious injury rates per registered vehicle continue in the future;
- Estimate the potential reduction of car occupant fatalities and serious injuries achieved thanks to implementing UN Regulation No. 140 on Electronic Stability Control;
- Estimate the economic benefits resulting from the prevention of fatalities and serious injuries that stems from the application of the regulation, i.e. from the systems effectiveness in avoiding these categories of casualties;
- Estimate the cost of applying the regulation, i.e. the increased cost of vehicles if all first time registered (Kyrgyz Republic and Serbia) or all new registered (Bolivia) vehicles, as of 2020, are fitted with the system;
- Calculate the benefit-cost ratios to evaluate the potential savings against the cost of implementation of UN Regulation No. 140.

9 The proposed model follows the methodology used in the 2019 TRL study (Wallbank et al., 2019) as an example, modified where necessary to accommodate for the limited data available for country case studies examined in this exercise.

For the VRU model, the following, similar, steps were taken:

- Estimate the number of pedestrian and cyclist casualties between 2020 and 2030 assuming past casualty trends continue in the future;
- Estimate the potential reduction of VRU fatalities and serious injuries achieved thanks to implementing UN Regulation No. 127 on pedestrian protection;
- Estimate the potential reduction of VRU fatalities and serious injuries achieved thanks to implementing UN Regulation No. 152 on AEBS;
- Estimate the economic benefits resulting from the prevention of fatalities and serious injuries that stems from the application of the regulations, i.e. from the systems effectiveness in avoiding these categories of casualties;
- Estimate the cost of applying the regulations, i.e. the increased cost of vehicles if all first time registered (Kyrgyz Republic and Serbia) or all new registered (Bolivia) vehicles, as of 2020, are fitted with the systems;
- Calculate the benefit-cost ratios to evaluate the potential savings against the cost of applying UN Regulations Nos. 127 and 152.

I. Casualty forecasts

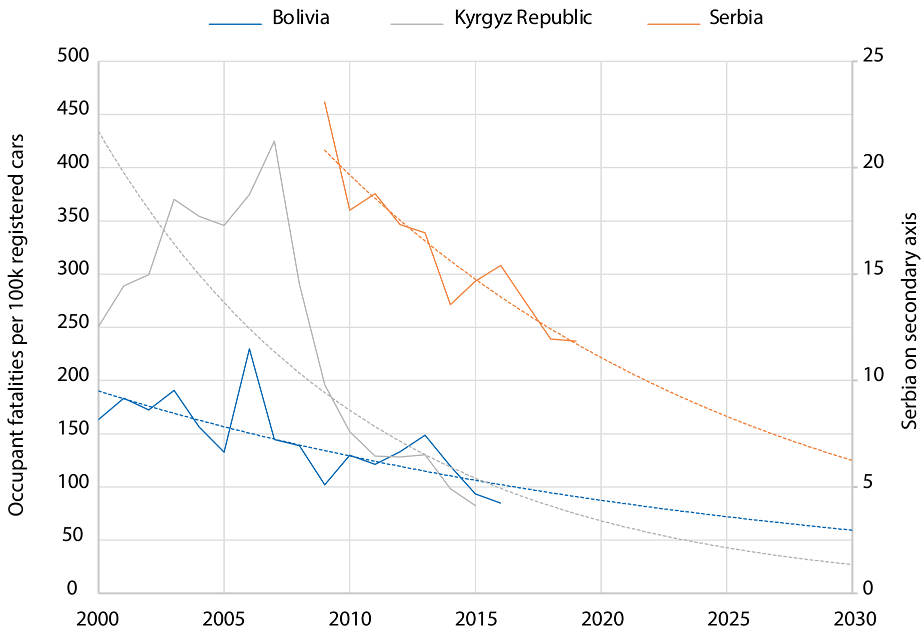
This section presents the fatality and serious injury forecasts for the period up to 2030, for each country. The estimates take into account the existing trends in fatality and serious injury rates per unit of the selected exposure measure – number of registered cars for the car occupant model, and number of inhabitants for the VRU analysis.

I.I. Car occupants

The first step to estimate baseline 2020-2030 casualties was to extrapolate forwards the car occupant fatality and serious injury rates. When estimating the number of car occupant fatalities, it is important to account for levels of exposure. For example, the number of fatalities is likely to be influenced by the amount of car travel (more casualties are expected when there is more car travel) and the size of the population (more casualties are expected in countries with a higher population). The number of registered vehicles per unit of population (motorization rate) was used as the exposure measure, as annual passenger vehicle fleet figures were available for all three countries under analysis for the preceding 20-year period. If available, the more precise exposure measure of passenger-kilometres, the unit of measurement representing the transport of one passenger by a defined mode of transport (in this case road transport) over one kilometre, should be used instead of the motorization rate.

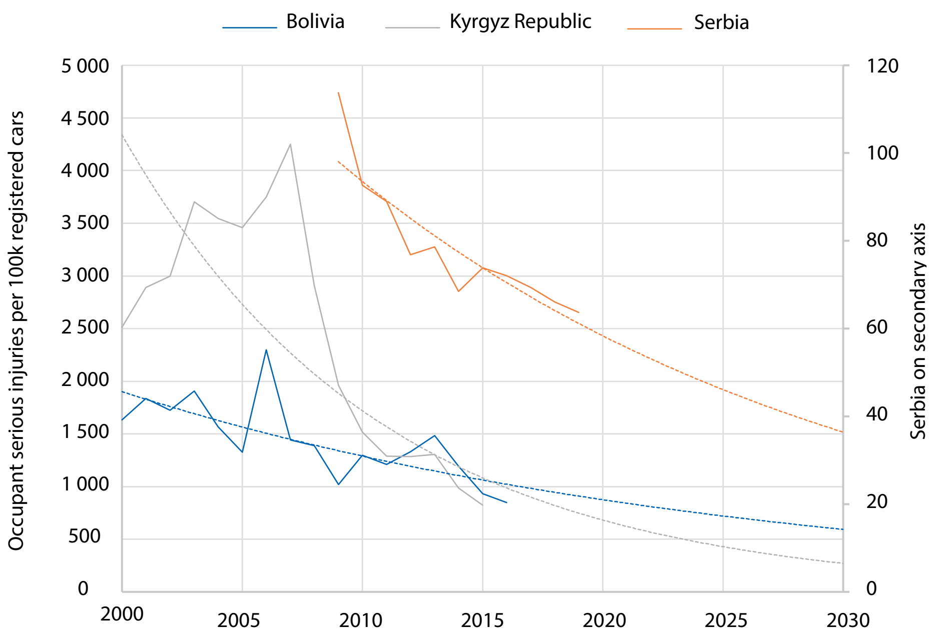
To obtain fatality and serious injury projections, these car occupant casualty rates were then plotted for the preceding years. The availability of casualty data for car occupants differed for the three countries. The latest available data for Serbia was from 2019, for Bolivia from 2016, and for the Kyrgyz Republic from 2015. In addition, information on car occupant injury severity levels was available only for Serbia. For Bolivia and the Kyrgyz Republic, a 10:1 ratio between serious injuries and fatalities was assumed (in line with the recommendation of the iRAP study "The true cost of road crashes" (Dahdah and McMahon, 2008)). Finally, annual fatality tallies in Bolivia and the Kyrgyz Republic were multiplied by 1.3, in order to account for underreporting that may result from road crash fatalities classification practices in these two countries, as only those deceased at the scene of the crash are considered as crash victims (in accordance with WHO, 2018). An exponential trend line has been fitted to each countries data because car occupant fatality and serious injury rates per unit of the exposure measure have been on a decreasing trend over time (Figure 5.1). Applying a linear trend to such cases would lead to unrealistic projections where fatality rates would trend to zero or enter negative territory.

Figure 5.1 - Car occupant fatality rate (per 100k registered cars) for Bolivia, Kyrgyz Republic (2000-2030) and Serbia (2009-2030, secondary axis)



Based on the predictions stemming from the current trajectory, the number of car occupant fatalities per one hundred thousand registered vehicles will by 2030 be slightly lower than 60 in Bolivia, about 27 in the Kyrgyz Republic and about 6 in Serbia.

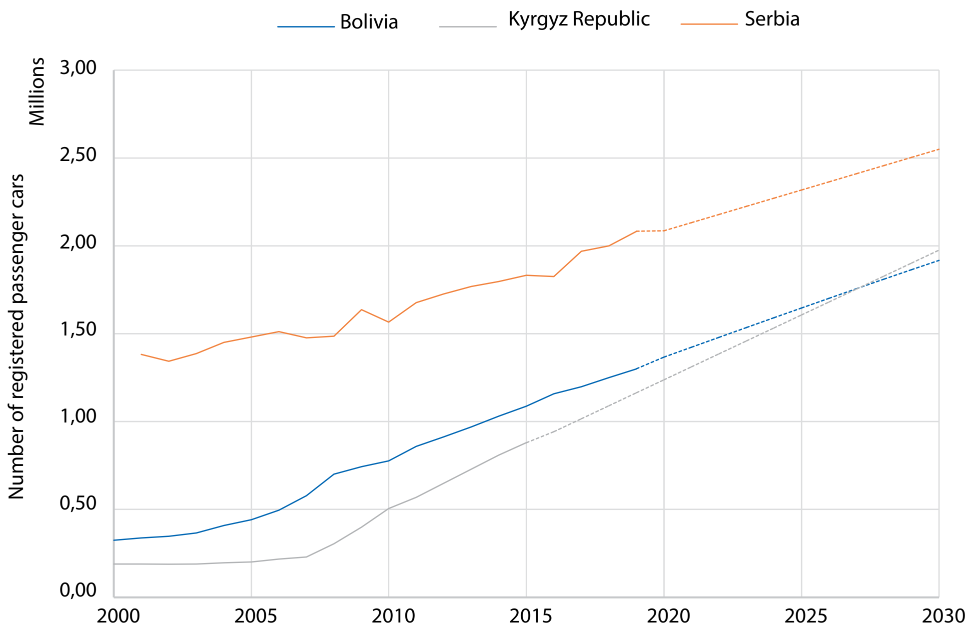
Figure 5.2 - Car occupant serious injury rate (per 100k registered cars) for Bolivia, Kyrgyz Republic (2000-2030) and Serbia (2009-2030, secondary axis)



As stated, serious injury data was not available for Bolivia and the Kyrgyz Republic. On the other hand, disaggregated and categorized serious injury data was available for Serbia. Past data on car occupant fatalities and serious injuries in Serbia follows a very similar trajectory, thus validating the assumption of applying a ratio to the case of the other two countries for which disaggregated injury data was not available online. Based on the current trajectory, less than 40 seriously injured car occupants per one hundred thousand vehicles are expected in Serbia by 2030, while slightly more than 500 and 250 are expected in Bolivia and the Kyrgyz Republic per one hundred thousand passenger cars by the same year, respectively (Figure 5.2).

Alongside fatality and serious injury rates, the number of registered four-wheel light passenger vehicles in the three countries was projected forward to 2030, based on available data (Figure 5.3).

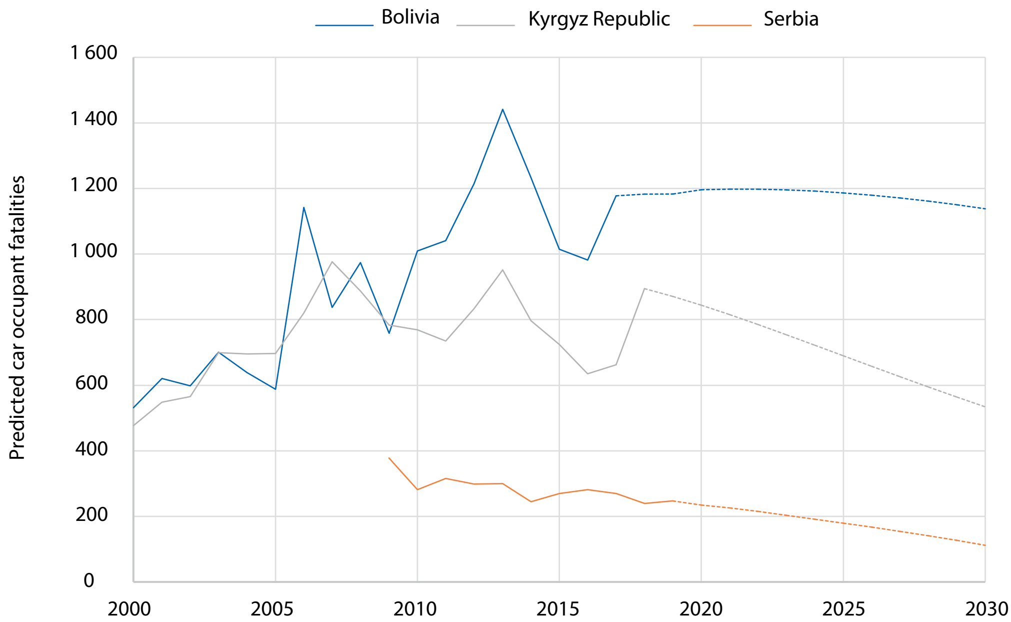
Figure 5.3 - Number of registered cars in Bolivia, Kyrgyz Republic (2000-2030) and Serbia (2001-2030)



The number of registered cars is by 2030 expected reach slightly less than 2 million in both Bolivia and the Kyrgyz Republic, while in Serbia it is projected to surpass 2.5 million. Taking into account the existing national vehicle fleet growth trends and projecting those past trends linearly forward in time also up to 2030, the number of casualties up to 2030 was projected for the three countries.

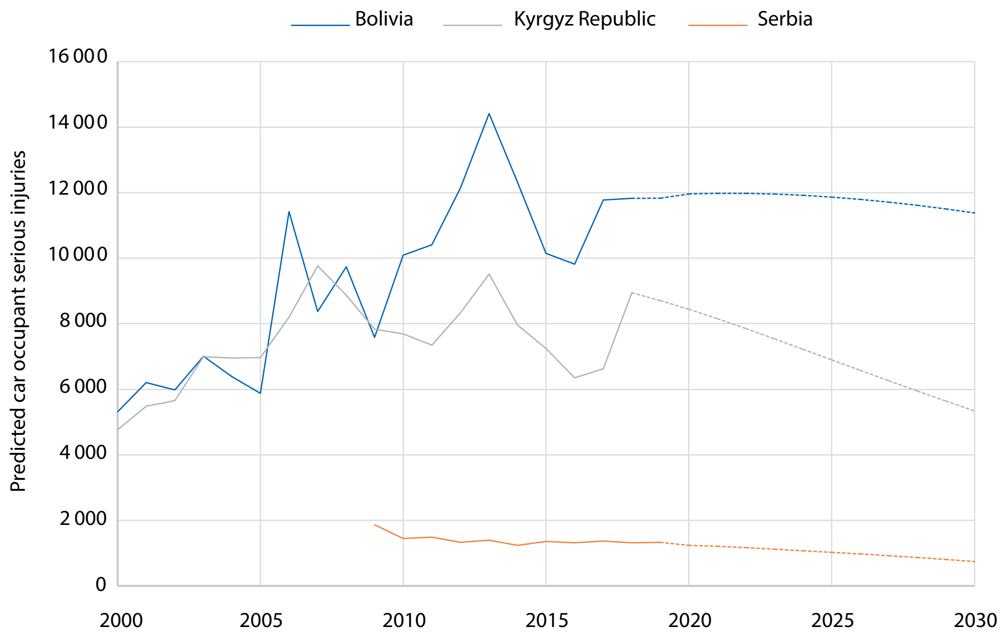
The casualty rates over recent years will reflect the effect of regulations that have already been introduced. As rates are decreasing for all three countries included in the analysis, the fatality rate was extrapolated forwards assuming an exponential trend, since this was shown to fit the data well and ensures that the casualty rates do not reach zero (which would be unrealistic) for any country during the timescale of this analysis (2020-2030). To estimate fatalities, the selected exposure measure, number of registered four-wheel light vehicles, was also predicted forwards, assuming a similar linear trend to that seen in since the year 2000. Other scenarios were modelled as part of the sensitivity analysis (Annex I). The fatality rate predictions and the registered car predictions were combined to estimate baseline projected casualties for the 2020-2030 period. These projected future casualty estimates do not take into account other vehicle regulations or road safety measures that may be introduced in the countries by 2030 since the impact of those cannot be modelled based on past casualty figures. They estimate how many car occupant fatalities and serious injuries will occur each year until 2030 assuming the past reference trend in car occupant safety progress.

Figure 5.4 - Number of car occupant fatalities in Bolivia, the Kyrgyz Republic (2000-2030) and Serbia (2009-2030)



The number of car occupant fatalities and serious injuries are projected to increase until 2024 after which a downward trend is predicted. In the Kyrgyz Republic and in Serbia the existing decreasing trend in both categories is projected to continue through 2030 (Figures 5.4 and 5.5).

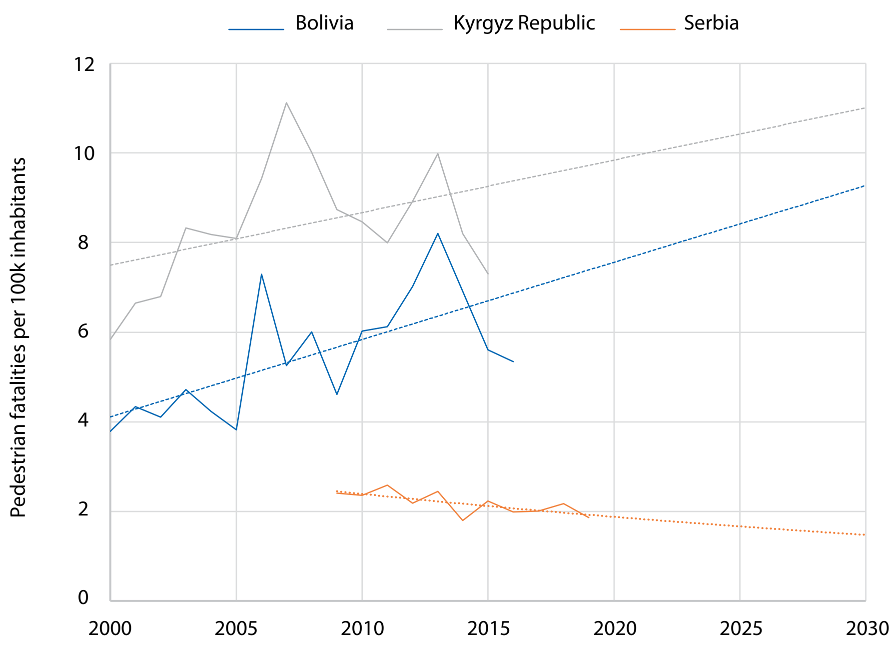
Figure 5.5 - Number of car occupant serious injuries in Bolivia, the Kyrgyz Republic (2000-2030) and Serbia (2009-2030)



I.II. Vulnerable road users

As with the car-occupant model, baseline fatality estimates were also required for pedestrians and cyclists. Estimates are based on past data available from the three countries under analysis. To compute VRU casualty projections by 2030, the trend in the pedestrian and cyclist casualty rate per unit of population was extrapolated. The availability of casualty data for VRUs differed for the three countries. The latest available data for Serbia was from 2019, while VRU casualty data for Bolivia and the Kyrgyz Republic was inferred based on VRU casualty estimates reported in WHO Global Status Reports on Road Safety (2008, 2013, 2015 and 2018 editions). In addition, information on VRU injury severity levels was available only for Serbia. For Bolivia and the Kyrgyz Republic, an 8:1 ratio between serious injuries and fatalities was assumed (in line with the recommendation of the iRAP study "The true cost of road crashes" (Dahdah and McMahon, 2008)). As in the case of car occupant data, annual fatality tallies in Bolivia and the Kyrgyz Republic were multiplied by 1.3, in order to account for underreporting that may result from road crash fatalities classification practices in these two countries, as only those deceased at the scene are considered as crash victims (in accordance with WHO, 2018). An exponential trend was assumed to extrapolate the future casualty rate for the case of Serbia as VRU casualties per unit of population had been declining in the previous period. Conversely, a logarithmic trend for Bolivia and the Kyrgyz Republic as casualties per unit of population had been increasing. The extrapolation of baseline fatalities provides a target population for the VRU safety measures to influence. In this case, the total numbers of VRU casualties of road traffic crashes are the target groups. For pedestrians, the existing rates and extrapolations are presented in Figures 5.6 and 5.7.

Figure 5.6 - Pedestrian fatality rate (per 100k inhabitants) for Bolivia, Kyrgyz Republic (2000-2030) and Serbia (2009-2030)



In order to calculate the number of baseline fatalities, population projections (generated by the United Nations Populations Division) are combined with the predicted pedestrian fatality rate. Equally as in the car occupant casualty data, the past annual rates were extrapolated forward to estimate annual pedestrian and cyclist casualty rates in each of the countries, up to 2030, assuming the existing trends in road safety continue into the future. An exponential trend line has been fitted to VRU casualty data for Serbia, as VRU fatality and serious injury rates per unit of population have been on a decreasing trend over time. For Bolivia and the Kyrgyz Republic, a logarithmic trend was plotted as it is a better fit to the apparent increase in VRU casualties in the two countries over the past period. For pedestrians, the results are shown for each country in Figures 5.8 and 5.9 – these estimates represent the figures expected if road safety continues to develop as it has done in recent years, but no new vehicle safety regulations are implemented.

Figure 5.7 - Pedestrian serious injury rate (per 100k inhabitants) for Bolivia, Kyrgyz Republic (2000-2030) and Serbia (2009-2030)

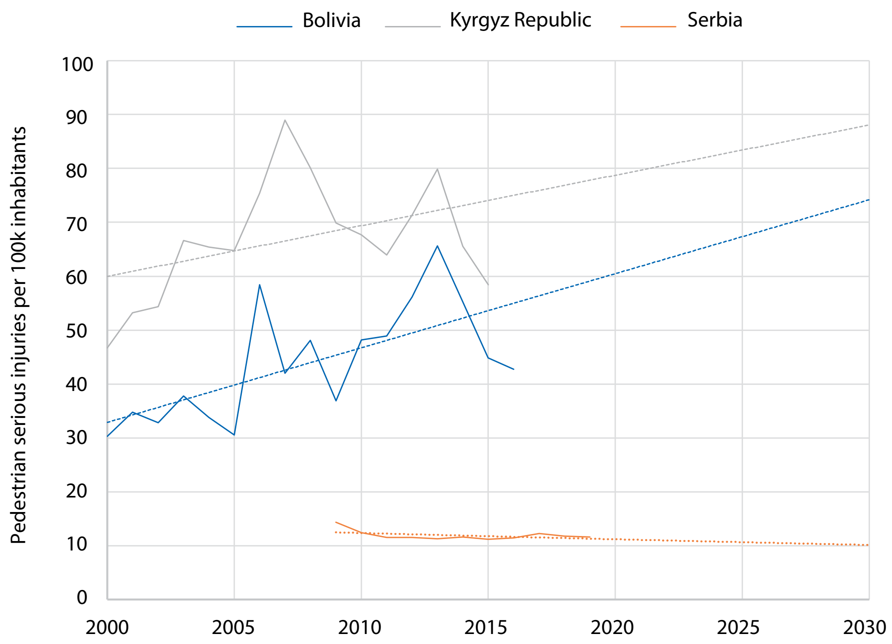


Figure 5.8 - Number of pedestrian fatalities in Bolivia, the Kyrgyz Republic (2000-2030) and Serbia (2009-2030)

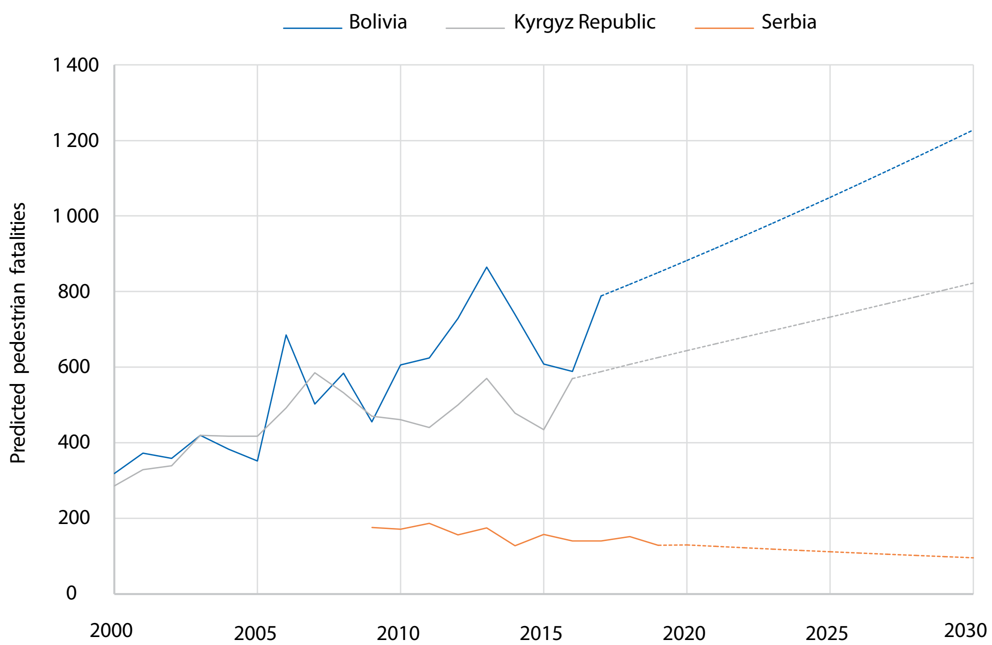
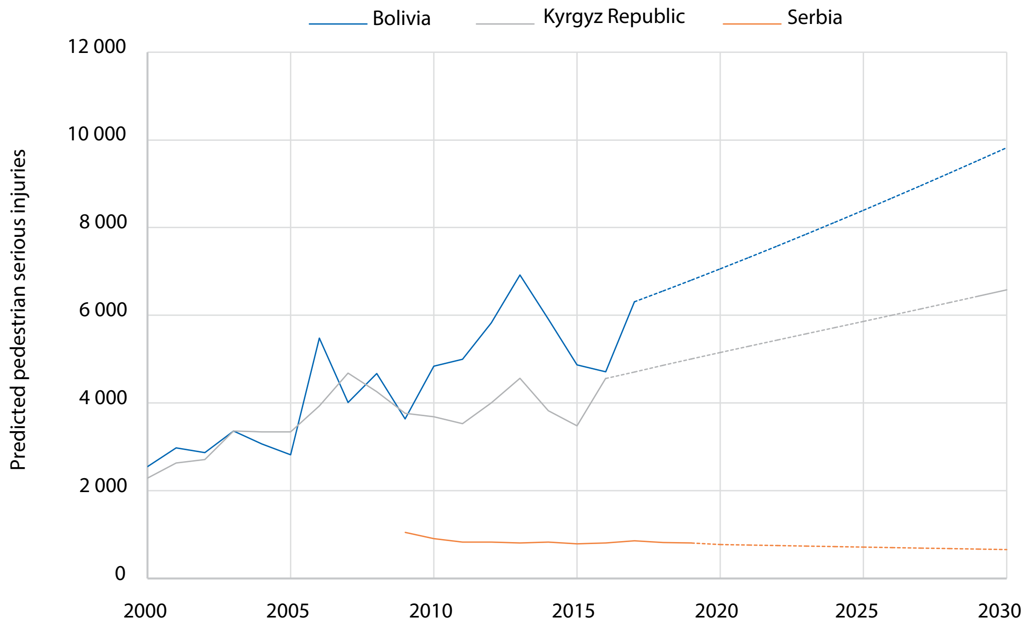


Figure 5.9 - Number of pedestrian serious injuries in Bolivia, the Kyrgyz Republic (2000-2030) and Serbia (2009-2030)



The same principles were applied to data on cyclist casualties. Casualty baselines per unit of population are shown in Figures 5.10 and 5.11 while estimates of cyclist fatalities and serious injuries by 2030 for the three countries are shown in Figures 5.12 and 5.13, below respectively.

Figure 5.10 - Cyclist fatality rate (per 100k inhabitants) for Bolivia, Kyrgyz Republic (2000-2030) and Serbia (2009-2030)

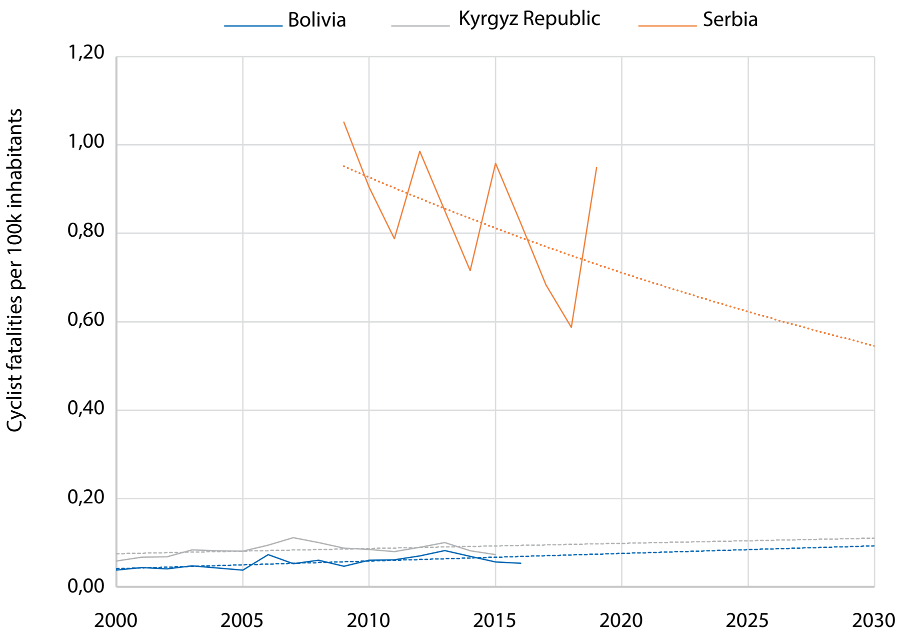
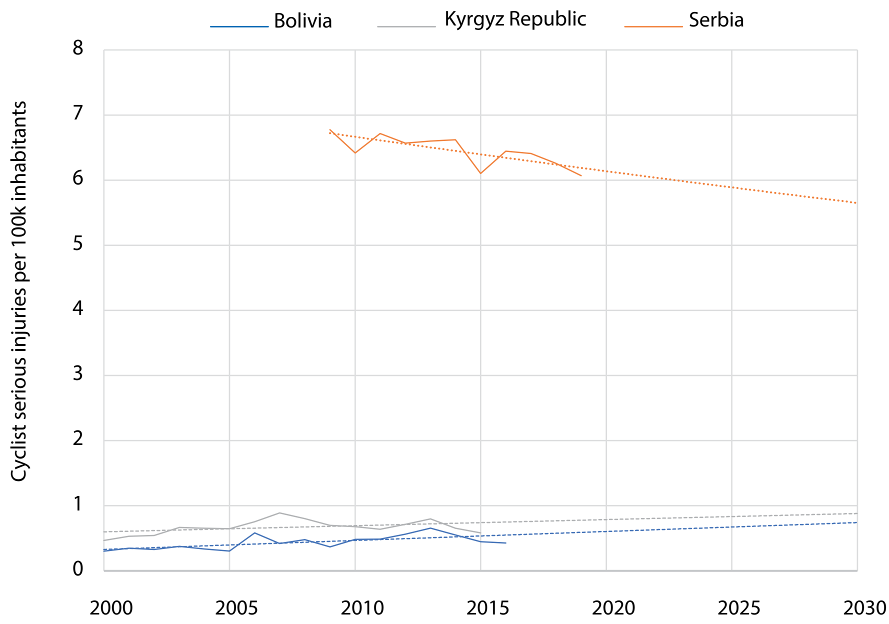


Figure 5.11 - Cyclist serious injury rate (per 100k inhabitants) for Bolivia, Kyrgyz Republic (2000-2030) and Serbia (2009-2030)



Cyclist casualty data from Serbia may indicate that there are some issues in terms year-on-year reporting of fatalities and serious injuries. Nevertheless, the data reflects a stable trend over time and was therefore considered as appropriate for establishing future casualty projections. Casualty rates for cyclist in Bolivia and the Kyrgyz Republic were generated based on total road traffic fatalities reported in the country and WHO Global Status Reports on Road Safety (2008, 2013, 2015 and 2018 editions) estimates that cyclists account for 1 per cent of total road traffic fatalities in both countries.

Figure 5.12 - Number of cyclist fatalities in Bolivia, the Kyrgyz Republic (2000-2030) and Serbia (2009-2030)

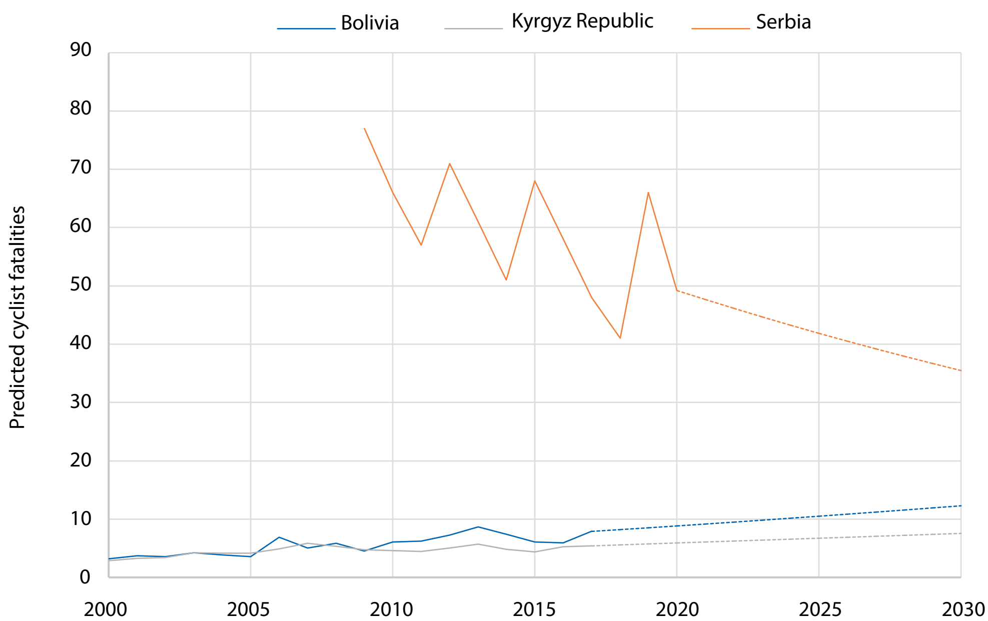
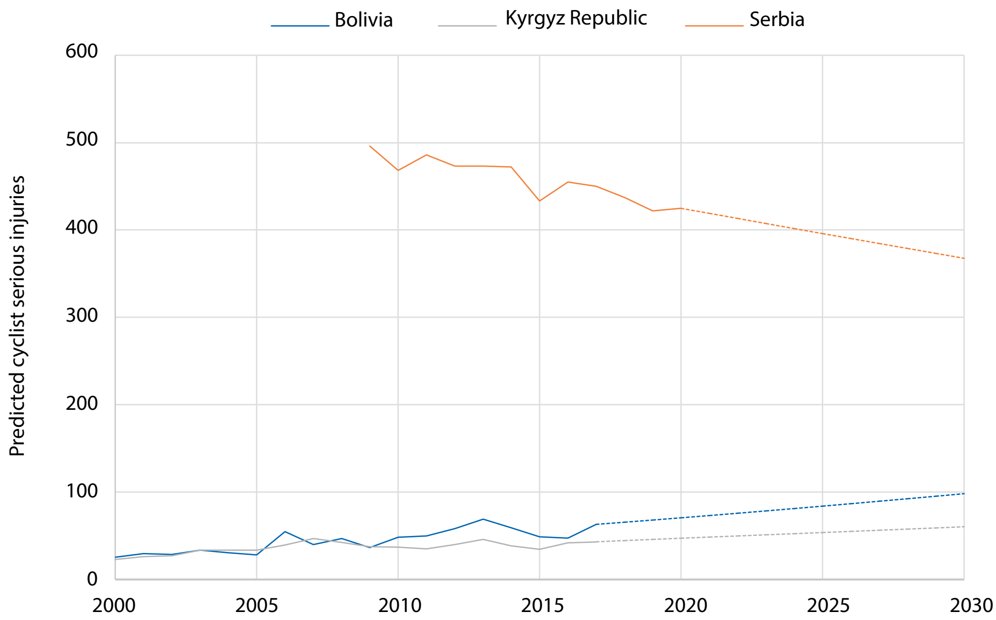


Figure 5.13 - Number of cyclist serious injuries in Bolivia, the Kyrgyz Republic (2000-2030) and Serbia (2009-2030)



The next step in the model was then to establish the potential effectiveness of AEBS, which detects and responds to VRUs (including pedestrians and cyclists), and conventional passive protection provided by changes to the geometry and stiffness of car fronts.

II. Casualty benefits and economic costs of implementing UN Vehicle Regulations

This section presents the results of the benefit and cost estimations of applying the UN Vehicle Regulations under consideration in the three case study countries. For each casualty type, the assumptions on fleet penetration of each technology are introduced, along with the number of casualties saved as a result of the technology (estimated using the effectiveness estimates for the technology and fleet penetration). The method described in chapter IV, the VSL approach, was employed to estimate the casualty benefits that could be incurred in the three case study countries through the application of UN Regulations No. 127 on pedestrian protection, No. 140 on ESC and UN Regulation No. 152 on AEBS, while described cost estimates were employed to calculate the cost side of the equation.

The number of lives saved and injuries avoided will depend on the introduction of vehicles equipped with the relevant equipment and technologies in the fleet over the timeline for which the estimates are calculated, on the projected population of car occupants exposed to car crashes where the technologies are effective and on the effectiveness of the technology in preventing casualties.

The fleet scenario for the Kyrgyz Republic and for Serbia assumes that all first-time registered cars, annually as of 2020, are cars fitted with ESC. For Bolivia, a scenario where all new registered cars, annually as of 2020, comply with UN Regulation No. 140 is considered. The number of first-time car registrations and of new car registrations for each year during the period 2020-2030 was derived by plotting a linear trend of vehicle registration data based on available annual car registrations figures from the countries during the previous decade. Registration figures were obtained from national statistical databases and supplemented where necessary with data from the UNECE statistical database and with country new car sales data of the International Automobile Manufacturers Association (OICA).

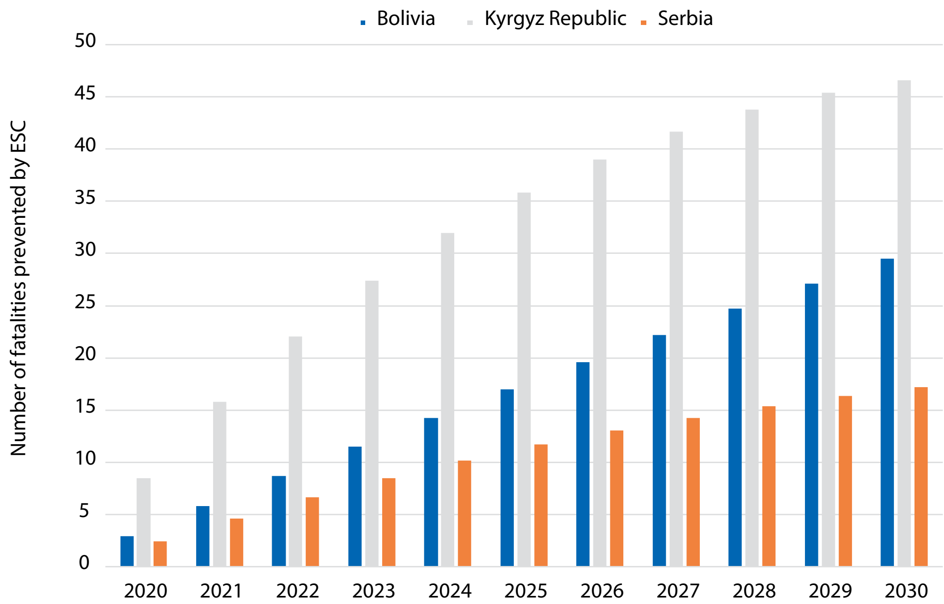
Additionally, it is possible for fleet fitment to be influenced via incentives to replace old cars with new cars. The effect of such initiatives would be to increase the benefits soon after implementation of the legislation, giving a corresponding increase in the total number of lives saved and higher benefits (particularly when accounting for the discounting of future benefits). These aspects have not been considered in the present analysis. If considered they can contribute to the robustness of estimates of the benefits of implementing vehicle regulations for improving road safety.

II.I. *Car occupants*

The next step in establishing the car occupant model was to determine the proportion of total casualties resulting from crashes that ESC is designed to mitigate, and the effectiveness of ESC in preventing fatalities and avoiding serious injuries resulting from that population of "ESC-relevant" casualty crashes. These factors were sourced from the literature review-based recommendation of the 2019 TRL study (Wallbank et al., 2019). In their analysis the authors of that study considered 37.9 per cent of total car occupant casualties as a target population of ESC related (loss-of-control) crashes. Within that target population, an effectiveness of 34.9 per cent for fatality prevention and 21 per cent for serious injury avoidance was used.

These figures were applied in the baseline analysis to estimate the number of fatalities and serious injuries that could annually and cumulatively be avoided by 2030 as a result of implementing UN Regulation No. 140 in the three countries included in this study, while alternative ESC-relevant road traffic crash population proportions and system effectiveness ratings were included in the sensitivity analysis (Annex I).

Figure 5.14 - Estimated number of car occupant lives saved due to implementation of UN Regulation No.140 as of 2020 (2020-2030)

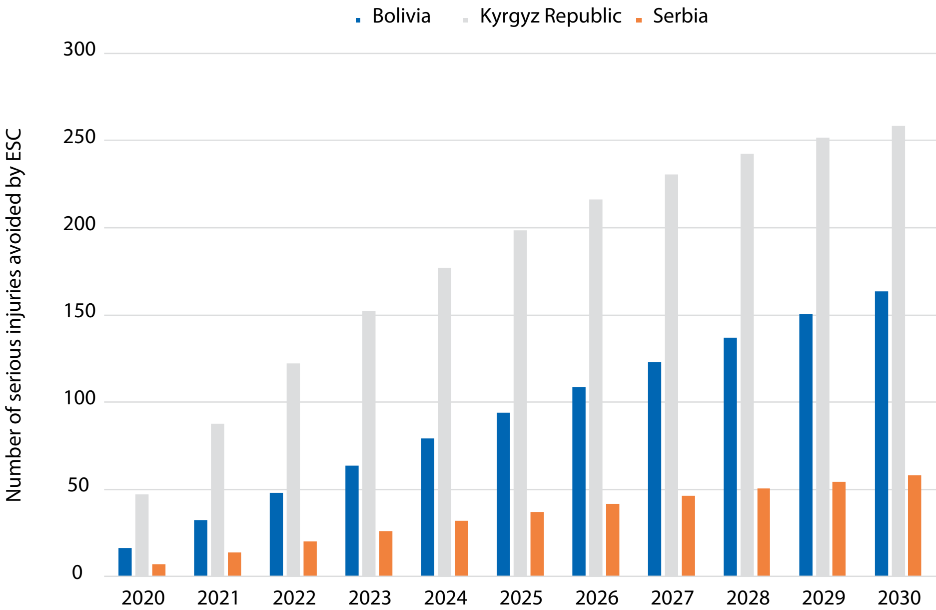


The results indicate that, based on the road traffic crash population, technology effectiveness estimates and vehicle fleet technology penetration as described above, the application of UN Regulation No. 140 may prevent 183 fatalities in Bolivia, 358 in the Kyrgyz Republic and 120 in Serbia by 2030 (Figure 5.14).

Based on the same model assumptions, more than 1,000 serious injuries may be avoided through the application of UN Regulation No. 140 in Bolivia by 2030, almost 2,000 in the Kyrgyz Republic and nearly 400 in Serbia (Figure 5.15). There are some significant limitations with the approach that has been taken, due to a lack of available data on serious injuries in Bolivia and the Kyrgyz Republic, and as such the results presented here should be treated with some caution.

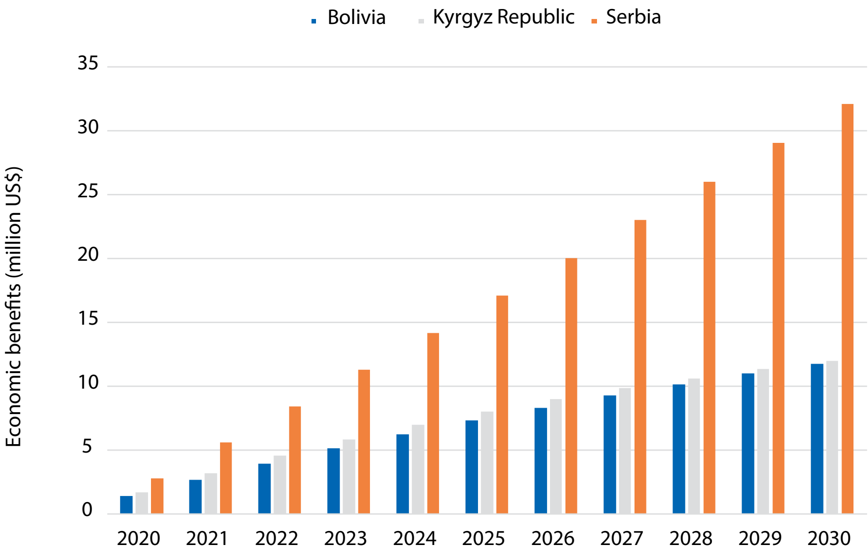
Once the reduction of fatalities and serious injuries for the period 2020-2030, was predicted, the value of statistical life (VSL) method was used to quantify the economic benefit of casualty reductions. Using the VSL method, which monetizes the loss of each life and each serious injury by expressing casualties as a factor of GDP, the economic benefits of applying UN Regulation No. 140 were inferred. These figures can be compared cross-nationally and are readily computable from health burden data. Based on examples from similar studies, the value of 103.6 times GDP per capita was used to calculate the economic loss resulting road traffic crash fatalities (Wallbank et al., 2019), while the value of 17 units of GDP per capita was used to compute the economic loss of a serious injury due to a traffic collision (Dahdah and McMahon, 2008). Further estimates of VSL, outlying high and low multipliers, were applied were used in the sensitivity analysis (Annex I).

Figure 5.15 - Estimated number of car occupant injuries avoided saved due to implementation of UN Regulation No.140 as of 2020 (2020-2030)



The annual economic benefits of casualties prevented for the three counties from 2020 to 2030 are presented in Figure 5.16, and the total casualty and economic benefits are presented in Table 5.1 below.

Figure 5.16 - Estimated economic benefit of car occupant casualties prevented by applying UN Regulation No. 140 as of 2020 (2020-2030)



As the economic benefits are based on multipliers of GDP per capita, the accrued benefits of each country are counter proportional to the actual casualty savings due to the fact that of the three countries in the case study, Serbia has the highest, current and projected, GDP per capita, followed by Bolivia. An inherent weakness of the VSL approach as a method to monetize casualty savings based on per capita national income data is that as such it is only valid for national estimates while not for international benchmarking.

TABLE 5.1

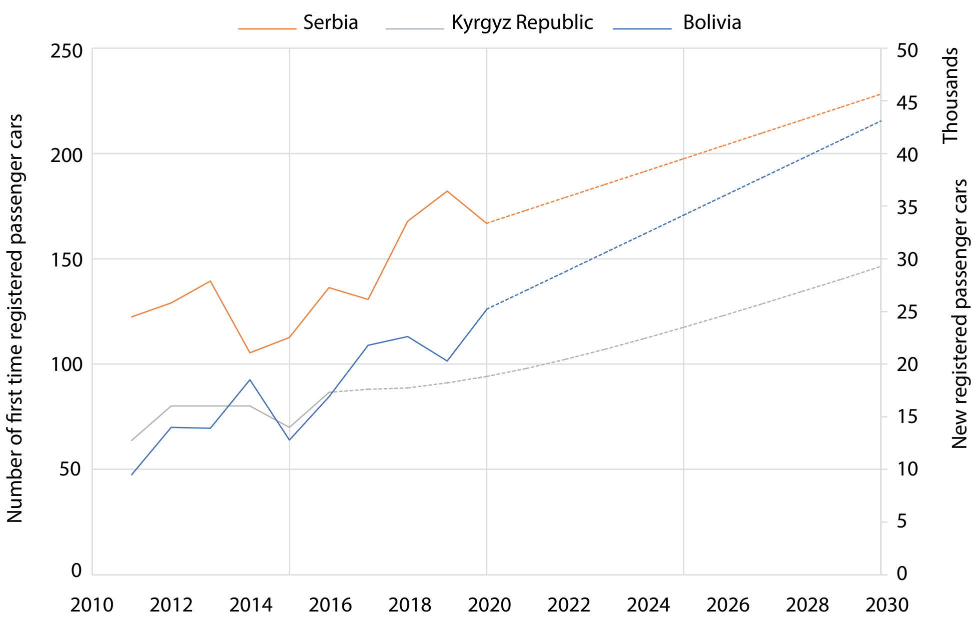
Estimated casualties avoided and economic benefits of applying UN Regulation No. 140 as of 2020 (2020-2030)

UN Regulation No. 140 - ESC economic benefit estimates					
	Cumulative lives saved 2020-2030	Cumulative serious injuries prevented 2020-2030	Mid estimate of economic loss due to one traffic fatality (2018 $US)	Mid estimate of economic loss due to one traffic serious injury (2018 $US)	Total economic benefits 2020-2030 (2018 $US)
Bolivia	183	1,016	225,814	36,983	77,169,196
Kyrgyz Republic	358	1,984	117,368	19,222	83,004,593
Serbia	120	387	965,008	158,059	189,694,632

It is estimated that the implementation of UN Regulation No.140, in accordance with the above stated fleet filament assumptions would result in a cumulative economic benefit of $77.2 million in Bolivia, $83 million in the Kyrgyz Republic and $189.7 million in Serbia during the 2020-2030 period. Future annual economic benefits have been discounted assuming a 4.5 per cent annual discount rate.

Estimates for costs of fitting a vehicle with an ESC system were sourced from literature. The central estimate of $ 50 per vehicle was used for obtaining the cost estimates by 2030 for applying UN Regulation No. 140 in the three countries, while the low and high cost estimates of $ 36.67 and $ 102 were used as part of the sensitivity analysis (as used in Wallbank et al., 2019). Figure 5.17 presents the predicted number of cars entering the fleet and fitted with ESC in each of the three countries, based on a linear trend from the existing data, under the respective fleet fitment assumptions stated above, at the start of the current section.

Figure 5.17 - Estimates of new registered cars in Bolivia (secondary axis), and first-time registered cars in the Kyrgyz Republic and Serbia (2011-2030)



To estimate the cost of equipping the considered country fleet segments with ESC as of 2020, the number of modelled ESC fitted vehicles entering the fleet is calculated. The figure is then multiplied by the costs for each vehicle - $50 per car. An annual discount rate of 4.5 per cent was applied to the total annual costs respectively, to take into account price inflation and learning curve effects. As a result, the figures presented in Table 5.2 represent the additional cost to each country of introducing the regulation (these costs are discounted to 2020 $US equivalent). Alternative cost estimates are considered in the sensitivity analysis (Annex I).

TABLE 5.2

Estimated costs linked to implementing UN Regulation No. 140 as of 2020 (2020-2030)

UN Regulation No. 140 - ESC cost estimates		
	Modelled additional vehicles equipped 2020-2030	Economic cost 2020-2030 (2018 $US)
Bolivia	375,668	14,869,889
Kyrgyz Republic	1,304,081	51,802,325
Serbia	2,172,988	86,835,967

Further costs can be assigned to application of UN Regulations in countries that apply the regulations. These relate to the costs of maintaining staff in government agencies that act as Type Approval Authorities and costs related to establishing Technical Services and test facilities where vehicles, their equipment and parts, are tested in accordance with individual applicable UN Regulations under the 1958 Agreement. The cost of establishing Type Approval Authorities can be zero if existing government units and their officers are charged with related tasks, or they can be estimated as two to five average annual civil servant salaries in a country that is establishing new designated units to carry out the activities. In addition, if funds are dedicated to establishing test facilities the costs can run as high as tens of millions of US Dollars. These costs were not considered within this analysis. However, the model laid-out can easily be adjusted to consider such expenditures, in-line with the situation, plans and needs of specific countries.

II.II. Vulnerable road users

The following effectiveness rates were applied to baseline projected VRU fatalities to estimate potential casualty prevention resulting from the application of UN Regulations Nos. 127 and 152 (based on Wallbank et al., 2019):

- 48 per cent effective for preventing pedestrian fatalities;
- 55 per cent effective for preventing cyclist fatalities;
- 42 per cent effective for avoiding pedestrian serious injuries;
- 33 per cent effective for avoiding cyclist serious injuries.

UN GTR No. 9 provides estimates of the effectiveness of vehicle design adjustment stemming from UN Regulation No. 127 performance requirements throughout Europe and other world regions. A value of 3.9 per cent effectiveness was applied for the pedestrian fatality population and 1.4 per cent for cyclists killed in road traffic crashes. In terms of serious injury avoidance, an effectiveness value of 11.8 per cent was applied to pedestrian serious injury cases, while a 4.7 per cent effectiveness value was applied for cyclist annual injury avoidance modelling. These effectiveness values reflect that:

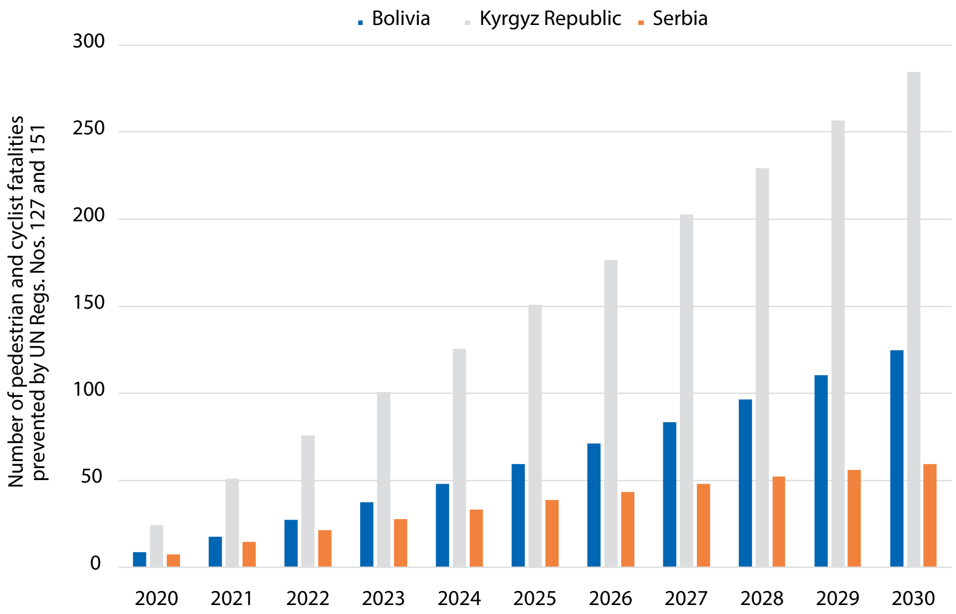
- Not all pedestrian fatalities are caused by cars;
- Not all pedestrian fatalities are caused by the fronts of vehicles;
- The regulation focuses on the central area of the vehicle front;
- Some injuries will occur from secondary contacts with the ground or other parts of the vehicle or other vehicles.

Accounting for all these aspects leads to the low effectiveness estimates quoted in the UN GTR and other studies (Wallbank et al., 2019). Alternative, both higher and lower effectiveness estimates for the VRU related regulations were applied as part of the sensitivity analysis (Annex I).

The effectiveness estimates from the literature suggest that UN Regulation No. 152 will be 48 per cent effective at reducing pedestrian fatalities and 42 per cent effective at reducing serious injuries. The equivalent figures for UN Regulation No. 127/ UN GTR No. 9 are 3.9 per cent and 11.8 per cent. Effectiveness estimates of these two regulations for preventing cyclist fatalities are 55 per cent and 1.4 per cent, while those for avoiding cyclist serious injuries are 33 per cent and 4.7 per cent, respectively. Combining these estimates with the fleet fitment enables the estimation of the number of lives saved by AEBS and pedestrian protection vehicle design to be estimated for the period 2020-2030 for the case study countries. The presented results are a combined estimate of the effect of both regulatory measures on pedestrian and cyclist casualties.

The results indicate that, based on the road traffic crash population, technology effectiveness estimates and vehicle fleet technology penetration as described above, the application of UN Regulations Nos. 127 and 152 may prevent 684 fatalities in Bolivia, 1,667 in the Kyrgyz Republic and 401 in Serbia by 2030 (Figure 5.18).

Figure 5.18 - Estimated number of pedestrian and cyclist lives saved due to implementation of UN Regulations Nos. 127 and 152 as of 2020 (2020-2030)



Based on the same model assumptions, more than 5,600 serious injuries may be avoided through the application the two regulations in Bolivia by 2030, almost 14,000 in the Kyrgyz Republic and nearly 2,700 in Serbia (Figure 5.19). As in the case of car occupant data, there are significant limitations with the approach that has been taken, due to a lack of available data on serious injuries in Bolivia and the Kyrgyz Republic, and as such the results presented here should be treated with some caution.

Figure 5.19 - Estimated number of pedestrian and cyclist serious injuries avoided saved due to implementation of UN Regulations Nos. 127 and 152 as of 2020 (2020-2030)

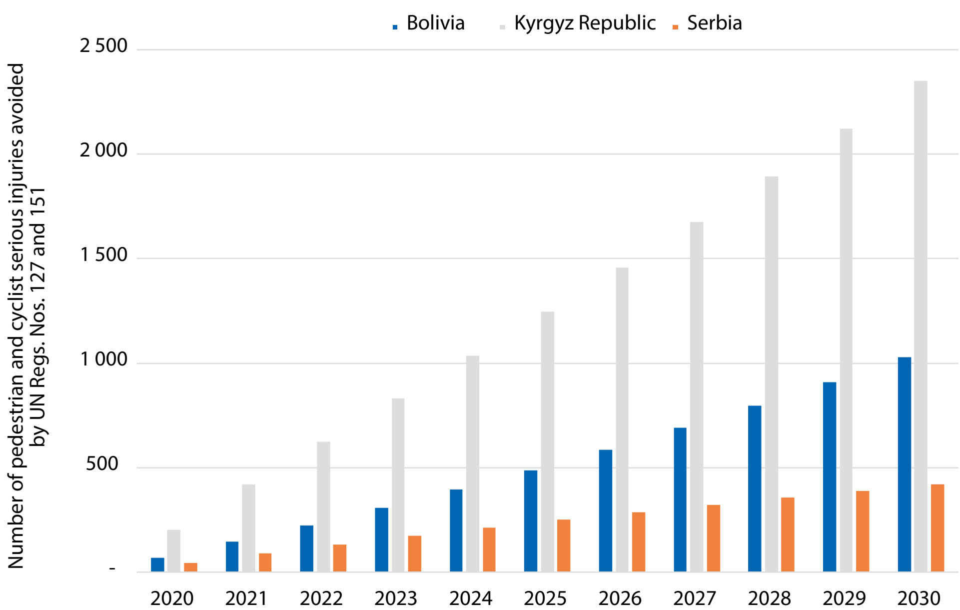
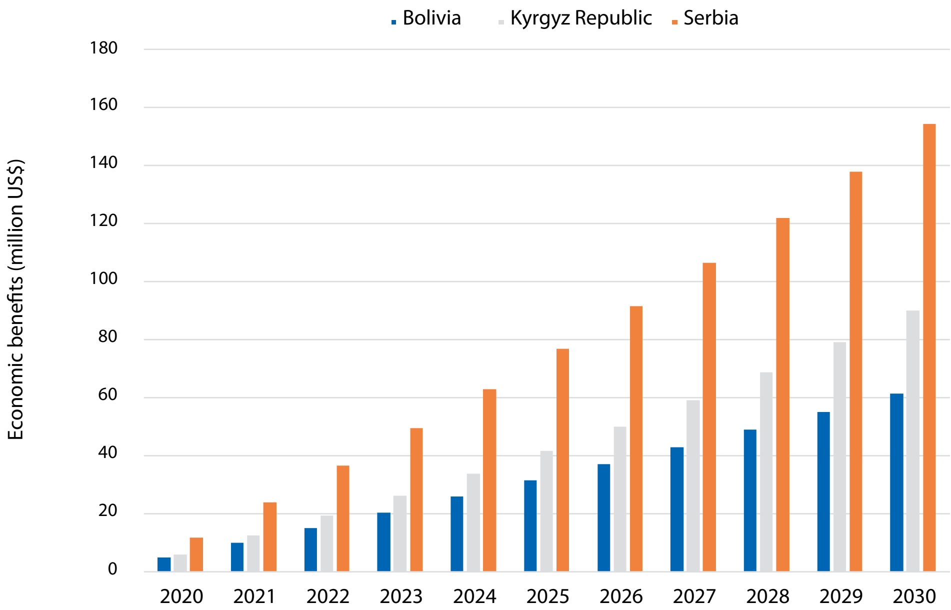


Figure 5.20 present the economic benefit of avoided pedestrian and cyclist casualties, employing the VSL approach for economic valuation of fatalities and serious injuries, where the value of 103.6 times GDP per capita was used to calculate

the economic loss resulting from road traffic crash fatalities (Wallbank et al., 2019), while the value of 17 units of GDP per capita was used to compute the economic loss of a serious injury due to a traffic collision (Dahdah and McMahon, 2008).

Figure 5.20 - Estimated economic benefit of VRU casualties prevented by applying UN Regulations Nos. 127 and 152 as of 2020 (2020-2030)



It is estimated that the implementation of UN Regulations Nos .127 and 152 in accordance with the above stated fleet filament assumptions would result in a cumulative economic benefit of $353.5 million in Bolivia, $486.7 million in the Kyrgyz Republic and $873.5 million in Serbia during the 2020-2030 period (Table 5.3). As in the case of the car occupant model, future annual economic benefits have been discounted assuming a 4.5 per cent annual discount rate.

TABLE 5.3

Estimated casualties avoided and economic benefits of applying UN Regulations Nos. 127 and 152 as of 2020 (2020-2030)

UN Regulations Nos. 127 and 152 - VRU economic benefit estimates					
	Cumulative lives saved 2020-2030	Cumulative serious injuries prevented 2020-2030	Mid estimate of economic loss due to one traffic fatality (2018 $US)	Mid estimate of economic loss due to one traffic serious injury (2018 $US)	Total economic benefits 2020-2030 (2018 $US)
Bolivia	684	5,647	225,814	36,983	353,491,732
Kyrgyz Republic	1,677	13,862	117,368	19,222	486,747,691
Serbia	402	2,688	965,008	158,059	873,546,247

For VRU related regulation costs, values of $236 for UN Regulation No. 152 and $ 225 for UN Regulation No. 127 (Martin et al., 2017), per vehicle were used respectively, while 50 per cent higher and lower costs were evaluated in the sensitivity analysis. An annual discount rate of 4.5 per cent was applied to all costs respectively, to take into account price inflation and learning curve effects. As a result, the figures presented in Table 5.4 represent the additional cost to each country of introducing the regulation.

As in the car occupant model, further costs that can be assigned to application of UN Regulations in countries that apply the regulations, relating to type approval, technical services and testing vehicle equipment and parts were not considered within the VRU analysis. The model proposed in this study may be adjusted to take into account such expenditures, in accordance with the situation, plans and needs in specific countries.

TABLE 5.4

Estimated costs linked to implementing UN Regulations Nos. 127 and 152 as of 2020 (2020-2030)

UN Regulation No. 140 - ESC cost estimates		
	Modelled additional vehicles equipped 2020-2030	Economic cost 2020-2030 (2018 $US)
Bolivia	375,668	137,112,272
Kyrgyz Republic	1,304,081	477,747,619
Serbia	2,172,988	873,564,247

The computed technology cost estimates and potential economic benefit estimates are used to derive benefit-cost ratios of implementing UN Regulations that aim at improving the safety of car occupant and VRUs in the corresponding section below.

III. Benefit-cost ratios of applying UN Vehicle Regulations

To assess the value of implementing the regulations and associated safety measures, it is necessary to compare the benefits with the costs. This section uses the casualty economic benefit and the cost estimates related to the implementation of the vehicle regulations presented in the above sections to calculate the benefit-to-cost ratio (BCR) for each country. These BCRs allow a comparison of the extent to which the benefits surpass or fall short of the costs related to implementation of the tested regulations over the period 2020–2030.

The final component of the model therefore brings together both the predicted benefits and costs, where the benefit value is divided by the cost to compute the BCR value:

- A value of less than 1 indicates that the cost of the measure exceeds the monetary valuation of benefits;
- A value of exactly 1 is the breakeven point where benefits equal the costs;
- A value of greater than 1 indicates that the benefits outweigh the costs. Modelled measures that return BCR values greater than 1 can be considered as recommendable for implementation. A BCR of 3.5, for example, implies that for every US dollar invested by consumers to purchase vehicles fitted these technologies, there is a 3.5$ US dollar economic benefit to society.

In addition to the best-estimate BCR values presented below, a sensitivity analysis where multiple parameters of the model are adjusted to evaluate their effect on the socioeconomic viability of applying the regulations is introduced in Annex I. Given the limitations inherent to some of the input data and assumptions, the sensitivity analysis represents a quality check. It is performed to evaluate the impact that changes in values of input parameters would have on the model's outputs – BCR values of applying UN Vehicle Regulations in the three case study countries.

III.I. Car occupants

The best-estimate benefit-cost ratios obtained for the implementation of UN Regulation No. 140 in the three case study countries for the 2020-2030 period indicate that by year 2025 it would be cost-beneficial to implement the regulation in all three countries. The BCRs for the case study countries and the respective sensitivity analysis ranges are summarized in Table 5.5 below.

TABLE 5.5

BCR estimates of applying UN Regulation No. 140 in Bolivia, the Kyrgyz Republic and Serbia (2020 – 2030)

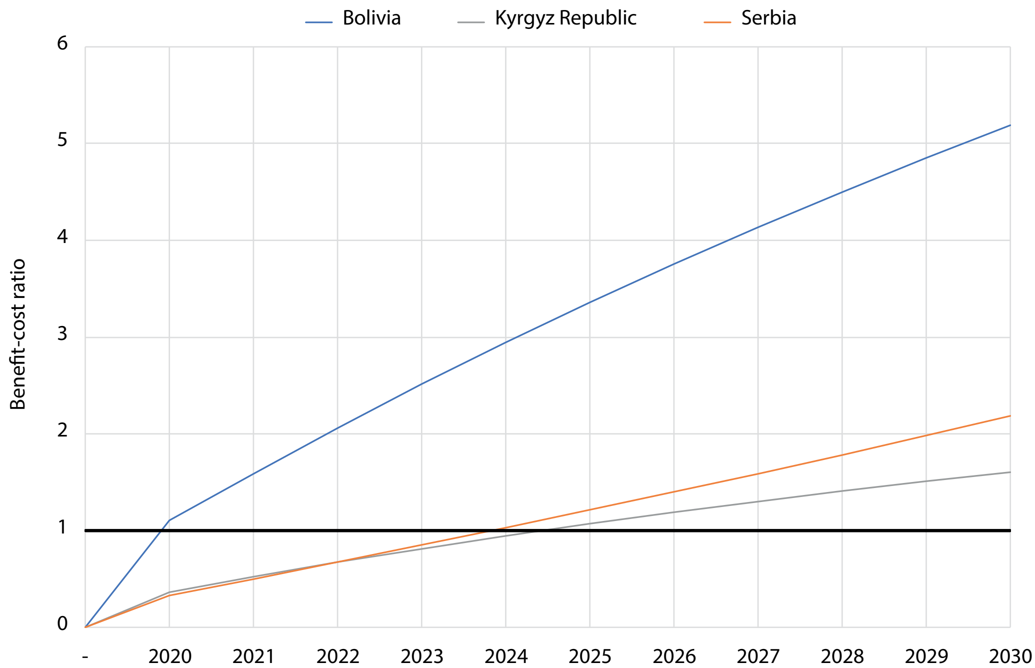
Bolivia BCR best estimate				
Cumulative lives saved	**Cumulative serious injuries prevented**	**Total economic costs $US**	**Total economic benefits $US**	**Benefit-cost ratio**
183	1,016	14,870,058	77,169,196	5.19
Sensitivity analysis ranges				
Cumulative lives saved	**Cumulative serious injuries prevented**	**Total economic costs $US**	**Total economic benefits $US**	**Benefit-cost ratio**
73 - 266	765 – 1,266	10,843,194 - 30,334,341	52,724,602 - 96,185,101	2,54 – 7.12

Kyrgyz Republic BCR best estimate				
Cumulative lives saved	**Cumulative serious injuries prevented**	**Total economic costs $US**	**Total economic benefits $US**	**Benefit-cost ratio**
358	1,984	51,802,325	83,004,593	1,60
Sensitivity analysis ranges				
Cumulative lives saved	**Cumulative serious injuries prevented**	**Total economic costs $US**	**Total economic benefits $US**	**Benefit-cost ratio**
142 - 520	1,495 - 2,472	37,774,035 - 105,674,031	79,588,503 - 103,458,447	0.79 - 2.20

Serbia BCR best estimate				
Cumulative lives saved	**Cumulative serious injuries prevented**	**Total economic costs $US**	**Total economic benefits $US**	**Benefit-cost ratio**
120	387	86,835,967	189,694,632	2,18
Sensitivity analysis ranges				
Cumulative lives saved	**Cumulative serious injuries prevented**	**Total economic costs $US**	**Total economic benefits $US**	**Benefit-cost ratio**
48 - 174	292 - 482	63,320,551 - 177,142,136	114,755,461 - 245,653,576	1.07 - 3.00

The results suggest that ESC would be cost beneficial in Bolivia already during the first year of implementation, while in the Kyrgyz Republic in 2025 and in Serbia during 2024 (Figure 5.21). This indicates that the implementation and harmonization of these regulations would be a positive on all levels for the three countries in the analysis.

Figure 5.21 - Estimated benefit-cost ratio of applying UN Regulation No. 140 as of 2020 (2020-2030)



III.II. Vulnerable road users

The best-estimate benefit-cost ratios obtained for the implementation of UN Regulations Nos. 127 and 152 in the three case study countries for the 2020-2030 period indicate that only by the last year of the period under observation would it be cost-beneficial to implement the regulations in all three countries. The BCR ratios for the case study countries and the respective sensitivity analysis ranges are summarized in following Table 5.6 - below.

TABLE 5.6

BCR estimates of applying UN Regulations Nos. 127 and 152 in Bolivia, the Kyrgyz Republic and Serbia (2020 – 2030)

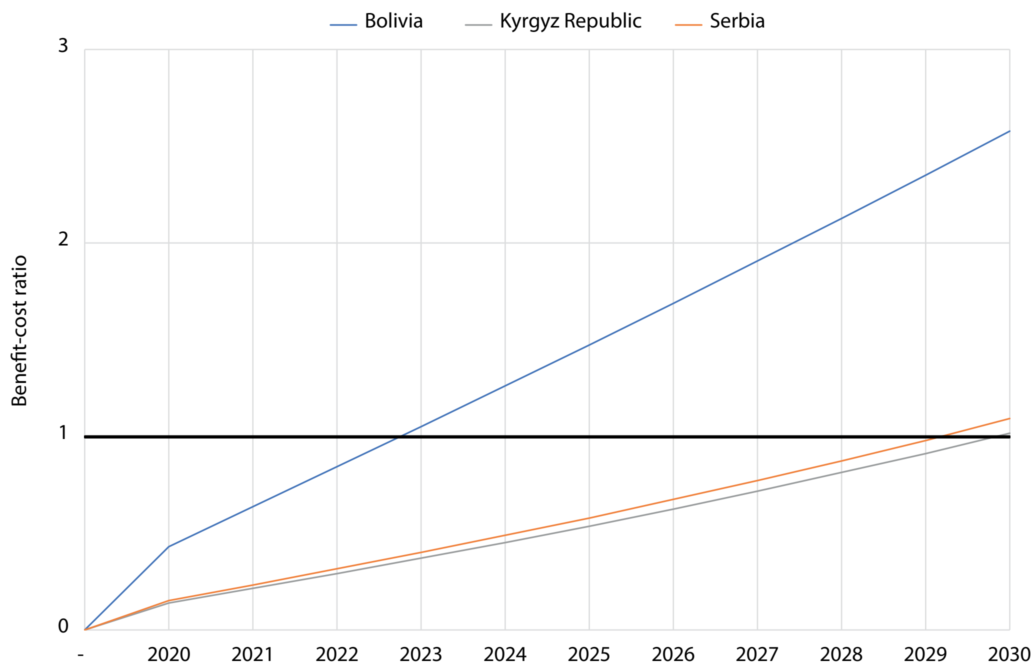
Bolivia BCR best estimate				
Cumulative lives saved	**Cumulative serious injuries prevented**	**Total economic costs $US**	**Total economic benefits $US**	**Benefit-cost ratio**
684	5,647	137,112,272	353,491,732	2.58
Sensitivity analysis ranges				
Cumulative lives saved	**Cumulative serious injuries prevented**	**Total economic costs $US**	**Total economic benefits $US**	**Benefit-cost ratio**
330 - 848	5,389 - 6,716	68,556,136 - 205,668,408	275,804,925 - 419,360,508	1.72 - 5.16

Kyrgyz Republic best estimate				
Cumulative lives saved	Cumulative serious injuries prevented	Total economic costs $US	Total economic benefits $US	Benefit-cost ratio
1,677	13,862	477,646,220	486,747,619	1.02
Sensitivity analysis ranges				
Cumulative lives saved	Cumulative serious injuries prevented	Total economic costs $US	Total economic benefits $US	Benefit-cost ratio
810 - 2,082	10,911 - 13,889	238,823,110 - 716,469,330	379,999,212 - 554,072,909	0.68 - 2.04

Serbia best estimate				
Cumulative lives saved	Cumulative serious injuries prevented	Total economic costs $US	Total economic benefits $US	Benefit-cost ratio
402	2,688	800,676,743	873,546,247	1.09
Sensitivity analysis ranges				
Cumulative lives saved	Cumulative serious injuries prevented	Total economic costs $US	Total economic benefits $US	Benefit-cost ratio
226 - 489	2,588 - 3,029	400,338,372 - 1,201,015,115	697,965,593 - 1,008,943,557	0.73 - 2.18

The results for the VRU regulation impact assessment suggest that applying the regulations as of 2020 would be cost beneficial in Bolivia by the end of 2023, while in the Kyrgyz Republic and in Serbia during 2030. The BCR for each year and for each country is presented in Figure 5.22 below. Although the BCR ratios for the Kyrgyz Republic and for Serbia are just above the break-even point in the best-estimate model, sensitivity analysis BCRs give strong support for applying VRU regulations in all three case study countries.

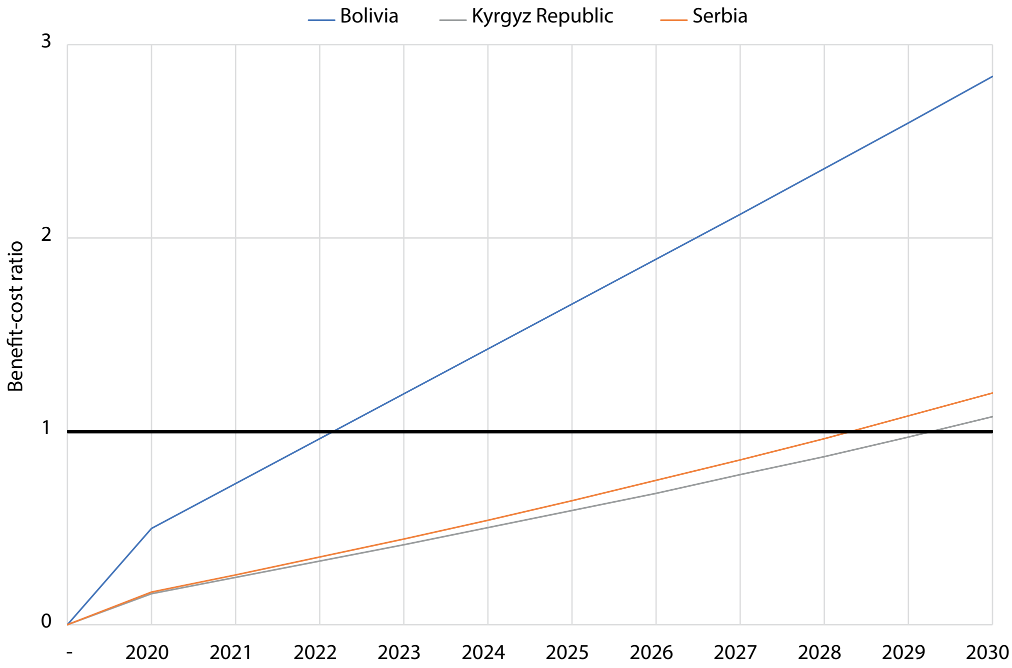
Figure 5.22 - Estimated benefit-cost ratio of applying UN Regulations Nos. 127 and 152 as of 2020 (2020-2030)



III.III. Overall benefit cost estimates

The combined results for the car occupant and VRU regulation impact assessment suggest that applying the regulations as of 2020 would exceed the neutral cost-benefit value of 1 in Bolivia during 2022, in the Kyrgyz Republic by the end of 2030 and in Serbia during 2029. The BCR for each year and for each country is presented in Figure 5.23 below.

Figure 5.23 - Estimated benefit-cost ratio of applying UN Regulations Nos. 140, 127 and 152 as of 2020 (2020-2030)



The BCR ratios, taking into consideration sensitivity analysis ranges, indicate support for applying the package of regulations in all three case study countries.

CHAPTER VI

Summary and Conclusion

Road traffic crashes and consequential injuries are among the leading causes of death globally, with 1.35 million deaths worldwide in 2016. On top of the fatalities, between 20 and 50 million people suffer serious injuries in road traffic crashes every year. While the most developed countries have in general terms succeeded in taming the rate of road crashes even as their motorization rates have increased steadily during the past two to three decades, low-income and middle-income countries still suffer from high mortality rates due to road traffic injuries with 27.5 and 19.5 deaths per 100,000 population respectively. Road traffic crashes also result in enormous economic losses, estimated at between 2 to 5 per cent of national Gross Domestic Product. Such levels of road traffic deaths and serious injuries are unacceptable in terms of human suffering and societal and economic costs and, are not sustainable.

The international community has strongly mobilized to address global traffic safety challenges. The UN's framework of Sustainable Development Goals (SDGs) address road safety within SDG 3 "Good health and well-being" and SDG 11 "Sustainable cities and communities". The highly ambitious SDG target 3.6 for reductions in both road crash fatalities and injuries poses a significant challenge to all governments to reinvigorate their national road safety policies and plans.

In addition, the UN Global Plan for the Decade of Action for Road Safety recommended that activities directed at improving road safety performance should take place at local, national, regional and global levels along the Plan's five pillars, one of which is Safer Vehicles. The UN Global Plan encourages universal deployment of improved vehicle safety technologies for both passive and active safety through a combination of harmonization of relevant global standards, consumer information schemes and incentives to accelerate the uptake of new technologies. Some of the recommended paths towards this end include:

- Encouraging UN Member States to apply and promulgate motor vehicle safety regulations as developed by the United Nation's World Forum for the Harmonization of Vehicle Regulations (WP 29).
- Ensuring that all new motor vehicles are equipped with safety-belts and anchorages that meet regulatory requirements and pass applicable crash test standards (as minimum safety features).
- Securing universal deployment of crash avoidance technologies with proven effectiveness such as Electronic Stability Control and Anti-Lock Braking Systems in motorcycles.

In support of these efforts, the present study introduces a methodology that governments and non-governmental stakeholders can use to assess the potential socio-economic impact of UN Regulations and UN GTRs on improving road safety. As an example, the methodology is applied to three national cases, Bolivia, the Kyrgyz Republic and Serbia, to calculate the potential impact of UN Vehicle Regulations on the safety of four-wheeled light vehicle occupants, pedestrian and cyclists, and the resulting socio-economic benefits of casualty reductions.

The model calculates the societal cost-benefit of regulating ESC, an active measure aimed at improving car occupant safety, through performance conforming to UN Regulations No. 140 and UN GTR No. 8. The model also, separately calculates the cost-benefit of regulating an Automatic Emergency Breaking System AEBS, a collision avoidance active safety measure, with performance conforming to UN Regulation No. 152, and pedestrian protection passive safety measures in conformance with UN Regulation No. 127 and UN GTR No.9, estimating the combined impact of these systems on preventing pedestrians and cyclist fatalities and serious injuries. The impact assessment and cost-benefit ratios are calculated for the projected victim population impacted by relevant crashes in the three countries during the period 2020-2030, using data accessible from online national sources and supplemented from UNECE and WHO road traffic statics databases.

The model, within the best estimate scenario, indicates that the fitting of all first time registered (Kyrgyz Republic and Serbia) or all newly registered (Bolivia) vehicles, as of 2020, with systems that comply with requirements set out through UN Regulations Nos. 127, 140 and 152, would result in 867 lives saved and 6,662 serious injuries prevented in Bolivia, 2,035 lives saved and 15.845 serious injuries prevented in the Kyrgyz Republic, and 522 lives saved and 3,075 serious injuries prevented in Serbia by 2030, as compared to a no action scenario (Table 6.1).

TABLE 6.1

Estimated casualties avoided resulting from applying UN Regulations Nos. 127, 140 and 152 as of 2020 (2020-2030)

Estimated casualty reductions 2020-2030						
	ESC for car occupants		VRU Regulations		Total	
	Lives saved	Serious injuries prevented	Lives saved	Serious injuries prevented	Lives saved	Serious injuries prevented
Bolivia	183	1,016	684	5,647	867	6,663
Kyrgyz Republic	358	1,984	1,677	13,862	2,035	15,845
Serbia	120	387	402	2,688	522	3,075

In terms of economic performance of the regulatory measures, the models best estimate scenario indicates that the combined impact of the application, as of 2020, of the assessed UN Regulations directed at car occupant and vulnerable road users safety would become cost-beneficial before the end the 2020s in all three countries – by the end of 2023 in Bolivia, and during 2029 in Serbia and during the last year of the decade in the Kyrgyz Republic (Table 6.2). The benefit-cost break-even trajectory for the case of Bolivia is aligned with the results of the benefit-cost analysis of applying crashworthiness, crash avoidance and pedestrian protection UN Regulations in Argentina, Chile, Brazil and Mexico carried out by the UK TRL (Wallbank et al., 2019). This study found that application of the considered set of UN Regulations would become, cumulatively, cost beneficial in those countries by 2023.

TABLE 6.2

Year when the BCR of applying UN Regulations Nos. 127, 140 and 152 as of 2020 becomes greater than 1

Economic cost benefit 2020-2030 - Break-even year (by end of year)			
	ESC for car occupants	VRU Regulations	ESC and VRU Regulations combined
Bolivia	2020	2023	2023
Kyrgyz Republic	2025	2030	2030
Serbia	2024	2029	2029

It should be noted that the benefits presented in this study are limited to the economic benefits associated with reducing the number of fatalities and serious injuries, and do not account for other benefits, such as reducing light injuries or avoidance of costs incurred due to property damage. Since the vehicle safety systems examined in this study are likely to be effective at reducing all types of injury and other related costs, including medical costs, the benefit-to-cost ratios may be an underestimate. It should also be noted that the calculations relating to serious injuries are based on substantial assumptions in the case of modelling carried out for Bolivia and the Kyrgyz Republic, more so than those for fatalities, due to the limited information on non-fatal injuries that was identified from online sources for these two countries.

The benefits of these regulations are also not necessarily distinct for the two populations. For example, it is possible that the introduction of ESC will also reduce the number of VRU fatalities and serious injuries, since it will reduce the number of drivers which lose control of the vehicle and subsequently collide with a pedestrian. However, the casualty data from the three countries that could be obtained from Internet databases was limited, and thus information on the number of collisions of each type and potential overlapping populations is not possible to obtain. In addition, the estimate of how effective each safety feature is at eliminating or mitigating fatalities and serious injuries is typically limited by an assumption in the analysis to the primary group of interest (e.g. car occupants in the case of ESC). As a result, two models are developed, one for car occupants and one for VRUs, and only the impact of the safety features outlined above are considered within each model. This might lead to further underestimates of the benefits of some technologies when considered as individual measures.

The potential for overestimation due to double-counting casualties within a package of measures is avoided with the assumption that no benefit can be attributed to a measure from the other target population. The accuracy of numbers of projected future victims, which is a key element in the equation for computing future economic benefits of their avoidance, hinges on the quality of historic longitudinal data and on the robustness of statistical methods applied.

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ANNEX I – SENSITIVITY ANALYSIS

The best-estimate benefit-to-cost ratios (BCRs) presented in Chapter V, represent the most likely outcome if road safety and motorization trends continue as they have done in recent years, taking into account mid-range estimates of the effectiveness of vehicle safety technologies, road traffic crash populations, technology costs and estimates for the VSL that are assessed in the model. However, as there is inherent uncertainty in all predictions made, exploring the impact of changing model input parameters on calculated BCRs, through performing a sensitivity analysis, is required to improve the robustness of the results over the timeline under observation.

Therefore, in order to quantify the range of uncertainty around the BCR values, scenario analysis was carried out to reflect the bounds of variation that could be expected if the input values were varied from low to high estimates, or if different assumptions were made at each stage. Specifically, the effect of changing the following inputs/assumptions was investigated:

- Road safety trend – alternative estimates of casualties 2020-2030;
- Motorization rates – alternative estimates of the proportion of a vehicle fleet containing systems that adhere to the UN Regulations under assessment;
- Effectiveness estimates – alternative estimates of the effectiveness of systems preventing casualties within the applicable crash population;
- Road traffic crash population – alternative estimates of the proportion of crashes where the technologies have an impact;
- VSL values – alternative estimates of the VSL GDP multipliers;
- Varying costs – alternative estimates for the costs of vehicle safety systems evaluated.

The range of alternative values for all the parameters was drawn from the literature presented throughout this study. For each scenario one of the inputs was adjusted while others remained as in the Best Estimate scenario, as reflected for car occupants and VRUs in Table A.I and A.IV, respectively. Tables A.II and A.V present obtained BCR values for car occupant and VRU sensitivity analysis for the three case study countries based on the scenarios considered within this exercise. In the both the car occupant and VRU sensitivity analysis, for the case of all three countries the outlying high and low BCRs were returned in the scenarios where assumptions on the costs of technologies were tested, with all other input parameters remaining unchanged.

Tables A.III and A.VI offer further sensitivity scenarios, where combined effects of changing technology effectiveness rates and technology costs assumptions, with all other inputs remaining as in the Best Estimate scenario, were modelled to compute BCRs, for car occupants and VRUs respectively. For the car occupant analysis, results indicate that the application of UN Regulation No. 140 in Bolivia is cost effective for all scenarios, including the low technology effectiveness and high technology cost scenario. For the Kyrgyz Republic all scenarios with assumed high cost of technology yield BCRs of less than 1, while for Serbia all scenarios apart from low technology effectiveness and high technology cost return BCRs of greater than 1. Results for the VRU model similarly indicate that all modelled scenarios return positive BCRs for the application of UN Regulations Nos. 127 and 152 in Bolivia, whereas the cost effectiveness of their application in the Kyrgyz Republic and Serbia will depend on the relationships between costs of technologies and their effectiveness in preventing casualties and serious injuries.

TABLE A.I

Sensitivity analysis scenarios for the impact of the application of UN Regulation No. 140 for car occupants on BCR estimates

Input parameters adjusted in the sensitivity analysis		Scenarios									
Timeframe 2020-2030	**Best estimate**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Casualty rate	Exponential trend	2020-2030 annual percentage change equal to the 2010-2019 period									
New/Newly registered vehicle data	Linear trend for all cars and new cars		2020-2030 annual percentage change equal to the 2009-2019 period								
ESC effectiveness in preventing fatalities in traffic crashes	Mid estimate 37.9 %			High 55 %	Low 15 %						
ESC target population	ESC impacts outcome of 34.9 % of crashes					High 43.5 %	Low 26.3 %				
VSL estimates	Mid estimate 103.8 x GDP per capita							High 137.6 x GDP per capita	Low 70 x GDP per capita		
ESC cost (in 2020)	Mid estimate 50 US$ per vehicle									High 102 US$ per vehicle	Low 36 US$ per vehicle

TABLE A.II

Sensitivity analysis scenarios for car occupant BCR estimates concerning the application of UN Regulation No. 140

Country case studies: Timeframe 2020-2030	Best estimate	Scenarios 1	2	3	4	5	6	7	8	9	10
Bolivia BCRs	5.19	5.08	4.93	6.42	3.55	6.47	3.91	6.08	4.30	2.54	7.12
Kyrgyz Republic BCRs	1.60	1.25	1.27	1.98	1.09	2.00	1.21	1.88	1.33	0.79	2.20
Serbia BCRs	2.18	2.21	2.18	2.83	1.32	2.72	1.65	2.65	1.72	1.07	3.00

TABLE A.III

Technology cost and effectiveness sensitivity analysis for car occupant BCR estimates concerning the application of UN Regulation No. 140

Technology cost: Timeframe 2020-2030	Technology effectiveness: Low	Best estimate	High
Bolivia	**Low**	**Best estimate**	**High**
Low	4.01	7.12	7.26
Best estimate	3.55	5.19	6.42
High	1.74	2.54	3.15
Kyrgyz Republic	**Low**	**Best estimate**	**High**
Low	1.50	2.20	2.72
Best estimate	1.09	1.60	1.98
High	0.54	0.79	0.97
Serbia	**Low**	**Best estimate**	**High**
Low	1.81	3.00	3.88
Best estimate	1.32	2.18	2.83
High	0.65	1.07	1.39

TABLE A.IV

Sensitivity analysis scenarios for the impact of the application of UN Regulations Nos. 127 and 152 for VRUs BCR estimates

Input parameters adjusted in the sensitivity analysis: Timeframe 2020-2030	Best estimate	Scenarios: 1	2	3	4	5	6	7	8	9
Casualty rate	Logarithmic trend for Bolivia and the Kyrgyz Republic. Exponential trend for Serbia	2020-2030 annual percentage change equal to the 2010-2019 period								
New/Newly registered vehicle data	Linear trend for all cars and new cars		2020-2030 annual percentage change equal to the 2009-2019 period							
UN R. No. 152 effectiveness in preventing fatalities in traffic crashes	Mid estimate: Pedestrians 55 %; Cyclists 48 %			Low 21 %; 42 %;						
UN R. No. 127/GTR No. 9 effectiveness in preventing fatalities in traffic crashes	Mid estimate: Pedestrians 3.9 %; Cyclists 4.1 %				High 16.4 % 10.2 %	Low 1 %; 1 %;				
VSL estimates	Mid estimate 103.8 x GDP per capita						High 137.6 x GDP per capita	Low 70 x GDP per capita		
Cost of systems Mid estimate per vehicle (in 2020)	UN. R. No. 127: 236 US$ UN. R. No. 152: 225 US$								High UN. R. No. 127: 354 US$ UN. R. No. 152: 337 US$	Low UN. R. No. 127: 118 US$ UN. R. No. 152: 112 US$

TABLE A.V

Sensitivity analysis scenarios for VRUs BCR estimates concerning the application of UN Regulations Nos. 127 and 152

Country case studies	Timeframe 2020-2030	Best estimate	Scenarios 1	2	3	4	5	6	7	8	9
	Bolivia BCRs	2.58	3.06	2.46	2.01	2.84	2.52	2.93	2.22	1.72	5.16
	Kyrgyz Republic BCRs	1.02	1.01	1.08	0.80	1.12	1.00	1.21	1.16	0.68	2.04
	Serbia BCRs	1.09	1.11	1.09	0.86	1.20	1.07	1.26	0.92	0.73	2.18

TABLE A.VI

Technology cost and effectiveness sensitivity analysis for VRUs BCR estimates concerning the application of UN Regulations Nos. 127 and 152

Technology cost	Timeframe 2020-2030	Technology effectiveness		
	Bolivia	**Low**	**Best estimate**	**High**
	Low	3.90	5.16	5.68
	Best estimate	1.95	2.58	2.84
	High	1.30	1.72	1.89
	Kyrgyz Republic	**Low**	**Best estimate**	**High**
	Low	1.54	2.04	2.25
	Best estimate	0.77	1.02	1.12
	High	0.51	0.68	0.75
	Serbia	**Low**	**Best estimate**	**High**
	Low	1.84	2.18	2.41
	Best estimate	0.84	1.09	1.20
	High	0.56	0.73	0.80

SUSTAINABLE DEVELOPMENT GOALS

UN Vehicle Regulations for road safety
Cost-benefit methodology

Part of the WP.29 "How it works – How to join it" series

Part of the WP.29, "How it works – How to join it" series, this publication introduces methodologies that are used to evaluate the socioeconomic utility of applying key UN Vehicle Regulations for improving road safety. It presents an overview of current global road safety and vehicle safety statistics, describes methodologies that are used for assessing the impact of vehicle regulations on national road safety performance, and provides examples for their application.

Readers are introduced to procedures that are applied in estimating the impact of UN Vehicle Regulations on prevention of road traffic casualties in countries around the world, the elements of related vehicle technology effectiveness estimates, impact valuation approaches and cost-benefit analysis exercises. Based on the literature review, three country case studies are developed to calculate expected benefit-cost ratios of applying a set of UN Vehicle Regulations, which address vehicle occupant and vulnerable road users safety, over the 2020-2030 period. The publication promotes an evidence-based approach to policy making in the area of vehicle regulations for road safety.

Information Service
United Nations Economic Commission for Europe

Palais des Nations
CH - 1211 Geneva 10, Switzerland
Telephone: +41(0)22 917 12 34
Fax: +41(0)22 917 05 05
E-mail: unece_info@un.org
Website: http://www.unece.org

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