UNECE

The United Nations Motorcycle Helmet Study

Part of WP.29, "How it works and how to join it", series

UNITED NATIONS

UNITED NATIONS ECONOMIC COMMISSION FOR EUROPE

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UNITED NATIONS
New York and Geneva, 2016

NOTE

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ECE/TRANS/252

UNITED NATIONS PUBLICATION
Sales No.: 16.II.E.9
ISBN 978-92-1-117107-5
e-ISBN 978-92-1-057788-5

Acknowledgements

The publication *"United Nations Motorcycle Helmet Study"* was produced by the UNECE Sustainable Transport Divisions' Vehicle Regulations and Transport Innovations Section. The Sustainable Transport Division wishes to express its sincere thanks to all those who contributed to this publication.

Among the major contributors and authors are Nicholas Rogers (Nick Rogers Consulting), Edoardo Gianotti, Branko Milićević, Heini Salonen and Nikola Šahović (UNECE). Special thanks are extended to Pierre Castaing (UTAC), and to the United Kingdom of Great Britain and Northern Ireland Department for Transport.

The authors worked under the guidance of and benefited from significant contributions by Eva Molnar, Director of the UNECE Sustainable Transport Division, the former, Juan Ramos Garcia, and the current, Walter Nissler, Chief of the Vehicle Regulations and Transport Innovations Section, and Miodrag Pešut, Chief of Transport Facilitation and Economics Section.

In addition, the team would like to express gratitude to all colleagues who contributed inputs and provided advice and support during the course of preparation of this publication and particularly to the editor Violet Yee (UNECE).

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, 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 analyses of the transition process, using its harmonization experience to facilitate the integration of Central and Eastern European countries into the global markets.

Today UNECE is the forum where the countries of the whole of Europe, Central Asia and North America—56 countries in all—come together to forge the tools of their economic cooperation. That cooperation encompasses economics, statistics, environment, transport, trade, sustainable energy, timber and habitat.

UNECE offers a regional framework for the elaboration and harmonization of conventions, norms and standards. In particular, UNECE's experts provide technical assistance to the countries of South-East Europe and the Commonwealth of Independent States. This assistance takes the form of advisory services, training seminars and workshops where countries can share their experiences and best practices.

Transport in the UNECE

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.

The ECOSOC Committee was set up in 1953 by the Secretary-General of the United Nations at the request of the Economic and Social Council to elaborate recommendations on the transport of dangerous goods. Its mandate was extended to the global (multi-sectorial) harmonization of systems of classification and labelling of chemicals in 1999. It is composed of experts from countries which possess the relevant expertise and experience in the international trade and transport of dangerous goods and chemicals. Its membership is restricted in order to reflect a proper geographical balance between all regions of the world and to ensure adequate participation of developing countries. Although the Committee is a subsidiary body of ECOSOC, the Secretary-General decided in 1963 that the secretariat services would be provided by the UNECE Transport Division.

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 on-going 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 (CO_2) 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.

In addition, 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).

Finally, 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.

Inland Transport Committee (ITC) – Centre of UN Transport Conventions

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List of Abbreviations

Acronym/Abbreviation	Definition
BSI	British Standards Institute
CERAM	Centre for Automotive Research and Testing
DENATRAN	National Transport Department of Brazil
DOT	United States of America Department of Transportation
EC	The European Commission
ECE	United Nations Economic Commission for Europe
ECOSOC	United Nations Economic and Social Council
EU	The European Union
FMVSS	United States of America - Department of Transportation - Federal Motor Vehicle Safety Standard
GDP	Gross Domestic Product
GNI	Gross National Income
GRSP	Inland Transport Committee Working Party for Passive Safety
HIC	High-income countries
IMF	International Monterary Fund
ISO	International Organization for Standardization
ITC	Inland Transport Committee
JAMA	Japanese Automobile Manufacturers Association
KFG	Austrian Motor Vehicles Act
LIC	Low-income countries
LMIC	Low-middle income countries
MAIS	Maximum Abbreviated Injury Scale
MIC	Middle-income countries
NHTSA	United States National Highway Traffic Safety Administration
PTW	Powered two-wheeler
TIR	International Transport of Goods
UMIC	Upper-middle income countries
UN	The United Nations
UNECE	United Nations Economic Commission for Europe
UTAC	Technical Union for the Automobile, Motorcycle and Cycle Industries
WHO	World Health Organization
WP	Working Party

"When your head hits the pavement or the ground your brain is going to move forward, hitting up against the bones inside the skull. It's going to deform. It's going to stretch nerve fibers. It's going to tear nerve fibers. And the torn ones are gone. When you lose a brain cell, there is no replacement for it. So that's where permanent damage occurs.

In fact, people who have an accident like that often don't get better. They've lost something. They may have lost some of their intelligence. They may have lost the capacity to take care of themselves because of the damage to their system that controls their muscles. They may have a behavior change – have difficulty dealing with other people, having proper social relationships. It's all a consequence of that unprotected skull, and nothing can take up the shock.

There is no cure for brain injury. A brain injury is forever. We can teach someone strategies for dealing with the handicaps, but the only effective approach in dealing with head injury is prevention…not to let the injury occur in the first place.

So, helmet laws -- they are a necessity."

William D. Singer, M.D., Harvard Medical School

Source: Insurance Institute for Highway Safety/Highway Loss Data Institute video

Executive summary

Motorcyclists are 26 times more likely to die in a traffic crash than the drivers of passenger cars. Wearing an appropriate helmet improves their chances of survival by 42 per cent and helps avoid 69 per cent of injuries to riders.

A motorcycle crash may result in head injuries, through either a direct contact with hard objects or as a result of excessive acceleration–deceleration. Most traumatic brain injuries are the result of closed head injuries, when there is no open wound. The motorcycle helmet is designed to minimize the risks of all kinds of head injuries. Helmet standards and regulations have been developed to test the effectiveness of helmets in providing protection.

Article No. 3 of the United Nations Universal Declaration of Human Rights states that "everyone has the right to life, liberty and security of person". In this sense, the work of the United Nations aims to protect human life and therefore it has always encouraged the use of the best helmets available, which offer a high level of protection and a fair chance to all riders to survive a crash, regardless of where they live.

In 1972 the United Nations Economic Commission for Europe (UNECE), following the implementation of the UN 1958 Agreement, adopted UN Regulation No. 22 which covers motorcycle helmets. UN Regulation No. 22 has since been periodically updated to reflect progress in technical, medical and materials research. Now in its fifth series of amendments (with each series increasing the level of stringency and protection), UN Regulation No. 22 provides uniform conditions for the approval of protective helmets for drivers and passengers of motorcycles.

An important feature of UN Regulation No. 22 is that it requires independent testing and product marking. This ensures that the helmet is of high quality and that it is safe. The approval mark in UN Regulation No. 22 is a key part of enforcing a helmet-wearing policy. Recognizing the value of UN Regulation No. 22, the majority of European countries, as well as many other countries in the world (42 in all), have made it part of their own legislation and have joined the UN type approval system. In addition, numerous countries that are not Contracting Parties to the 1958 Agreement also base their national motorcycle helmet legislation on Regulation No. 22.

The type approval system is based on:

- Testing of UN Regulation No. 22 annexed to the 1958 Agreement;
- "Mutual recognition" of the type approval certificate, e.g. "approved once and sold everywhere", avoiding the need for expensive test facilities;
- Maintaining conformity of production to the type tested. Countries involved in the UN system can, thus, rely on each other in the implementation and maintenance of their national legislation.

Sometimes a country may find it necessary to introduce additional requirements to the most recent version of UN Regulation No. 22 in order to address local needs. This may not affect the principle of mutual recognition. Nevertheless, countries not yet Contracting Parties to the 1958 Agreement are encouraged to base their national legislation on UN Regulation No. 22 as it provides the minimum set of requirements for safe helmets, and would ease subsequent accession to the Agreement.

In many low and low-middle income countries motorcycles are the main form of motorized transport. In some of these countries, economic progress has caused sharp increases in the number of motorcycles in circulation. Motorcycle markets in low income countries have developed particularly rapidly. As a general rule, the poorer the country the higher the motorcycle fleet growth rate. With more motorcycles on the road there will certainly be an increased risk of accidents causing injury or death, in particular if appropriate helmets are not used.

The affordability and availability of appropriate helmets in low income countries are issues of great concern. However, progresses in affordability and availability should certainly not compromise the quality of helmets or their ability to provide the best possible protection if they are worn properly.

One of the key objectives of the UN Decade of Action for Road Safety (2011-2020) is to reduce motorcycle casualties by encouraging the use of safety helmets. This study exhibits that up to 3.4 million deaths might result from motorcycle crashes between 2008 and 2020. As many as 1.4 million of those fatalities can be avoided with the proper use of safety helmets. A policy on wearing motorcycle helmets is, therefore, essential for promoting safety.

Up to 3 per cent of victims of motorcycle accident related fatalities worldwide are children. UN Regulation No. 22 contains provisions that allow helmets for children to be tested. The adoption of national laws stipulating mandatory use of helmets for children being transported on motorcycles would encourage the development of markets for child helmets. Mass production could expand the availability and induce affordability of helmets for children, as is already the case with bicycle helmets.

This study recommends:

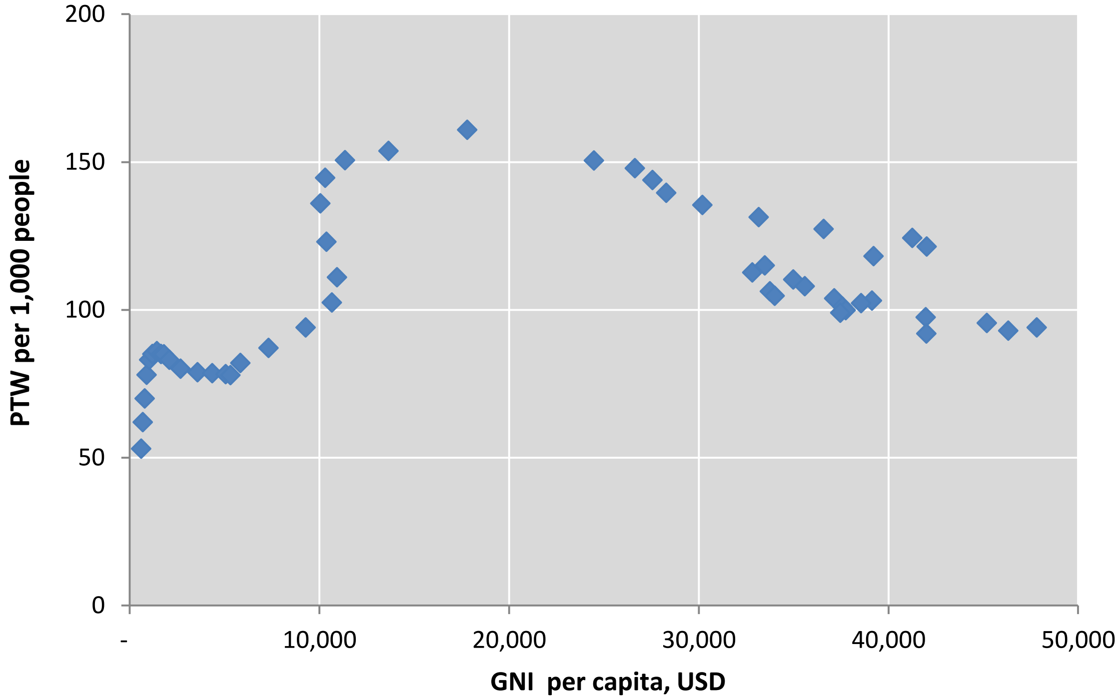
What countries can do?	How they can do it?
Introduce a helmet-wearing policy	See Section 2: Introducing helmet-wearing policies
Accede to the 1958 UNECE Agreement	See Section 3.7: How to join and implement the UN 1958 Agreement; and Annex I
Apply UN Regulation No. 22 on helmets, either in its current or one of the former versions	See Section 3: UN Regulation No. 22 sets safety requirements for helmets; and Annex I
Make helmets more affordable in low income countries	See Section 5.2: Affordability and availability
Increase awareness at the political level to encourage the use of appropriate helmets for children of different ages, who are old enough or tall enough to be allowed to be transported on a motorcycle	See Section 5.3: Children and helmets
Update transport policies and traffic rules taking into account the growing use of e-bikes	See Chapter 6: New challenges: Pedal assisted bikes - Electric bikes (Participate in international policy debates and exchange of best practices, e.g. the UNECE ITC, THE PEP, and similar initiatives)
Improve the quality of national statistical data on motorcycles in use, accidents involving motorcycles, and deaths and injuries, so that policies are based on sound data	Refer to Annex II: Statistical work, which describes some of the data needed and methods applied

1. Motorcycle markets and accidents

1.1 The development of motorcycle markets

Motorcycles can provide a less expensive and a more sustainable form of transport than cars. They are often the primary, or most abundant, form of transport in low income countries (LIC)[1]. Since 1945, new markets for motorcycles have rapidly developed in a number of countries. They have typically developed through imports, followed by production in local assembly plants, finally leading to full manufacturing of motorcycles and motorcycle equipment. The rate of market development varies with local circumstances. Once the production is located in a country, sales and thus the number of motorcycles in use, i.e. the 'fleet' grow rapidly. When people attain a certain level of wealth they move on to driving cars and the rate of increase in the motorcycle fleet declines, stabilizing at a plateau somewhat below the peak. Figure 1 offers insight exemplifying such developments in the Japanese powered two-wheeler (PTW) market through an overview of PTW ownership relative to individual wealth during the last 52 years (1962-2014).

Figure 1
Development of the powered two-wheeler fleet in Japan



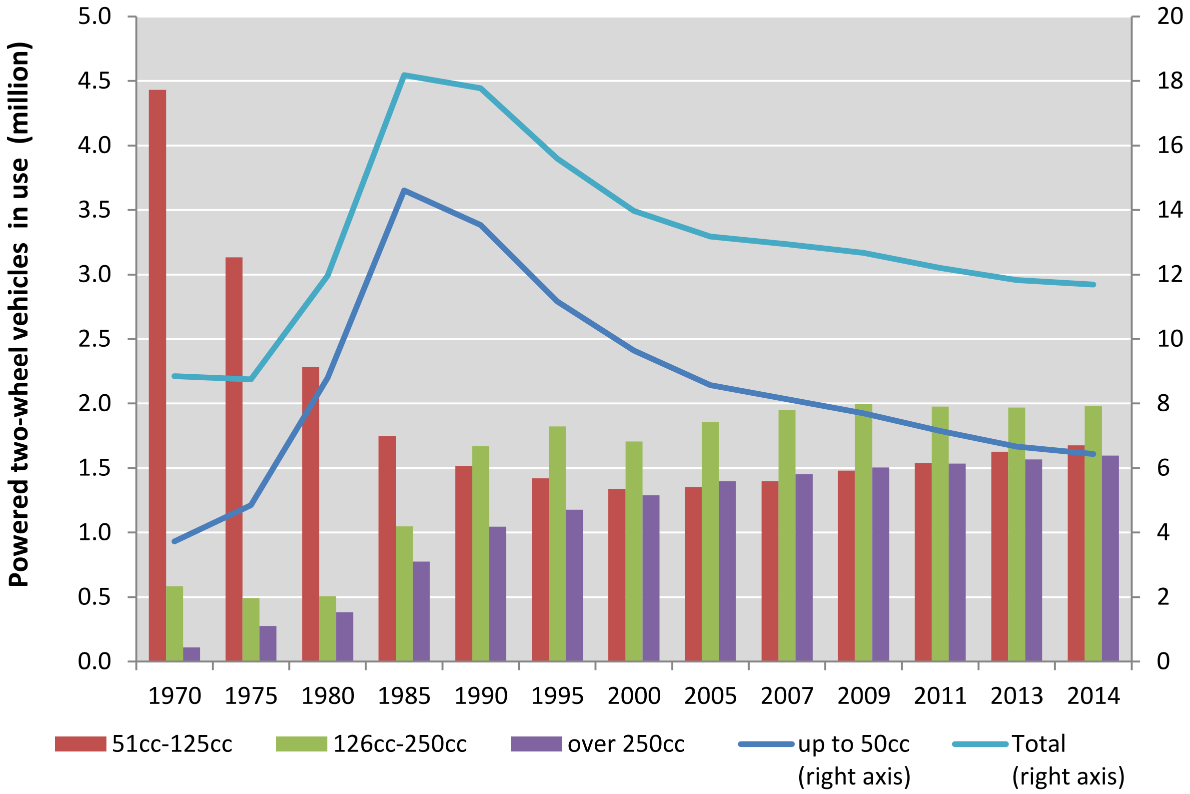
Source: Based on data from World Bank and national sources (see Annex II: Statistics explained)

[1] Countries are categorized in this section as follows:
Low income countries include India, Kyrgyzstan, Uganda and Viet Nam. Low-middle income countries include Indonesia, Moldova, the Philippines and Ukraine. Upper-middle income countries include Azerbaijan, Belarus, Brazil, Bulgaria, Kazakhstan, the former Yugoslav Republic of Macedonia, Malaysia, Poland, the Russian Federation, Romania, Thailand and Turkey. High income countries include Austria, Belgium, Canada, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Ireland, Israel, Italy, Latvia, the Netherlands, Norway, Portugal, Slovenia, Spain, Sweden, Switzerland, the United Kingdom of Great Britain and Northern Ireland and the United States of America. (World Bank , 2011)

This general trend is very well illustrated by the history of the motorcycle market in Japan[2] (Figure 2). In 1945, the country had a dramatic need for cheap transport and many companies entered the automotive industry, e.g. Suzuki diversified from textile machinery, Yamaha from musical instruments, while Mr. Honda, founder of the Honda Motor Company, began setting small engines on bicycles.

Figure 2[3]

Motorcycles in use in Japan[4]



Trends in Japan prior to 1966 are replicated in today's rapidly growing motorcycle markets, for example in India, where the fleet is growing with income (GNI per capita).

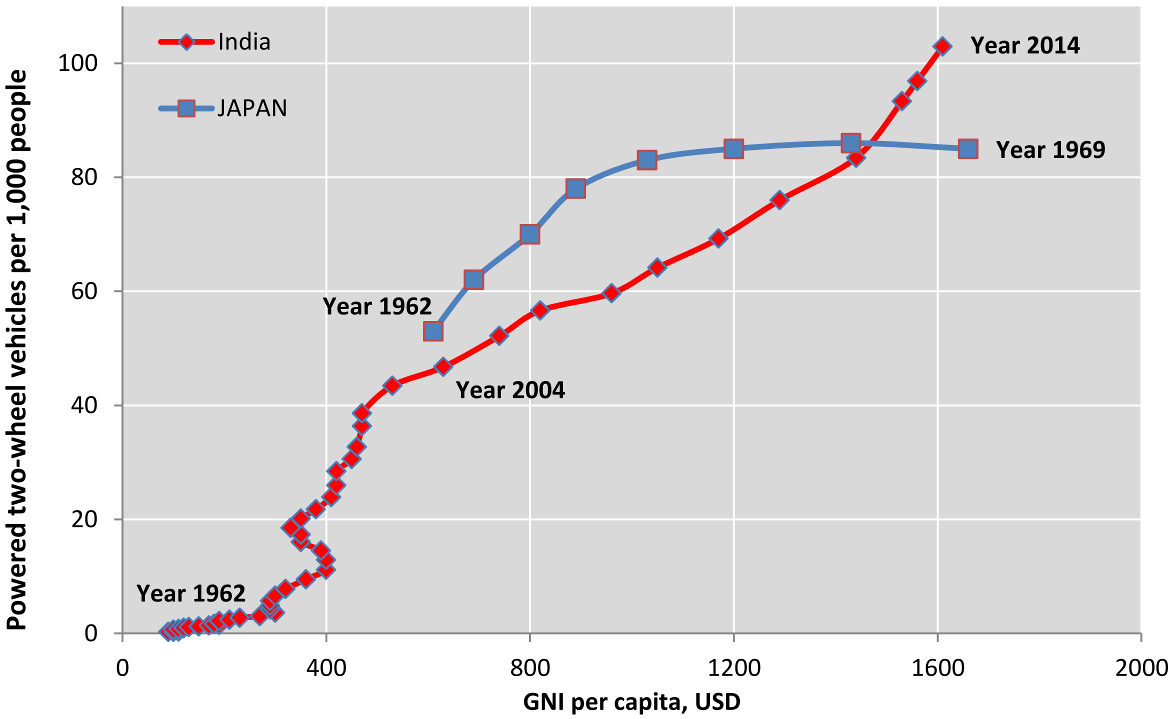
The comparison between Japan and India (Figure 3) suggests that countries with a developing motorcycle market may be mirroring the Japanese example as their motorcycle markets mature.

[2] See Annex II for a discussion of the data and statistical methods and sources used in this study.

[3] According to today's definitions, up until 1966 Japan would have been classified by the World Bank as a low-income country. Until then, growth of the motorcycle fleet was rapid and very closely linked to the growth of the average income. From 1967 to 1985, Japan would have been classified as a middle income country (MIC) and growth of the motorcycle fleet was slower. Finally, from 1986 onwards Japan has been a high income country (HIC) and the motorcycle fleet has declined in line with further growth in income.

[4] Note: Motor-driven cycle data is as at April 1, and since 2006 motorcycles with engine capacity of 125cc and under whose owners fail to pay the mandatory motorcycle ownership tax are not included in this data.

Figure 3
Growth of motorcycle fleets in Japan and India as a function of income



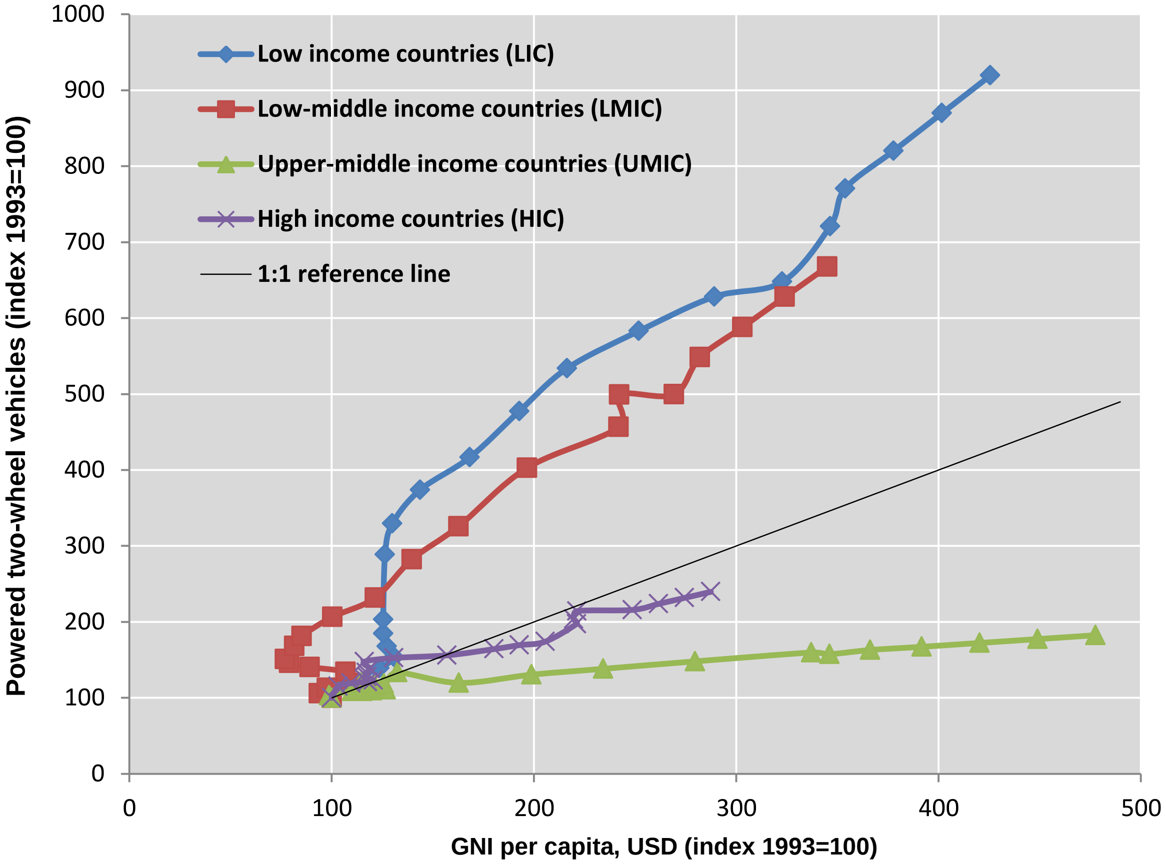
Source: Based on data from World Bank and national sources.
Note: see Annex II Statistics explained.

Figure 4 shows motorcycle fleets growth trends of as a function of income. If the growth in PTW vehicle fleets exactly matched the growth in GNI per capita, the data points would be along or close to the 1:1 reference line. From Figure 4 one can note the following trends:

- In low income countries, the growth in motorcycle fleets significantly outpaced economic development. For example, as GNI tripled, the fleet grew more than six fold.
- A similar trend, somewhat less pronounced, can be noted in the case of low-middle income countries (LMIC): as their GNI per capita doubled, the size of the fleet quadrupled.
- The upper-middle income countries (UMIC) show an opposite trend to that in LIC and LMIC. The UMIC data might be skewed by the fact that among UMIC there are many East European countries with economies in transition. Typically, such countries have experienced a direct transition from public transport to cars. Even though two members of UMIC group—Thailand and Brazil—have large markets for motorcycles, the growth in these markets has probably not been sufficient to offset the weight of other countries in the UMIC group.
- The trend in high income countries, which have mature markets, resembles a sine wave that has the 1:1 line as its axis.

In conclusion, as GNI per capita rises the motorcycle fleet expands – the poorer the country, the higher the growth. In low income countries fleets can grow almost exponentially, which may result in a rapid increase in the number of motorcycle crashes.

Figure 4
Powered two-wheel vehicle fleets in the world[1] as a function of economic growth



Source: Based on data from World Bank and national sources.
Note: see Annex II Statistics explained; PTW and GNI per capita time series are given for the period 1993-2014.

1.2 *Estimation of motorcycle fatalities*

In this section, different methods are used to estimate the number of motorcycle accident related fatalities for the period 2008 – 2020. This period was selected because of the availability of data and because the United Nations Decade of Action for Road Safety[5] ends in 2020. The analysis uses data on killed riders from WHO (2009) and covers the countries mentioned in the above analysis (more details in Annex I). The link between the size of the motorcycle fleet and the number of motorcyclist killed was analysed using four different methods:

1. Applying the percentage changes for the period 1996 – 2008 to the period 2008 – 2020;
2. A trend analysis to predict the future values for key variables;
3. The use of regression equations to calculate the trend in the number of fatalities;
4. Application of the trends used in method 3 to the starting point given by the WHO figures for 2008.

[5] The United Nations Decade of Action for Road Safety 2011–2020 was launched on 11 May 2011. Its goal is to reduce the number of road casualties by 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, and improving post-crash care.

As of 2008, the expected percentage change in motorcycle accident induced fatalities by 2015 and 2020 was calculated using each of these methods. The results are presented in Table 1.

Table 1

Projection of killed motorcyclists until year 2020 in different countries, grouped according to income (see Annex II for details)

Changes in the index when 2008 = 100									Range of changes in the index %			
Country group	Method 1		Method 2		Method 3		Method 4		2015		2020	
	2015	2020	2015	2020	2015	2020	2015	2020	Min	Max	Min	Max
LIC	90	83	115	152	118	158	158	199	90	158	83	199
LMIC	90	83	115	152	118	158	158	199	90	158	83	199
UMIC	126	149	152	190	122	141	438	680	122	438	141	680
HIC	124	124	138	129	118	126	122	138	118	138	124	138

Note: Low income countries (LIC), lower middle income countries (LMIC), upper middle income countries (UMIC), high income countries (HIC)

According to the estimates, in 2020 lower and lower-middle income countries represented in the sample may see an increase in fatalities of up to 99 per cent. The growth in fatalities in upper-middle income countries are high, ranging between 41 per cent and 580 per cent. It must be noted that these large numbers may be due to data issues as many UMICs have large motorcycle fleets. High income countries have a much more narrow range of projected values (between 24 and 38 per cent). All predicted trends depend on the assumption that the motorcycle fleet will continue to grow following general trends.

"The use of motorcycle helmets decreases the incidence of lethal and the severity of non-lethal head injury in motorcycle crashes when compared to non-helmeted riders"
(Macleod et al 2010)

The minimum and maximum values in Table 1 were used to generate the predictions for 2015 and 2020 for each group of countries. From these predictions, the reduction in rider fatalities resulting from wearing an appropriate helmet was calculated using the percentage benefit determined by Liu et al (2009); 42 per cent for fatalities and 69 per cent for injured riders. Estimates for serious injuries in 2015 and 2020 were calculated based on fatality to serious injury ratios developed by iRAP (Dahdah and McMahon 2008). Table 6 in the Annex II contains the totals for these calculations.

Figure 5 presents the potential lives that would be saved by wearing helmets, and Figure 6 the potential prevented injuries, given the predicted total fatalities.

Figure 5
Estimated range of potentially saved lives by helmet-wearing

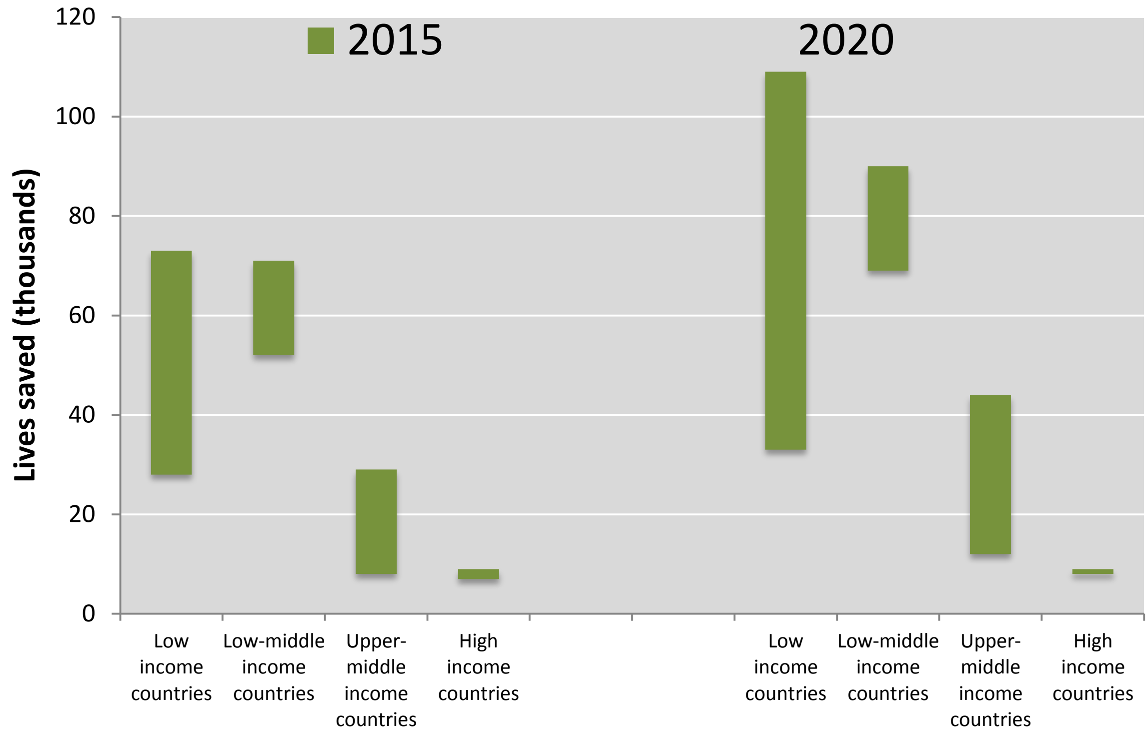
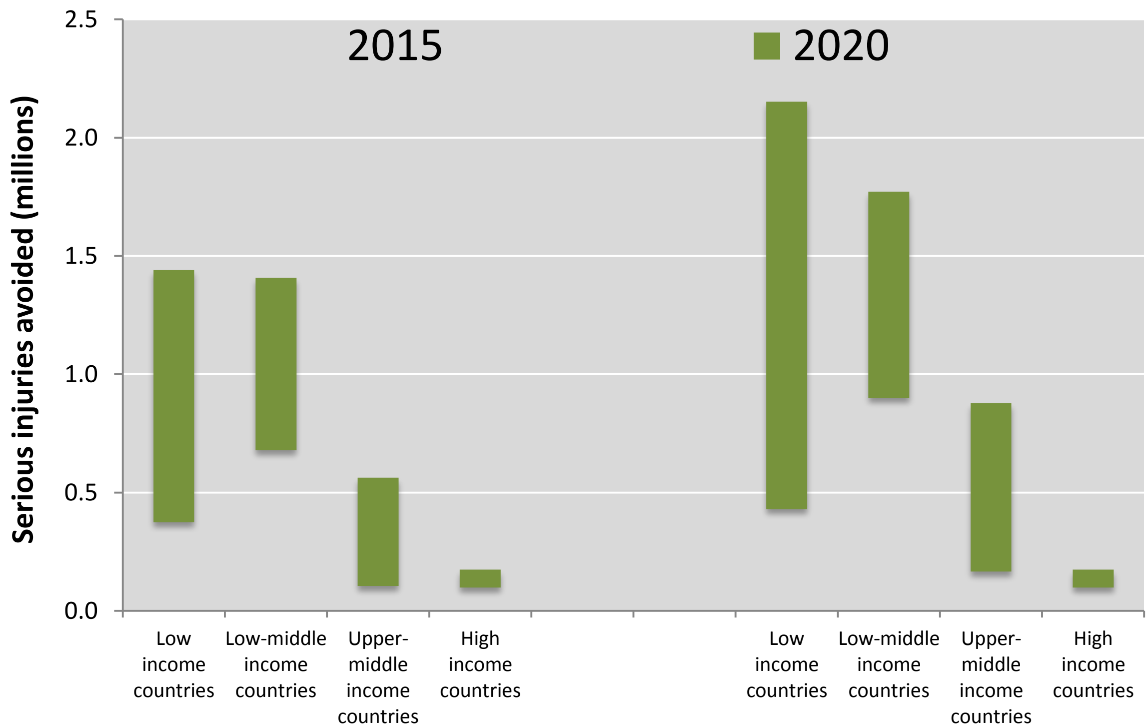


Figure 6
Estimated range of potentially avoided serious injuries by wearing helmets



The conclusion that can be drawn from the analysis above is that regardless of whether the minimum or maximum values are considered, many lives could be saved by using appropriate helmets. In 2020 alone, between 122,000 and 250,000 lives would be saved. Taking the average of the indices, the total fatalities for the period 2008–2020 would be 3.4 million riders worldwide and the number of lives saved by wearing adequate protective helmets would be 1.4 million.

In terms of injuries, for which statistics are more uncertain, the estimates of worldwide serious injuries avoided thanks to motorcycle helmets in 2020 are 1.6 to 5 million. Regardless whether the high or low estimates of fatalities and serious injuries associated with riding motorcycles in each country are considered, there is a substantial benefit to be gained from implementing and enforcing a mandatory helmet-wearing law.

1.3 Estimation of monetary savings as a result of avoided fatalities and serious injuries

The reduction in pain and suffering for the riders and their families and the reduction in the burden on a country's medical services can also be assessed from a monetary perspective. When the iRAP (International Road Assessment Programme) economic appraisal model (Dahdah and McMahon 2008) parameters are applied to the results of the above described fatality and serious injury projections for 2015 and 2020, and when they are tested for sensitivity, results imply potentially significant monetary savings from prevention of serious injuries and fatalities through helmet wearing.

Figure 7
Estimated range of potential monetary benefits from lives saved by helmet-wearing

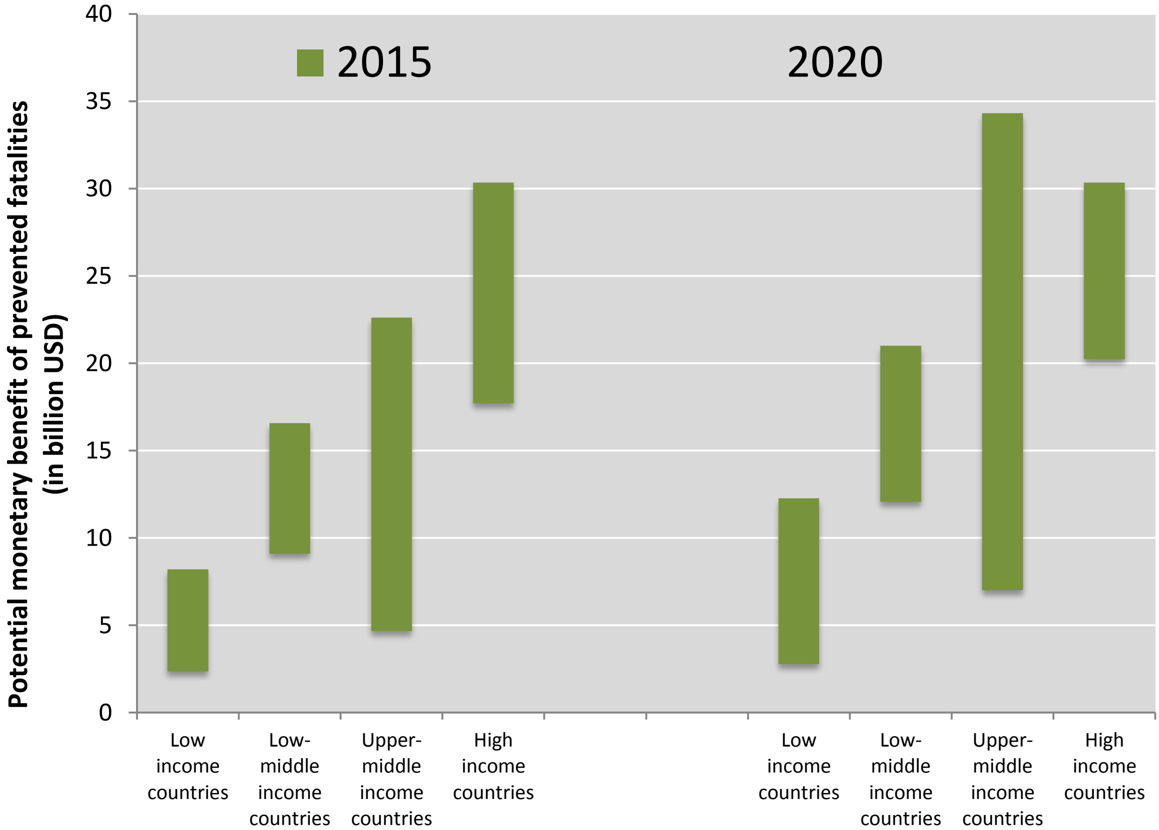
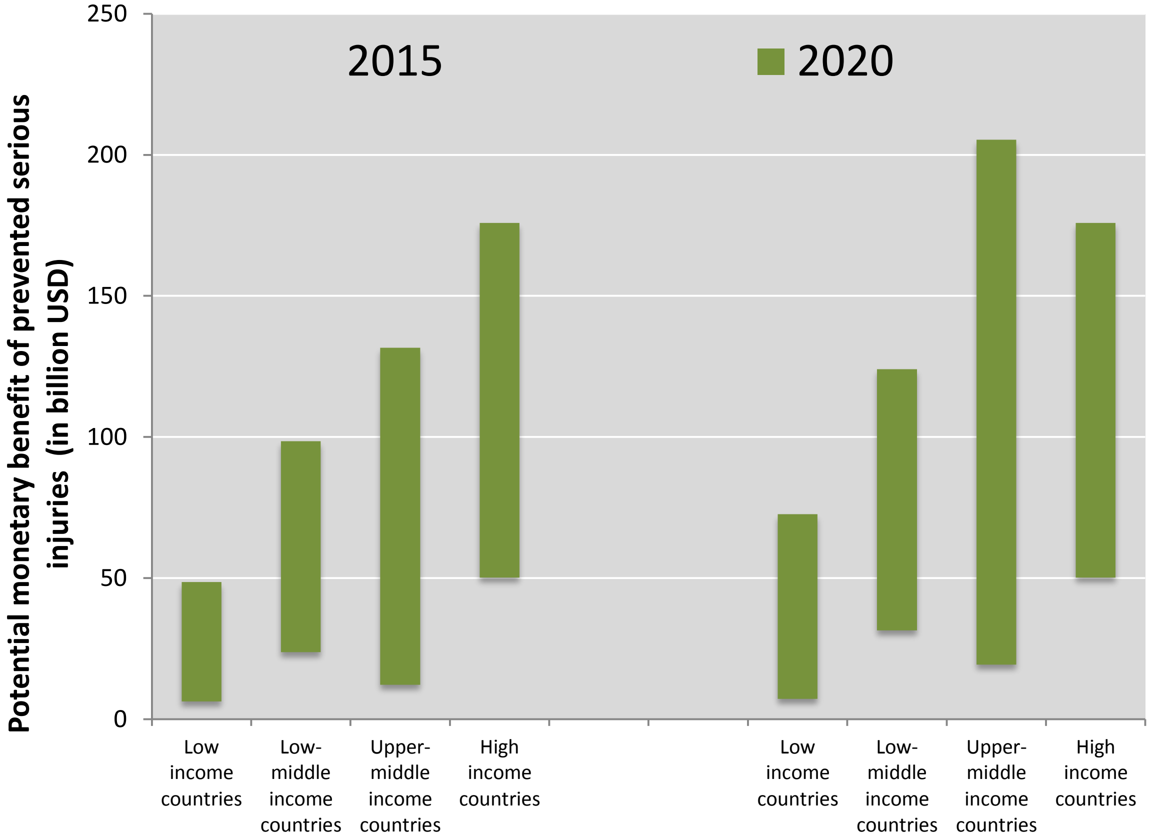


Figure 7 presents the potential monetary benefits accrued as a result of lives that would be saved by wearing helmets, while Figure 8 shows the potential monetary benefits stemming from prevented serious injuries (where serious injury is defined as category 3 or higher on the Maximum Abbreviated Injury Scale (MAIS[6,7])), given the predicted number of total fatalities. The same limitations regarding data and results described as inherent to the projections of fatalities and injuries apply to projections of potential monetary benefits.

Figure 8
Estimated range of potential monetary benefits from serious injuries avoided by helmet-wearing



The results show that worldwide aggregate savings of up to 676 billion US dollars can be achieved in 2020 as a result to fatalities and serious injuries prevented through enforcement of helmet wearing policies. Low and Upper-middle income countries can save up to 2.1 and 3 per cent of GDP, respectively, in 2020; High income countries can save about half of one per cent, while Low-middle income countries can save as much as 7 per cent of GDP in 2020. Although the potential savings projected for Low-middle income countries may seem unrealistically high, they should be understood bearing in mind that motorcycles constitute between 50 and 80 per cent of all registered vehicles in the largest countries of this income category that were included in the analysis.

[6] MAIS – Maximum Abbreviated Injury Scale categorises casualties according to the most severe injury suffered. It is widely used do describe the 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=Maximum.

[7] The UNECE acknowledges that the AIS (in all of its versions) is the property of the Association for the Advancement of Automotive Medicine (AAAM), owner of the Copyright. The so-called AIS (Abbreviated Injury Scale) is mentioned in this UNECE study for information purposes only.

The analysis also provides projections for 2015, indicating that globally savings between 126 and 532 billion US dollars can be achieved with the adoption and enforcement of helmet wearing policies that mandate use of certified helmets. Low and Upper-middle income countries can save up to 2.2 and 2.7 per cent of GDP, respectively, in 2015 with enforcement of helmet wearing policies; High income countries can save about half of one per cent, while Low-middle income countries can achieve average savings of 5.7 per cent of GDP in 2015.

> *"Motorcycle crashes create a burden to society, consuming public funds for emergency responses, emergency room costs and insurance premiums. In the USA, the economic burden from crash related injuries and deaths in one year amounted to $12 billion."* (CDC 2012)

Benefit-cost ratios of society's investment in motorcycle helmets can be calculated based on the projected monetary savings achieved in a scenario where all motorcycle riders are wearing helmets. The benefit-cost ratios obtained for the four different income groups for the year 2015 included sensitivity analysis calculations based on above presented potential savings range from avoided fatalities and serious injuries, and on respective estimated ranges of helmet prices in the different income category countries[8].

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. 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 Low-middle income countries and for Upper-middle income countries 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 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. This may present an exceptional case where subsidies could be justified.

Achieving economies of scale on the helmet market would certainly improve the benefit cost-ratio of helmet expenditures in this group of countries. 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, there is still room for improving the negative economic impact resulting from motorcycle accidents. 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

[8] See Statistical Annex – Tables 7 to 15 – for details. All results are based on a one helmet per motorcycle supposition.

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 accidents in which riders are not wearing helmets.

Helmet-wearing is clearly highly desirable but experience in lower income countries - that have introduced a mandatory helmet-wearing policy - shows that it is paramount to have proper helmet regulation which mandates approval marks on the product. Such a marking facilitates the enforcement of helmet-wearing legislation by e.g. the police.

Figure 9
Motorcycle riders without a proper helmet

2. Challenges specific to emerging countries

2.1. Helmet-wearing

Evidence that wearing a proper helmet significantly improves the chances of surviving an accident is overwhelming. Yet a large number of riders persist in riding without helmets, or with the chinstrap undone. In markets where motorcycles are a new phenomenon, this reluctance to wear helmets or to wear them correctly is often the result of a lack of knowledge. Therefore, suitable education programmes would improve the situation. Where motorcycles have been part of the transport system for some time, education remains an issue for each new generation of riders, but other arguments and myths also develop to resist the pressure to wear helmets. The reasons vary in their content and sophistication according to the type and maturity of the motorcycle market and the legislation on protective helmets in place.

Where there is substantial resistance to helmet-wearing, governments tend to legislate mandatory wearing of helmets at all times while riding motorcycles. However, this step is a political one because it involves constraints on the freedom of citizens. Similar opposition has arisen with safety-belt wearing in passenger cars.

Experience has shown that a combination of persuasive/voluntary measures followed by a second stage of compulsory requirements produces good results. The persuasive arguments provide understanding and create acceptance, and serve as a justification for introducing compulsory measures for those who remain resistant.

Some of the reasons for rejecting to wear helmets are:

- Peer pressure among young riders, e.g. ridiculing helmet-wearers;
- Helmets are only needed for long trips (even though most accidents occur close to home);
- Helmets are considered hot and uncomfortable, e.g. in regions with tropical climates;
- The damaging effect on women's hairstyles, whether it is a traditional hairstyle or simply fashion;
- The issue of special headgear, e.g. turban;
- The practical issue of what to do with the helmet when it is not being worn: theft, damage or sheer inconvenience when, for example, shopping;
- Hygiene, if the helmet is not owned by the rider.

Possible countermeasures include:

- Improving the image of helmet-wearing (making it "cool");
- Changing helmet design;
- Looking for solutions to the "what do I do with it now" problem, e.g. under-seat storage, top-boxes, helmet parks, helmet-carrying and securing devices;
- Educating riders through awareness raising campaigns.

Particularly in mature markets, a number of myths[9] surrounding helmet use have increased (see Table 2).

[9] Most of these myths and facts are summarized in the WHO (2006) manual on helmets.

Table 2
Myths and facts of helmet use

Myth: Helmets cause neck or spinal cord injuries.
Fact: Research has proven that helmets conforming to international regulations and correctly worn do not cause neck or spinal cord injuries.
Myth: Helmets impair hearing and sight.
Fact: Helmets do not affect peripheral vision or contribute to crashes. Helmets may reduce the loudness of noises, but do not affect the ability of a rider to distinguish between sounds. Some studies have indicated that properly fitted helmets can actually improve the ability to hear by reducing noise from the wind (UN Regulation No. 22[10] covers both these points).
Myth: Motorcycle helmet laws violate individual rights.
Fact: All road safety laws require some action from individuals — e.g. wearing safety-belts, not driving while impaired, strapping a child into a child restraint system, or stopping at a stop sign. These traffic rules are accepted, because all motorists recognize that failing to obey them could create a serious danger to themselves and others. Motorcycle helmet laws have exactly the same purpose.
Myth: Fatality rates are lower without helmet laws.
Fact: Studies conducted in two states in the United States that recently repealed their motorcycle helmet laws showed that deaths from head injuries actually increased following the repeal of the law.
Myth: Any helmet is better than no helmet.
Fact: A low quality helmet might give the rider a false sense of protection. In case of a crash, a rider using a low quality helmet could get more severely injured or even killed, sending the false message that all helmets are useless, and thus threatening helmet-wearing campaigns.
Myth: UN Regulation No. 22 will encourage the sale of fake helmets.
Fact: The following elements are established within the type approval system: the conformity of production procedures; exchange of information among T.A.A.s[11] on type approvals granted, counterfeit products and products not meeting the requirements. All this aims to prevent the delivery of fake helmets to the market.
Myth: There is no need to make helmet use mandatory for all: age-specific motorcycle helmet laws are effective / sufficient.
Fact: Age-specific helmet laws are more difficult to enforce, because it is difficult for the enforcement community to identify the age of a child when he or she is riding past on a motorcycle. Consequently, age-specific laws are less effective than those which are related to society as a whole.
Myth: Motorcycles are a small percentage of registered vehicles, thus motorcycle crashes represent a minor burden to society.
Fact: Whether motorcycles make up a small proportion of vehicles (as in some high-income countries) or the bulk of vehicle fleets (as in many Asian countries), the fact that motorcyclists are about 27 times more likely than passenger car occupants to die in a traffic crash and about 6 times more likely to be injured, means that crashes are a significant problem in all societies where their use is common. (WHO, 2006)
Myth: UN Regulation No. 22 approved helmets are not suitable for tropical climate.
Fact: The ECE 22 helmet requirements are performance oriented and not design oriented. Therefore they do not prevent sufficient ventilation making these helmets suitable for tropical climate by keeping the level of safety.
Myth: Motorcycles helmets in accordance with UN Regulation No. 22 are too expensive for users in low income countries.
Fact: The relative costs of helmets go as low as one per cent and as high as 10 per cent of the motorcycle price. Therefore, helmets should be affordable for buyers of new or second-hand motorcycles in low-income countries too.

[10] UN Regulation 22 and the 1958 Agreement are discussed in detail in section 5, and in Annex I, hereinafter.

[11] Type Approval Authority – see Annex I section: Creation of technical services and conformity of production procedures (paragraph 1)

In European countries, by the time helmet-wearing became mandatory, there was often already a very high rate of use, resulting from previous education efforts and campaigns. Such efforts are now widely accepted and the consensus is that voluntary helmet use should be increased first and then be followed by the introduction of mandatory legislation.

Some of the measures to increase voluntary helmet-wearing include:

- Public education on all aspects of helmet performance, use, benefits, etc. for motorcyclists and even cyclists. Not only do such efforts reach the target group but they influence societal views, which is very important if legislation is considered;
- Simple commercial marketing, advertising campaigns and "product placement" in films can all get the message across;
- As a variant of the point above, using role models can be very significant for particular groups of riders, especially young riders; examples include motorcycle racers, actors or politicians. The key point is that unanticipated people use motorcycles and if this becomes known they influence "their" segment of society;
- Incentives/instructions to employees, which in the case of well-known employers can add to the role-model point;
- Government measures to remove barriers, e.g. by subsidising helmets for children.

Once the situation has developed to the point that compulsory helmet-wearing should be introduced by the government, there are some basic activities that need to be undertaken:

- The introduction of a regulation for helmets with a clear marking requirement, e.g. Regulation No. 22. It creates conditions that thwart riders wearing any kind of helmet to comply with the law, e.g. construction site helmets, children's toy helmets, etc., which will have no effect at all;
- The dissemination of information before the law is introduced;
- Once introduced, the law needs to be enforced, with appropriate fines and other disciplinary measures for repeat offenders. Enforcement has to be consistent and well-advertised, with repeated efforts on a regular basis. Studies have shown that the fear of being caught makes people obey laws.

To increase the use of helmets a mix of measures has to be used successively and in combination. However, there is a particular practical issue undermining the willingness of riders to use helmets in emerging economies — the issue of affordability.

2.2. Affordability and availability: two sides of the same coin

There are two distinct perspectives from which the affordability of motorcycle helmets could be observed. The first perspective is the cost of the non-use of appropriate helmets, i.e. asking the question: how much does it cost not to use a safe helmet? This question could be answered by analysing possible adverse consequences—additional fatalities or injuries sustained by motorcycle users involved in crashes. From this perspective one could analyse affordability by comparing the total cost of helmets if purchased by all motorcyclists with the social and economic cost of injuries and fatalities that would have been avoided if a stricter helmet-wearing policy were in place (as carried out and discussed in chapter 1). To calculate social and economic cost of human life is very difficult, practically impossible; nevertheless, an effort can be made to look at the problem of affordability from this perspective.

The second perspective deals with the cost of purchasing a helmet. These costs can be absolute (e.g., in US dollars) or relative (as compared to other countries or other similar passive safety devices). In some countries helmets made to meet most stringent safety standards are almost prohibitively expensive, which results in meagre sales of such helmets.

The price of a helmet expressed as a fraction of the motorcycle price could be also used as the indicator of such relative affordability. For example, in many European countries (where all helmets on sale are in conformity with UN Regulation 22), motorcycle helmets are sold for as low as $50; high-end helmets, designed primarily to provide additional comfort, are sold at prices over $600. At the same time, most new motorcycles cost between $2,000 and $15,000. In other words, motorcyclists in Europe purchase helmets that cost approximately three per cent of the value of the motorcycle. The relative cost of helmets may go as low as one per cent and as high as 10 per cent of the motorcycle price.

> *"Strategies aimed at reducing the costs of standard helmets, combined with legislation and enforcement will be required to maximize effects of helmet use programs."*
> (Ackaah., et al 2013)

In low income countries motorcycles are a path to overcoming existing mobility gaps. Public transport is often underdeveloped and/or unsafe. As a result, people dedicate their limited resources to procuring new or used motorcycles, which commonly serve as the mobility solution for the whole family and essential to meeting their basic socio-economic needs. Unfortunately, helmets are quite often left out of the equation due to on the one hand their prices, while on the other to the simple lack of additional funds.

Another challenge that low income countries were faced with is the availability of helmets. As Hendrie et al (2004) reveals, in many low income countries motorcycle helmets were not always available. In China, the Philippines, Thailand, Viet Nam, and Venezuela, motorcycle helmets are considered luxury goods that are primarily sold to foreigners and a small group of wealthy local consumers. In Brazil, no safety devices, except child restraint systems, are easily available.

When there is no market for motorcycle helmets, the prices at which they are sold are practically irrelevant. For example, as Hendrie et al (2004) found, the price of a booster seat in China is $627. This is equivalent to one and a half times the average monthly salary in China. At the same time, the average price of the booster seat in a reference group of high income countries is $21 (in most of these countries the booster seats are, in fact, imported from China). If the use of booster seats in China was enforced and otherwise encouraged, their market prices could be significantly less than $21. Helmets manufactured in China but sold in the United States are sold at $8; yet, because of ineffective helmet-wearing enforcement, cultural and other factors, even bicycle helmets are not readily available in China at this relatively low price.

Thus it would not be entirely correct to conclude that in low income countries helmets are not sold because they are too expensive. In fact, the opposite might be true. In these countries, the helmets are expensive because no one is buying them.

The high price of motorcycle helmets may result from their low availability. Creating conditions that would increase helmet availability is of utmost importance. This could be done through, for example, making the use of helmets mandatory. A strict enforcement of such legislation would help create a market pull for helmets, which, in turn, through economies of scale, would encourage production and drive prices down significantly.

In creating helmet legislation, one of the most important pieces of information is a helmet ranking list, both in terms of the level of protection and the price. Many countries do this, such as Australia and the United Kingdom[12]. However, the information transmitted (e.g. through the internet or pamphlets at rider training centres, schools, etc.) aims at showing that safe helmets come with a variety of price tags. The fact that the information comes from an independent source is essential.

In conclusion, there are several ways to make helmets more affordable in low income countries. A low income country may consider:

1. Introducing a government subsidy programme, perhaps initially for children only, as proposed by Miller et al (1998). It should be borne in mind that the hospital treatment and other related costs incurred in the case of a crash will be far greater than the cost of a basic helmet. It would therefore be rational for governments to become involved by offering some forms of subsidy.

2. Including a helmet in the sale of the vehicle. As motorcycle manufacturers have nationwide networks and are in direct contact with riders, a country may agree with the manufacturers that they include a helmet in the sale of the vehicle. This would, of course, only work for new sales.

3. Reducing the number of requirements that the helmet has to meet by applying an earlier version of UN Regulation No. 22, as described in detail in section 3 and in Annex I. The basic jet style helmet, covering the ears and much of the neck, may not be convenient in hot climates, without redesign of the ventilation as focus groups have shown. Such a redesigned helmet, approved following the latest Version of the UN Regulation No. 22, has recently entered the market.

4. Creating conditions for the mass production of helmets. The resulting economies of scale would drive the cost of helmets down. Announcing that a helmet-wearing policy will be introduced and enforced starting from a given date in the future would provide the needed market pull and make mass production much easier.

[12] Sharp – The helmet safety scheme (http://sharp.direct.gov.uk/)

Figure 10
Family on a motorcycle in the congested traffic of Karachi

2.3. *Children and helmets*

In general, the practice of carrying children as passengers on motorcycles is controversial. At the same time, the reality in many low income countries is that the motorcycle is the family's only means of transport[13]. Indeed, in many low income countries motorcycles are the only way for families to get access to education and health care, or meet other social and economic needs.

2.3.1. Number of children involved in accidents

Accurate data on children involved in motorcycle crashes is not available. Consequently, the discussion of helmets for children is based on 'best estimate' statistics and biomechanical information from medical sources. The two main references in this area are Mohan (2009) and Arbogast et al (2003), which provide overviews of the literature and the continuing discussion.

Mohan's (2009) review concludes that, in most countries around the world, the proportion of children involved in fatal motorcycle crashes as passengers seems to be less than 1-3 per cent of all motorcycle fatalities. To some extent this is a surprising finding, when, for example, a Malaysian study found that only 26 per cent of children in urban areas and 40 per cent in suburban areas wore helmets (Azhar et al, 2010). Furthermore, with the advent of mandatory helmet-wearing legislation, there has been a growth in the number of children wearing toy helmets or bicycle helmets which provide or only a very low level of protection or no protection at all.

There is no evidence that children will suffer more, or less, head, neck or other injuries than adults. Motorcycle crashes are sufficiently chaotic, with people riding as "loose parcels" being thrown in all possible directions, that adults and children run the same risks. However, the consequences for children are more severe due to their more vulnerable physique.

2.3.2. Physical considerations

Arbogast et al (2003), identify the main issues regarding the build and size of children:

- Children are more likely than adults to suffer severe consequences of concussions;
- The brain and skull of a child are in a more vulnerable developmental stage than those of an adult;
- By the age of four, the size of a child's head (as indicated by head length, width and circumference) is 90 per cent that of an adult and by the age of twelve it is 95 per cent of adult size. It is not until the age of twenty that the bone plates of the skull fully close;
- The neck, in contrast to the head, is only 75 per cent of adult size at the age of four and 85 per cent of adult size by the age of 12. The neck muscles of children are weaker than those of adults, and children's neck ligaments can stretch more. Children's vertebral joints do not restrict forward motion as much as in adults and their spinal columns also have more cartilage and less bone.

Nevertheless, Mohan's (2009) review concludes that there is insufficient information on how children differ from adults to justify changing the 300g acceleration limit that is currently the standard for adult motorcycle helmets, when considering a standard for children's helmets.

[13] For the purposes of this discussion, persons under 16 years of age are considered as children, as in most countries teenagers older than 16 years of age are allowed to use mopeds.

2.3.3. A standard for children's helmets ?

In every country, except Viet Nam, helmets are tested for children and adults using the same standard. From the beginning, UN Regulation No. 22 has been used as a basis for testing helmets for children. However, as reported by Arbogast et al (2003), children's heads are smaller than those of adults in height; and consequently, adult-sized helmets do not fit properly. For example an adult's helmet may actually rest on the shoulders of a small child.

The technical issues for children's helmets are the same as those for adult's helmets.

- Providing protection against low impact (resulting in concussion) and protection against high impact (resulting in permanent brain injury) may be hard to achieve with a single helmet of a reasonable size and mass. Discussions on this issue have focused on the conclusions of the COST 327 project (European Union, 2001), and the possibility of introducing multi-density liners as the way forward (Ford, 2005).
- A thicker liner, to increase protection, also means that the mass of the helmet will increase, increasing the risk of greater neck injuries, particularly for children;
- The use of new materials that reduce mass but maintain a high level of protection may be impossible for reasons of cost, as few customers are able to afford such helmets.

Mohan (2009) concludes that, there remains much disagreement on most major issues and that consensus is unlikely to emerge in the near future on changing the indices used for setting the severity of helmet impact standards.

The case of motorcycle helmets suitable for children is, therefore, an issue that needs focused research in order to find the appropriate criteria for creating a dedicated helmet regulation for this vulnerable group of riders. So far, Contracting Parties to the 1958 Agreement have yet to make a proposal on this subject.

Producing a range of helmets to suit children of different ages (starting from 2 years old) and type approved according to UN Regulation No. 22 is possible. Nevertheless, small children must not be taken on motorcycles. Therefore, many countries introduced a minimum age and/or a minimum height (see Table 3) for children to be transported on motorcycles, and those countries, e.g. Switzerland and Austria, have a very good child safety record. The aim of the minimum height threshold is to make sure that children are tall enough to take advantage the safety benefits of being able to adequately use the passenger foot-rest. Having such legislation and securing its appropriate enforcement is very important in guaranteeing children's safety.

On the US market, motorcycle helmets designed to fit children of ages 4–12 and meeting the US Federal Motor Vehicle Safety Standard (FMVSS) No. 218 are becoming popular and are being sold at a price similar to that of adult's helmets. This shows how the protection of children is taken seriously by parents and encouraged by US policy makers and manufacturers. Information for the public that certified helmets, besides being the only helmets that are legal, are also those that will actually offer protection in case of an accident, is made available through manufacturer's websites.

Table 3
Legal age for children to ride as a motorcycle passenger in selected European countries

Country	Legal age	Additional provisions and comments	Source
Austria	8-12	The minimum age for children to be transported on motorcycles (and tricycles) is twelve years; furthermore the child has to be able to reach the foot rests intended for use by the passenger. As regards mopeds, children younger than eight may only be transported in an appropriate child seat.	Article 106 of the Austrian Motor Vehicles Act (KFG).
Belgium	3-8	"3<age<8 - allowed only on motorcycles with a maximum of 125 cm^3 and if seated in a child restraint system/ forbidden on motorcycles of more than 125 cm^3. Age > 8 - allowed on all motorcycles."	Article 35 of the Belgian Royal Decree on the general regulation of road traffic policing and use of the public highway.
Czech Republic	12	Only a person older than 12 years may be transported on the second seat of the motorcycle. Such person has to have the helmet put on his head and properly fastened. This helmet must be approved type according to the special legislation regulation.	Article 7 of the Czech Republic Law on Road Traffic.
Denmark	5	"Children with a height less than 135 cm may not be transported on a two-wheeled motorcycle, unless the child is at least 5 years old and using a child seat or other safety equipment that meets the requirements established pursuant to article 68. Furthermore, children under 5 years of age shall not be transported on tricycle or in a motorcycle sidecar, unless the passenger seat is equipped with safety belts."	Article 52 of the Danish Road Traffic Act.
France	5	Any passenger of a powered two-wheels vehicle is obliged to wear an helmet, adapted to the size of a child if it's the case. Article R. 431-5 requires that the transport of a passenger be made on a fixed seat, if necessary different from the one of the driver. Article R. 431-11 requires that the passenger can hold a handle and that his/her feet can be on footrests. For children less than 5 years old, a specific seat is mandatory. The driver shall take care that the feet of the children cannot be damaged in the fixed and mobile parts of the vehicle.	Article R. 431 of the Traffic Code.
Italy	5	"When older in any case it is mandatory for the carried passenger to be able to hold a safe, stable position according to the structure and the fitting of the motorcycle."	Articles 170 and 171 of the Italian Traffic Code.

Country	Legal age	Additional provisions and comments	Source
Lithuania	12	It is forbidden to transport children under 12 on moped, motor cycle (except carriage in trailer) and on any quadricycle.	Road Traffic Rules 201.3 confirmed by Resolution No. 1950 (December 2002) of the Government of the Republic of Lithuania.
Luxembourg	8-12	The passenger on a PTW (motorcycle) has to be at least 12 years old and must be able to use footrests properly. The passenger on a moped (50 ccm) has to be at least 8 years old and must be able to use footrests properly; if the rider of the moped is at least 18, a passenger of less than 8 years is allowed on the moped when being able to use footrests properly and if placed in a special seat (adapted to its height and weight and having a restraint system).	Article 52 of the Traffic Code of Luxembourg.
Portugal	7	"No children under 7 years old can be carried on a motorcycle unless it has a rigid box destined to hold not only cargo."	Article 91 of the Portuguese Road Code.
Slovakia	12	"Transport of a person younger than 12 years on a motorcycle is forbidden."	Article 46 of the Slovak Republic Road Traffic Law.
Spain	7-12	A passenger over 12 years of age may travel on mopeds and motorcycles, provided that this is stated in the driving licence for the moped or motorcycle, he/she wears a safety helmet and fulfils the following requirements: a. To sit astride with both feet on the lateral footrests. b. To ride pillion, on the proper seat. Under no circumstances may the passenger sit somewhere between the rider and the moped/motorcycle handlebar for steering. As an exception, children over seven years of age may travel on motorcycles or mopeds ridden by their father, mother or guardian or by persons legally of age who are authorized by them, provided that they wear an approved safety helmet and the above requirements are fulfilled. (Article 11.4 of the text).	Article 11.4 of the Traffic Code.
Switzerland	7	Children younger than 7 years have to be carried in a specific and authorized child seat.	Article 63 of the Ordinance on Rules of Road Traffic 741.11.

2.4. Counterfeiting and other challenges

The issue of counterfeit products has extensive implications and solving this problem is outside the scope of the UN regulatory system. However, the Contracting Parties to the UN 1958 Agreement can contribute to developing a solution.

The term counterfeiting is used in many ways. In its strictest meaning, it refers to the copying and selling of another product under the real brand name. More generally, the term covers the marketing of a product that pretends to be of a particular quality when it is not.

There is no information available on whether counterfeit versions of motorcycle helmets have been sold. In case of such an event, it would lie outside vehicle regulations and would probably fall in the area of trademark abuse.

The more general definition of counterfeiting is, however, applicable in this analysis. There have been instances where helmets have been put on the market with a false type approval mark/number and without type approval. There are also cases where helmets have been type approved and then subsequently produced but not in conformity with the type approval. Clearly, both of these cases can be addressed within the current provisions to re-ensure the conformity of production and the validity of approval marks.

Conformity of production is based on two points — quality control and sample testing. Before applying for type approval, a manufacturer must pass an initial assessment by the authority to obtain approval for his/her quality control system and the record keeping of batches, sample tests, etc. Once approval has been granted, the emphasis moves to regular quality control visits and to spot testing products to check their conformity. In practice, when a manufacturer has established a good track record of the on-going production, checking is reduced, allowing the authority to focus on new or suspect producers.

> *"The use of non-standard helmets undermines multinational efforts aimed at reducing the burden of road traffic injuries associated with motorcycle crashes."*
> (Ackaah., et al 2013)

The enforcement method depends on the administrative structures in the country concerned. However, there are certain basic options for consideration or adaptation to local circumstances. The first control point is either in the factory or, in the case of imports, at the port of entry. Both these control points have the advantage of controlling the first entry into the market. Approval certificates and markings can be checked and, in the case of a factory, samples can be taken for testing.

The main warehouse of the manufacturer or his/her importer is also a good control point, although possibilities already exist that some stock may no longer be at that location. The next control point is the point of retail sale. This check controls a far fewer number of helmets, but it is the last point at which products can be prevented from being used. All controls should be done by special inspectors. Even a few inspectors can control a large market.

The last control point is the roadside. During an enforcement campaign for helmet-wearing, for example, or even a routine control of papers, a police officer can check helmet markings. In the event of suspicion, (s)he can then refer the matter to special control agencies. A police officer can usually do little more, unless there are road traffic regulations that allow, for example, confiscating the helmet.

UNECE is working on a database system for exchanging type approval documentation using the internet and hand-held technology. Once this system is in place, it will become possible for a police officer to check approval numbers on the move. Eventually, countries will be able to introduce this system, once they have the structures in place that can make use of it.

3. Why are harmonized helmet standards and regulations needed?

Motorcyclists are 26 times more likely to die in a traffic accident than drivers of passenger cars (NHTSA, 2015). The number of fatalities and injuries can however be reduced by implementing a set of standards and other regulatory activities. Understanding the importance of standards and regulations[14] necessitates an understanding of how head injuries occur and how the helmet acts to protect the head. This section, therefore, describes the injury mechanisms, the role of the helmet, and the process of drafting regulations and their development over time.

3.1 The helmet protects the head

According to the World Health Organization (WHO) (2006)[15] there are two principal mechanisms through which injury can be sustained to the brain during a motorcycle crash: (i) through direct contact or (ii) through acceleration–deceleration. Both mechanisms cause different types of injuries.

> *"Wearing a helmet is the single most effective way of reducing head injuries and fatalities resulting from motorcycle and bicycle crashes. Motorcyclists who do not wear helmets are at a much higher risk of sustaining head injuries and from dying from these injuries."* (CDC 2012)

Head injuries that result from either mechanism can be further divided into two categories: open or closed head injuries. Most traumatic brain injuries are the result of closed head injuries — i.e. there is no open wound to the brain.

The protective helmet is designed to minimize the risk of a rider suffering from either of these types of injuries. The main components of a helmet, as shown in Figure 11, are:

- The shell, which provides mechanical protection by distributing the impact energy transmitted to the liner (protective padding); it maintains the liner in contact with the head and provides a mounting for the retention system;
- The liner, which reduces the deceleration of the skull and therefore the brain by dissipating the impact energy through controlled deformation of its structure
- A chin guard, (in full-face helmets);
- The retention system, e.g. a chinstrap;
- Comfort padding;
- In addition, helmets may incorporate a face shield (visor) to protect the face and eyes from airborne objects (grit, stone, insects, etc.).

Helmet materials have been developed and improved over time, resulting in lighter overall mass and, in some cases, economies of scale in production. Commonly used plastic materials for the shell are Acrylonitrile Butadiene Styrene (ABS), polycarbonates (PC) and polypropylene (PP); carbon fibre and Kevlar®. Other advanced material mixes are increasingly used as an alternative to fibre glass. The deformable liner (protective padding) inside the shell is usually made from Expanded polystyrene (EPS), a low-cost material that absorbs shocks and impacts.

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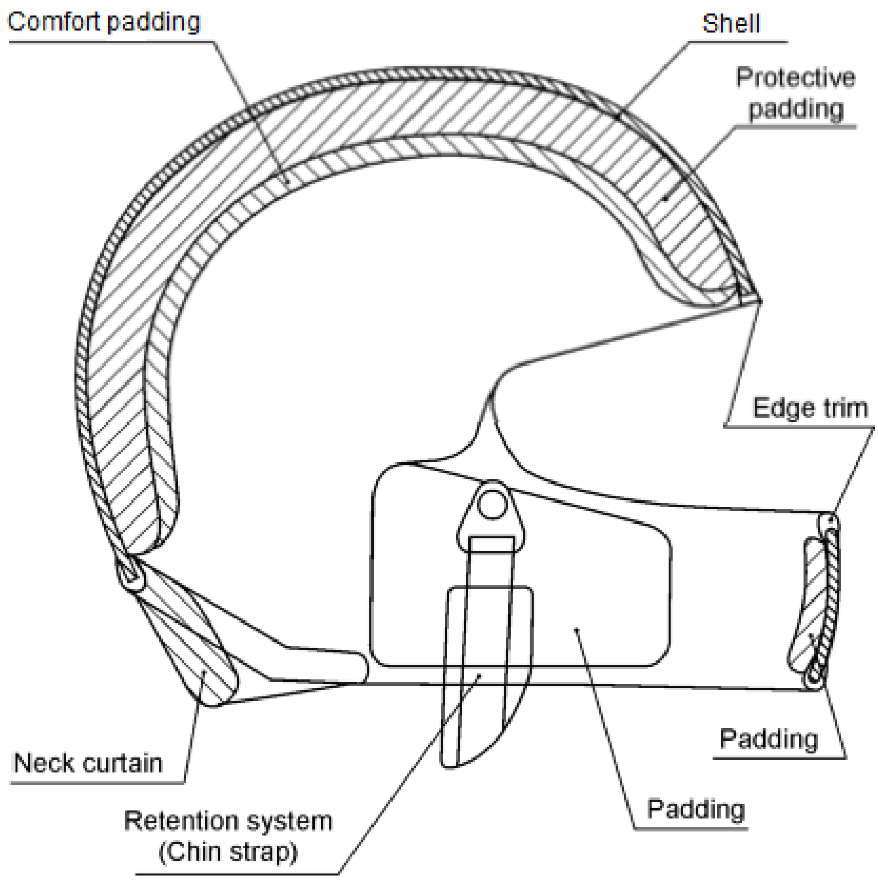
[14] Regulations are performance-oriented standards, i.e. they include stringency requirements (limit values).

[15] Please see WHO (2006) for a step by step guide for introducing a comprehensive motorcycle helmet policy.

Figure 11
Elements of a Full Face Motorcycle Helmet



Source: UN Regulation No. 22, Annex 3

3.2. The evolution of helmet standards and regulations

At first, helmet standards were closely associated with the development of motorcycle racing. Subsequent research into crashes and helmet properties has led to major improvements in the quality of helmets and benefitted both the racer and the ordinary motorcyclist.

The first systematic investigations of helmet function and effectiveness were done in the United Kingdom of Great Britain and Northern Ireland in the 1940's. After the Second World War, the British Road Research Laboratory studied head injury mechanisms, the mechanical properties of human tissues, potential helmet materials and helmet test methods. The results of this work provided the basis for the first performance standards for protective helmets. The first of these standards, based on applying shock loadings to a helmeted head form, was British Standard 1869:1952 - Crash Helmets for Racing Motor Cyclists. It was followed by British Standard 2001:1953 - Protective Helmets for Motor Cyclists. (Yoganandan, 1998).
Qualifying helmets were marked with the British Standards Institute (BSI) certification mark and had to identify the manufacturer, country of origin, helmet size and the number of the British standard. This external verification was an essential step in establishing both the standard and introducing helmets with a defined quality.

Similarly, during the 1960s, the United States of America Snell Memorial Foundation published their first motorcycle helmet standard and introduced a certification scheme.

In 1973, the British government made it mandatory for motorcyclists to wear protective helmets meeting the BSI standard. In 1974, the United States Government introduced a motorcycle helmet standard (US Federal Motor Vehicle Safety Standard (FMVSS) No. 218) and every helmet sold for road use in the USA was required to meet the standard and be marked with the Department of Transport (DOT) symbol. Subsequently, other governments have also used a standard as a basis for legislation.

At the international level, UNECE, in the context of the "1958 Agreement on the type approval of vehicles, equipment and parts"[16], created a motorcycle helmet regulation in 1972, which is now in its fifth series of amendments (level of stringency). UN Regulation No. 22 provides uniform conditions for the approval of protective helmets for drivers and passengers of motorcycles. The UN Regulation requires independent testing and product marking, and therefore extends the British/USA performance standard and certification approach into an international context. This Regulation is regularly adapted to reflect the technical progress and advances in research.

Although this international regulation exists, it is not yet universally used. Many governments still prefer to adopt national standards based on a mix of already existing ones and thus creating the need to harmonize standards.

3.3. The problem of non-harmonized standards

When countries have different standards in regulation for protective helmets, or even indeed vehicles and products in general, it creates barriers to trade and progress, and thwarts safety improvements. Differences in standards cause expenses to manufacturers and may delay technological progress by diverting finite research and development resources into multiple directions.

> *"The widespread use of non-standard helmets in low- and middle-income countries may limit potential gains of helmet use programs."*
> (Ackaah., et al 2013)

The main concerns are the varying levels of stringency among standards. Different standards and regulations require different levels of performance and methods of measurement in tests that appear to be the same. Some standards may also omit tests that others require. Table 4 illustrates differences between some existing standards.

[16] More information on the 1958 Agreement can be found in section 3.

Table 4
Comparison of tests included in different motorcycle helmet standards or regulations

Standard test description	**Malaysia MS 1:1996**	**Singapore SS 9:1992**	**Thailand TIS 369-2520**	**Viet Nam TCVN 5756: 2001**	**Indonesia SNI 1811-2007**	**Japan JIS T8133:2000**	**United Kingdom BSI 6658:1985**	**USA FMVSS 218**	**UN Regulation No. 22.05**	**Australia AS 1698-1988**
Extent of shell/ extent of coverage	✓	✓	×	✓	✓	✓	✓	✓	✓	✓
Shell stiffness test	×	×	✓	×	×	×	×	×	✓	×
Internal projections evaluation	✓	✓	×	✓	✓	✓	✓	✓	✓	✓
External projections test	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Visor test	×	×	×	✓	×	×	✓	×	✓	✓
Peak flexibility test	×	×	✓	×	×	×	×	×	×	×
Peripheral vision test	✓	✓	×	✓	✓	✓	✓	✓	✓	✓
Retention system effectiveness	×	✓	×	×	✓	✓	✓	×	✓	×
Retention system strength	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Retention strap slippage	×	✓	×	×	✓	×	✓	×	✓	×
Retention strap abrasion	×	✓	×	×	✓	×	✓	×	✓	×
Retention system release by pressure	×	✓	×	×	×	✓	✓	×	✓	×
Retention system release by inertia	×	✓	×	×	×	×	✓	×	✓	×
Retention system ease of release	×	✓	×	×	×	×	✓	×	✓	×
Durability of quick release retention system	×	✓	×	×	×	×	✓	×	✓	×
Impact test	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Oblique impact test	×	✓	×	×	✓	×	✓	×	✓	×
Chin guard test	×	✓	×	×	✓	×	✓	×	✓	×
Penetration test	✓	✓	✓	✓	✓	✓	✓	✓	×	✓
Flammability test	×	×	×	×	✓	×	✓	×	×	×
Helmet marking requirements	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Information label requirements	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Source: Smith (2008).

Such differences introduce different levels of stringency in the performance requirements for helmets and therefore in the protection offered to motorcyclists. Many consumers may think that a helmet is safe as long as it complies with any standard. In reality, the safety performance of helmets can differ markedly depending on the standards according to which they are tested.

Different national regulations also create barriers to trade, requiring manufacturers to design helmets to meet each individual standard and to test them in each country. These costs are passed on to the consumer. A harmonized standard creates economies of scale in production and, as a result, new technologies can be made available to a superior number of helmet users.

Although it might be feasible to design a protective helmet that can meet all existing regulations, most likely it would be expensive, particularly if it had to be tested according to many different national standards. UN Regulation No. 22 for motorcyclists' helmets was developed as part of the effort to overcome these constraints and obtain the best protection at the lowest possible cost.

4. Introducing helmet-wearing policies

Introducing a helmet-wearing policy is a complex and costly decision. Its enforcement requires engagement of significant resources. To make an informed "go/no go" decision, policy makers need to review a range of data from the region where a helmet-wearing legislation is to be introduced. In their deliberations the decision-makers might wish to follow the following seven steps.

> *"The single most effective way for states to save lives and save money is a universal helmet law."* (CDC 2012)
>
> *"The USA saved 3$ billion due to helmet use in 2010 and could have saved an additional $1.4 billion if all motorcyclists had worn helmets."*

i Determine whether a helmet-wearing policy is needed

The decision on whether a helmet-wearing policy is needed should be based on facts and accurate statistics on the nature and magnitude of the risk that riders without helmets may pose to themselves and to the safety of road traffic participants in general. The required statistics are:

a) Road traffic crashes and the relative ratio of motorcycle fatalities and injuries.

According to WHO (2006)[17], the following indicators may be constructed and used as diagnostic tools:

- Number or registered motorcycles as a proportion of all motorized vehicles;
- Rate of motorcycle crashes (per 10,000 vehicles, or per 100,000 people);
- Distribution of motorcycle crashes across different road types;
- Age and gender of those involved in these crashes.

b) Head injuries

Data on head injuries is needed to create further indicators such as:

- Proportion of motorcycle crashes that involve head injuries;
- Socio-economic impact of head injuries;
- Geographic distribution of motorcycle head injuries;
- Population most vulnerable to head injuries (e.g., certain age or occupational groups).

c) Helmet-wearing rates can be accessed through the following indicators:

- Proportion of helmet users among the general population;
- Distribution of helmet use by age, gender, purpose of travel;
- Use of correctly-sized and properly fastened helmets.

d) Helmet affordability

In developing helmet legislation, one of the most important pieces of information is a comparison between the level of protection and the price. The affordability of helmets could be observed from two distinct perspectives, as described in detail in section 2.2 of this study.

[17] "Helmets: a road safety manual for decision-makers and practitioners", page 29, www.who.int/roadsafety/projects/manuals/helmet_manual/en/

e) Existing helmet-wearing regulations

Policy-makers also need to assess the current legal landscape, state of law enforcement and the helmet standards already in force, as well as identify principal stakeholders.

ii Establish a working group

In addition to the lead agency in charge of road safety a working group should include:

- Government officials dealing with transport, health, education and law enforcement;
- Public health specialists (physicians);
- Engineers;
- Motorcycle associations;
- Helmet and motorcycle manufacturers and distributors;
- Employers that own large motorcycle fleets;
- Non-governmental organisation.

iii Prepare a plan of action

A good plan of action should be based on sound data, such as the above described indicators. Such a plan should include the following steps:

- Define objectives and targets;
- Select indicators;
- Determine implementation modalities for activities;
- Make an estimate of available and needed resources;
- Set up monitoring and evaluation mechanisms.

iv Develop and implement a helmet law

The procedure of implementing the law consists of:

- Developing the law;
- Introducing and implementing legislation;
- Setting a timeframe for law implementation.

v Implement a harmonized helmet standard

There are many standards in use today. Table 4 compares the requirements of various standards.

vi Improve compliance with the newly introduced law

In general, a combined approach that involves both voluntary and mandatory measures seems to produce the best results. Voluntary measures include public education, commercial marketing, use of role models, and various incentives. Mandatory measures include legislation and law enforcement typically involving traffic police.

vii Educate the public, in particular young motorcycle riders and passengers

For successful introduction of a helmet-wearing policy it is essential to involve the public from the very beginning. A public relations campaign is useful in raising awareness and conveying the right messages to the general public directly or through the media.

Educating young people, who are first-time helmet users, is the most critical aspect of a public relations campaign.

Safety Helmet Assessment and Rating Programme (SHARP)
A case study from the United Kingdom

Safety Helmet Assessment and Rating Programme (SHARP) came into being in 2007, after the Department for Transport of the United Kingdom (UK) found real differences in the safety performance of motorcycle helmets available in the UK. Actually, it constitutes a unique assessment programme of helmets.

While all helmets have to meet minimum safety requirements, research showed that up to 50 lives could be saved each year in the UK if motorcyclists wore the safest helmets available to them.

SHARP provides motorcyclists with clear guidance regarding the important issue of helmet fit and also provides objective advice about the level of head protection that a particular helmet can provide.

Using the most rigorous existing requirements from established standards, SHARP tests motorcycle helmets using rigorous impact scenarios that reflect real world accidents leading to injury.

Thanks to a simple five star scoring system, SHARP provides motorcyclists with independent and objective advice, revealing the different safety performances of motorcycle helmets available on the UK market.

SHARP routinely adds helmets to its database, the most recent on March 2015, taking the total number of helmets rated by SHARP to 350 full face and flip-front helmets.

Source: Sharp – The helmet safety scheme (http://sharp.direct.gov.uk/)

5. UN Regulation No. 22 sets safety requirements for helmets[18]

5.1. UN Regulation No. 22

The 1958 Agreement is one of the three agreements administered by the UN World Forum for Harmonization of Vehicle Regulations (WP.29) serviced by the UNECE Sustainable Transport Division. The 1958 Agreement provides the legal and administrative framework for establishing international UN Regulations (annexed to the Agreement) with uniform performance oriented test provisions and administrative procedures for granting type approvals. The Regulations also cover the conformity of production and the mutual recognition of the type approvals granted by Contracting Parties.

All UN countries can join WP.29 and become Contracting Parties to the UN 1958 Agreement. Contracting Parties can apply the UN Regulations at the national level and propose amendments by participating in the discussions. Through the discussions countries have the opportunity to have their local needs reflected in the international Regulation requirements. UN Regulation No. 22 on helmets is only one of the 135 UN Regulations annexed to the 1958 Agreement currently in force. The regulation is supervised and updated by the Working Party for Passive Safety (GRSP), which is one of the subsidiary Working Parties to WP.29[19].

Harmonized regulations allow the benefits of economies of scale and the resulting spread of new technologies to accrue to a greater number of riders. UN Regulation No. 22 was adopted in response to the need to harmonize different national technical provisions on helmet design and testing. Since its adoption in 1972, UN Regulation No. 22 has been updated to reflect new scientific developments.

5.2. The original version UN Regulation No. 22

The original version of UN Regulation No. 22 (from 1972) contained *General requirements* that addressed the coverage of the head and ensured an adequate field of vision and adequate hearing for the user, provided for the possibility of ventilation holes, minimized projections (which may get caught when the helmet slides over a surface and thus increase the rate of rotation), and ensured the durability of materials used. The requirements at the time also stipulated a maximum helmet mass of 1 kg[20].

Conditioning procedures included cold, heat and moisture treatments, which replicated typical conditions of use. Furthermore a series of tests, and *head-form sizes for their administration*, were prescribed to replicate adverse conditions upon which the helmet needs to perform its protective role. Those included:

- *A shock absorption test* replicating an impact to the head;
- *A penetration test* designed to replicate puncturing of the helmet[21];
- *A rigidity test of the helmet* when compressed longitudinally and then laterally;
- *A test for chinstrap deformation and a test for its tearing*;
- *Tests for peak flexibility and non-flammability*[21];

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[18] See Annex I for a more detailed discussion about 1958 Agreement, the evolution of safety requirements embedded in UN Regulation No 22 and options available to countries in its implementation.

[19] Other Working Parties include: Working Party on Noise (GRB), Working Party on Pollution and Energy (GRPE), Working Party on Lighting and Light Signalling (GRE), Working Party on Brakes and Running Gear (GRRF), and Working Party on General Safety Provisions (GRSG).

[20] Modern helmets range in mass from 1.35 kg to 2.05 kg, with an average of 1.66 kg.

[21] Tests subsequently dropped from the Regulation as a result of improved testing methods.

A helmet is not sufficiently protective if it is not properly secured on the rider's head; an obvious reality but one that is apparently not understood by many riders. A comprehensive study of motorcycle crashes across Europe showed that around 12 per cent of helmets fell off during the course of an impact (EC 2001). Wearing a helmet that fits correctly dramatically increases the chances of surviving a crash. The shape of the human head is such that it is quite easy to remove a helmet by pulling upwards on the back. Though, it was a common opinion that the chinstrap should fasten tightly, presently it is understood that helmet loss is a more complex issue and not necessarily limited to the setting of the chinstrap (which, incidentally, should not be fastened tightly). Compatibility of head shape with the internal shape of the helmet is paramount. Premium manufacturers produce different liner shapes for different markets reflecting the various physiologies of the consumers in the market (Asia – North America – Europe).

5.3. The technical development of UN Regulation No. 22

Early versions of the regulation contained elements for which a suitable test procedure was not developed yet. As a result the evaluations were made by inspection. This was the case in the "general requirements" section mentioned above. This approach has the disadvantage of being subjective and open to different interpretations. As a result, test procedures were developed and added to the regulation. For example, the potential for the helmet to create rotation of the head when in contact with another surface, such as the road, is now tested because the dangers of rotational accelerations to the brain are better understood. Rotational acceleration of the brain destroys the tiny ligaments that hold the brain in place within the skull, increasing the risk of severe brain damage.

Similarly, testing methods have been developed over time, becoming more precise and more stringent. It has partly been driven by the need to obtain repeatable results, particularly in different test centres, partly reflecting an improved understanding of crash dynamics and the biomechanics of impacts and injuries, and partly reflecting the improvement of real tests. Thus, for example, modern impact tests include letting the helmet fall onto the anvil rather than having a striker hit the stationary helmet. The chinstrap deformation test is now also dynamic, with a mass being dropped to pull suddenly on the chinstrap. Results from tests and research are crucial in the evolution of the safety of helmets.

Major developments in helmet design have necessitated new methods of testing. For example, there are now full-faced helmets with integrated visors and chin-guards. The visor offers protection, but at the same time allows the driver full visibility. These helmets have also been associated with the introduction of new methods of fastening the chinstrap, e.g. by means of a device similar to those used in car seatbelts. The impact absorption test introduced by the 02 series of amendments (April 1983) is a free fall test with a metal head-form (with a three-directional accelerometer) that checks the helmet performance even during lateral impacts. This type of test can be administered and successfully passed by a full face or open face helmet type.

5.4. The most recent version of UN Regulation No. 22

All of the above described factors have over the last 40 years led to considerable amendments to the original version of UN Regulation No. 22. Today, Regulation No. 22 is considered the most comprehensive regulation on protective helmets in the world.

The general requirements concerning the basic structure of the helmet and materials durability, the extent of the helmet's head coverage visors, peaks and the need to identify non-protective chinstraps are much more detailed. The same requirements for hearing and ventilation have been maintained. Additional specific testing has been introduced, such as shear testing and peripheral vision testing, impact absorption, surface friction, retention systems test, and variable loads and abrasion tests for chinstraps. Furthermore, with the introduction of visors, a new series of tests was developed to evaluate their mechanical impact resistance, light transmission, light diffusion, scratch resistance and mist retardant properties.

To ensure easy availability of information to the helmet user, UN Regulation No. 22 requires the helmets to be labelled with the size and maximum mass, information on the proper attachment and fitting of the helmet, a reminder to replace the helmet after a violent impact, a warning against using or the helmet coming into contact with petrol, paints and solvents and info on the types of visors approved for use with the helmet.

Non-protective chinstraps must be marked, thus indicating that they have not been tested or have failed to meet the requirements. Visors have to be labelled with the type of helmet to which they can be fitted and they shall be accompanied by information on cleaning, use at night and in poor visibility, and any mist retardant properties. Critically, the helmet shall carry the type approval mark (see Figure 12). This mark shows which type approval authority granted the helmet type, the status of the Regulation when it was approved (in the first two digits of the approval number), subtypes and a serial number. The approval mark provides immediate evidence that the helmet has been type approved and that it meets all of the requirements of the regulation.

Figure 12
Helmet visor type and a helmet approved according to UN Regulation No. 22

Source: UNECE
Note: The "E" mark identifies type approval according to the 1958 Agreement and "13" identifies Luxembourg as the Contracting Party having delivered the type approval of the helmet and visor.

5.5. Administering UN Regulation No. 22

UN Regulation No. 22 has been developed by the UN World Forum on Harmonization of Vehicle Regulations (WP.29) which is advised by industry, consumers and other experts. UN Regulations aim at harmonizing existing requirements to match the stringency level of the participating country that has the highest level of stringency in its national regulation.

Each new package of changes known as a "series of amendments" has strengthened the stringency of the UN Regulation. Although the latest version of the Regulation is the most stringent, other versions are also available. Any country, even if not a Contracting Party to the 1958 Agreement, can adopt on its national basis the most updated or, if the cost of meeting the most recent requirements is too high, any former, less stringent, versions of the Regulation. However, if a Contracting Party to the 1958 Agreement does not adopt the most recent version of the Regulation, other Contracting Parties to the Agreement will not recognize its type approval.

A future revision of the 1958 Agreement would allow recognition of type approval of Contracting Parties applying a previous version of UN Regulations. Thus the country can step onto the most suitable rung of the "ladder" and then advance upwards to more stringent levels of helmet requirements as their national conditions progress. Countries that do so, and, at the same time, accept all helmets that meet more recent versions of the Regulation, set a suitable minimum for their national legislation and still enjoy the benefit of having type-approved, more advanced technologies enter the market.

5.6. Joining the 1958 Agreement and implementing UN Regulation No. 22

The 1958 Agreement is open to all United Nations Member States and regional economic integration organizations. The meetings of the WP.29 are public and open to representatives of any UN Member State. Representatives may be full members or observers. Many non-ECE States are already Contracting Parties. To become a Contracting Party, States have to deposit an instrument of accession with the United Nations Secretary General. There is no fee to accede the Agreement. All UN Regulations that are annexed to the 1958 Agreement are therefore part of it; they are considered international law.

> *"Policies directed towards increasing acceptance of helmets as a protective device can have a significant impact on reducing the overall traffic fatality count."* (NHTSA 2004)

Once a Regulation has been published a country may use it to develop its national rules. The country can use the text as a basis for a national regulation, with no further obligation. In such cases the advantages of mutual recognition and international type approval are not available to the country. Therefore, any testing associated with the regulation would have to be carried out at the national level.

Conversely, a country may apply the text of the UN Regulation and also accept type approval certificates from other countries that are Contracting Parties to that UN Regulation. This reduces the need for the country to have their own test facilities and all manufacturers benefit from a reduced test burden. For the industry it means that only one approval process and one set of expenses is required. Both governments and industry benefit from the freedom of trade that mutual recognition brings and consumers benefit from new technologies that are available at a low price.

"This happened to James three years ago, and he's still not coming back. He was riding along the road, but he did not wear a helmet. And he lost control and hit a tree. He was in a coma eight months. I mean, he was so sick that every time I saw him I didn't know whether he was going to make it. He had lost so much weight that he was just a complete skeleton.

They had to weigh in a bag. He looked like he was from a concentration camp, everything was sunk in. I mean, I was frightened seeing my son like this. It was horrifying.

His goal is to get back his speech. His goal is to be able to walk again. But it is very slow and it will never be the same. That will never, ever happen. Before the accident James used to carve. He did beautiful carving. He was really a craftsman. He doesn't have that control that he wants to have. So many things that he does when he finally finishes looks like a child did it. But we're dealing with an adult that's making this mess.

It's sad. I have another son and he's hurt by it too because they were great companions, and there was a loss with the whole family. It's a hard thing and it's very hard on the family watching a loved one be destroyed.

He still has a tube in his stomach so he's just starting to eat very slowly pureed foods and we don't know if he'll ever go beyond that. He's lost his sense of smell, his sense of taste.

I try to look ahead now because he will never be the way he was before. I just can't have the same person back, so I have to deal with James as he is now and progress and get him as far as he can go. I don't know if there is a future for him. I think that hurts me more than anything else. A lot of the things that he wanted to do in his life he can no longer do. And this could probably have been avoided. At worst he could have hurt his leg, but his brain is something that you can't replace it. He will wear a prosthetic but his brain will never come back to the capacity that it was before."

Mother of James,
a brain injury patient who crashed his motorcycle
and was not wearing a helmet

Source: Insurance Institute for Highway Safety/Highway Loss Data Institute video

6. New challenges: Pedal assisted bikes - Electric bikes

6.1. Electric bikes are becoming a popular means of transport

Electric bicycles (e-bikes) are bicycles with a battery-powered electric engine activated by a throttle on the handle bars or assisted by the rider's pedalling. These lighter and cheaper alternatives to mopeds have been in production for 20 years.

Electric bikes are sold mainly in Asia and Europe. According to estimates (Jamerson and Benjamin, 2013), 32 million electric bikes were sold in China in 2013, though their quality could be questioned. Europe is the second largest market for electric bikes. Compared to China, electric bikes sold in Europe have stricter quality standards and are sold at prices ten times higher (around $3,400 USD). Other countries in Asia, such as Japan and India, are also likely to become large markets for e-bikes. In the United States, sales are not yet significant but they are growing. By 2016, annual sales are expected to be around 400,000 units, as manufacturers and retailers are increasing the supply of electric bikes. Within the next 20 years, the number of electric bikes sold could rise to 2 million, making the United States one of the biggest markets for electric bicycles in the world (Jamerson and Benjamin, 2013).

Electric bicycles have many advantages. They offer the consumer a less polluting mobility alternative and the exercise that people get when pedalling is beneficial for health. On a larger scale, as the world population is growing and cities are becoming bigger and denser, e-bikes can potentially become one of the transport solutions for "sustainable cities". As identified within the Transport Health and Environment Pan-European Programme (THE PEP), cycling as a means of urban transportation has many benefits for human health and the environment. Shifts from driving to cycling can contribute to reduce traffic congestion, the costs of road and parking facilities as well as the environmental impact, and can improve public health. In urban areas with high density, cycling is, along with walking, the most convenient mode of transport and provides better accessibility to the workplace and to leisure activities. Furthermore, in addition to environment and health benefits, findings of THE PEP indicate that redirecting urban transport towards the more sustainable mode of biking supports the local economy and has significant induced job creation potential[22].

There is evidence that consumers are finding this new mobility option attractive. According to a recent survey of U.S. electric bike owners, 74 per cent of respondents said they had purchased their electric bikes to replace some of their car trips. The survey revealed that people of different age groups and with physical conditions not allowing the use of conventional bikes showed interest in electric bikes. There are indications that e-bikes could encourage more and more people to bike (Berg, 2014).

As the sale of e-bikes is likely to expand in the future, it will become increasingly important to protect the safety of e-bike users. The safety of riders of electric bikes cannot be compromised even if electric bikes promise less congested cities or new economic assets. Reducing the number of accidents leading to injury involving four wheeled vehicles, while at the same time allowing the number of accidents leading to injury involving two-wheelers to increase, is not an option. In order to provide a safe and orderly environment for e-bikes riders, and other road traffic participants, it is essential to determine the most appropriate environment for e-cyclists in urban settings. Should e-bikes share bicycle lanes with riders of traditional bicycles or should they, as mopeds and motorcyclists, use traffic lanes dedicated to motorized vehicles, are questions that need to be addressed urgently. In addition, developing a safe helmet for e-bikers must stand as a primary goal for manufacturers and policy makers alike.

[22] For detailed information on the THE PEP please see www.unece.org/thepep/en/welcome.html

6.2. Finding a common definition for electric bicycles

Harmonizing regulations worldwide could bring more electric bikes to the streets and reduce bureaucracy and designing costs, as it has done for cars. However, developing an internationally accepted definition for the electric bicycle has been difficult. Different countries have different standards concerning speed and the engine power. For instance, in China the maximum speed allowed for an electric bike is 20 kilometres per hour (12 mph), in the European Union (EU) it is 25 kilometres per hour, while in the United States of America and Canada it is 32 kilometres per hour (20mph). Electric bike power in the EU can be up to 1000 watts, while in the United States of America it can be between 750 watts and 1,500 watts (depending on the State in question).

Accordingly, there are several names for electric bikes around the world: "motor-driven cycle", "bicycle with helper motor" (USA), "power-assisted bicycle" (Canada), "power-assisted cycle" (United Kingdom),"electric pedal-assisted cycles", "pedelecs" (EU) or "electric bicycles". The lack of harmonization in the definition and naming of electric bikes can lead to contradicting road and helmet use regulation. Namely, use of electric bicycles with same performance as mopeds with internal combustion engines should be regulated by law the same way as mopeds. Nevertheless, in some countries national legislation requires registration of the vehicle or even the helmets, while in other countries it does not. Harmonization of regulations is therefore important, but it will take time.

6.3. International harmonization of policies and legislation

The 1968 Vienna Conventions on Road Traffic and Road Signs and Signals establish standard traffic rules for road users, both for motor vehicles and for bicycles. The provision of special lanes on urban road, such as contra-flow cycling facilities, contributes to car drivers respecting the rules of the road by not driving over cycling lanes. It minimizes stress for cyclists in close proximity to motor vehicles and decreases risk of accidents. The increasing share of e-bikes on urban roads will require a rethinking of policies in terms of whether these vehicles have an appropriate space within the current system or whether a new set of lanes, and maybe also introduction of new signs and signals, would be the most optimal solution.

The same is true in terms of head protection. Although motorcycle helmet use is mandatory in the European Union, legislation concerning bicycle helmet use in Europe is much more varied. Whereas Malta has made cycle helmets mandatory, Sweden and Slovenia mandate only children less than 15 years of age to wear helmets. In Spain helmets are mandatory only outside urban areas (Avenoso and Beckmann, 2005).

Although there is evidence that a helmet can significantly reduce the risk of brain and head injuries in the event of a crash (EC 2015), some oppose the mandatory use of helmets. In some countries the mandatory use of helmets for cyclists, especially for minors, has been opposed, because it would make cycling look more dangerous than it is and would reduce the number of cyclists. The opponents argued that "cycling is a very safe and healthy activity and one that has considerable potential to address illnesses such as obesity and heart disease, which are the principal causes of premature death in western countries" (Stephens, 2013).

But does the debate on bicycle helmets apply to electric bicycles? The problem is, as with the question of where they should be ridden, where to draw the line between bicycles and motorbikes. The term electric bicycle is generic and includes pedelecs, e-bikes and combinations of these types. European Union Regulation No. 168/2013 on the approval and market surveillance of two or three-wheel vehicles and quadricycles sets harmonized rules for the type-approval of L-category vehicles. The Regulation defines and classifies L-category vehicles as shown in Table 5. These definitions are particularly relevant to identifying whether a vehicle should be considered a bicycle or a motorbike.

Table 5
Classification criteria for L-category vehicles

Category	Category name	Classification criteria
L1e	Light two-wheel powered vehicle	1. Two wheels and powered by a propulsion as listed under Article 4(3) of Regulation No. 168/2013 2. Engine capacity ≤ 50 cm3 if a PI internal combustion engine forms part of the vehicle's propulsion configuration 3. Maximum design vehicle speed ≤ 45 km/h 4. Maximum continuous rated or net power[23] ≤ 4 000 W 5. Maximum mass = technically permissible mass declared by the manufacturer
Sub-categories	**Subcategory name**	**Supplemental sub-classification criteria**
L1e-A	Powered cycle	6. Cycles designed to pedal equipped with an auxiliary propulsion with the primary aim to aid pedalling 7. Output of auxiliary propulsion is cut off at a vehicle speed ≤ 25 km/h 8. Maximum continuous rated or net power ≤ 1 000 W 9. A powered three- or four-wheel cycle complying with supplemental specific sub-classification criteria (6) to (8) is classified as being technically equivalent to a two-wheel L1e-A vehicle
L1e-B	Two-wheel moped	10. Any other vehicle of the L1e category that cannot be classified according to the criteria (6) to (9) of a L1e-A vehicle

Source: Regulation (EU) No. 168/2013, Annex 1.

All electric bicycles, except pedelecs up to 25 km/h and a maximum continuous rated motor output of 250 watts are subject to type-approval as laid down in Regulation 168/2013. Electric bikes are classified in vehicle category L1e, which is subdivided in L1e-A for "powered cycles" and L1e-B for "mopeds". The type approval rules come into force on January 1, 2017. L1e-A "powered cycles" are defined as cycles designed to be pedalled, equipped with auxiliary propulsion with the primary aim to aid pedalling. The propulsion should be limited at a speed of 25 km/h and its maximum continuous rated power should not exceed 1000 watts. L1e-A includes two-, three- and four-wheel vehicles, i.e. also electric cargo bikes with more than two wheels.

L1e-B "mopeds" are defined as vehicles with a maximum design speed of more than 25 km/h but up to 45 km/h, and a maximum continuous rated power of in between 1000 watts and 4000 watts. As a result of this categorisation, a pedelec with maximum speed of 25 km/h and with 750 watts power for instance will come under L1e-A, an e-bike 25 km/h with 500 watts as well, whilst a pedelec up to 45 km/h with 1000 watts will come under L1e-B. A vehicle that combines pedal assistance with open throttle will come under L1e-A. Technically, this legislation, does not allow for e-bikes above 25 km/h.

[23] The power limits are based on maximum continuous rated power for electric propelled vehicles and maximum net power for vehicles propelled with a combustion engine. The weight of a vehicle is considered equal to its mass in running order.

In the past, EU directives have sometimes been harmonized with United Nations regulations. For example, in 2006, the EU repealed a number of its Directives regarding vehicle regulation and replaced them with the corresponding UN Regulations annexed to the United Nations 1958 Agreement, which concerns the adoption of uniform technical prescriptions for wheeled vehicles, equipment and parts which can be fitted to and/or used on wheeled vehicles. This reduced the administrative burden of the type-approval process, as vehicle manufacturers were allowed to seek type approval, where appropriate, directly by means of obtaining approval under the relevant UN Regulations.

It is possible that EU Regulation 168/2013 could also be harmonized with UN Regulations. This could be a first step in harmonizing regulations and developing common definitions for electric bikes. Once a clear cut difference between electric bicycles and mopeds is drawn, legislators will find it easier to make laws describing the proper use of helmets.

6.4. Encouraging safe cycling

If legislation mandates helmet use for electric bikes, it should fulfil a minimum set of safety requirements in type and design. However, e-bike riders can easily be put off if they are required to wear the same type of bulky helmet as when riding a moped or a motorcycle. Riders of electric bikes are engaged physically and thus sweating, making an aerated helmet more important for them. It is also necessary for the helmet to be lightweight without compromising on safety. Electric bikes are becoming particularly popular in emerging economies, which often have a tropical climate. How can helmet-wearing be encouraged in these countries, where wearing a heavy helmet is uncomfortable and inconvenient?

The United Nations Regulation No. 22 does not prevent a design oriented solution tailored for e-bike riders. Dr. Ing Pierre Castaing, Head of Regulatory Affairs Service at the Center for Automotive Research and Testing (CERAM), which is a part of the Union Technique de l’Automobile du motocycle et du Cycle (Technical Union for the Automobile, Motorcycle and Cycle Industries - UTAC) and member of the French delegation to ITC WP.29 Working Party on Passive Safety (GRSP), has been involved in the design and type approval of helmets for more than thirty years. According to him:

> *"The lack of a broad range of light and aerated helmets available to consumers is not a regulatory issue but rather a marketing issue. UN Regulation No. 22 does not prevent the design of these kinds of helmets, as it is technologically neutral. New materials and new technologies could allow the construction of extremely light, strong and durable helmets that correspond to the highest test standards. In the future, I will not exclude that the market will provide jet helmets, aerated or not, with shock absorbing composite multi-layer materials including plastic or paper honeycombs designed for the most demanding use on motorbikes or mopeds and all them type approved according to the most stringent test requirements that is UN Regulation No. 22."*

In other words, encouraging safe cycling and helmet use does not happen only through legislation, but also through marketing. Having unified prescriptions, such as those in UN Regulation 22, would allow easy mass production of helmets that are both safe and comfortable in use irrespective of climate. Mass production would also lower the price of helmets and make them affordable for everyone.

> As a matter of fact, most recently a helmet manufacturer received type approval according to UN regulation No. 22 of its helmet weighing 850 grams (just twice the weight of bicycle helmets) and equipped with six aeration vents. This exceptionally well aerated helmet is suitable for use in very warm and humid climates. Although the helmet is type approved for motorcycles, it was is also adequate for e-bike and pedelec riders, exactly because of its light weight and its ventilation capabilities, which make it comfortable for the rider even while peddling and riding at lower speeds.

Figure 13
Pedelec riders with safety equipment

7. Conclusions and recommendations

7.1. Conclusions

This study estimates that 3.4 million deaths may be caused by motorcycle crashes during the period 2008-2020. Some 1.4 million of these could be prevented by the proper use of safety helmets. Substantial benefits could therefore be derived from implementing and enforcing helmet-wearing legislation. Introducing a helmet-wearing policy will not only markedly improve the safety of motorcycle riders but will set the foundations for good national legislation with respect to vehicle safety and environmental performance.

Helmet regulations have been developed to test the performance of protective helmets in case of an impact, in terms of their ability to:

- Reduce skull deceleration;
- Absorb the shock of the impact;
- Prevent direct contact between the skull and the striking object;
- Stay in place on the rider's head.

These performance requirements are used to introduce national or international certification and therefore they are an excellent basis for enforcement activities.

In low and lower-middle income countries motorcycles are often the first or only form of motorised transport. As income increases, the number of motorcycles in circulation also increases. With more motorcycles on the road, the risk of deaths and injuries rises. Wearing motorcycle helmets can save 42 per cent of lives and avoid 69 per cent of injuries to riders.

Different national regulations create different levels of protection, as well as barriers to trade. Harmonised regulation provides for a high level of protection and allows manufacturers to benefit from economies of scale and, as a result, more riders can benefit from the new technologies developed. This is why UN Regulation No. 22 was established in 1972 and has subsequently been adapted to reflect the technical progress made in research and new materials and designs. The Regulation has been conceived so that the different progressive adaptions form the rungs of a "ladder of protection", from which countries may choose the level that best suits their purposes.

The UN type approval system is based on the testing of product types, "mutual recognition" of the approvals, i.e. "approved once and sold everywhere", and maintaining conformity of production to the type tested. Countries involved in the UN system can therefore rely on each other for support in the creation and maintenance of their national legislation.

For an active motorcycle helmet policy, experience has shown that a combination of persuasion/voluntary measures, followed by compulsory requirements produces good results. The persuasive arguments provide understanding and acceptance and act as the justification for taking compulsory measures against those who remain resistant to helmet use.

Affordability is a serious problem especially in low income countries. A helmet meeting any level of The UN Regulation No. 22 will provide a good level of protection; but can be costly in such countries. In addition, the acceptability of even open-face helmets may not be great. Alternatives for reducing the cost of the helmets include government subsidy, motorcycle industry sponsorship or accession to the 1958 Agreement; all of which should be considered.

It is estimated that 1 to 3 per cent of all motorcycle fatalities worldwide are children. Children do not have the same resistance as adults to the trauma of a crash. Existing helmet regulation might have the potential to be improved with regard to testing child helmets and, therefore, focused research is needed in order to find the appropriate criteria for this vulnerable group. For the time being production and availability of protective helmets for children type approved according to UN Regulation No. 22 should be increased and made affordable on mass scale.

Finally, electric (pedal-assisted) bike markets are experiencing strong growth worldwide. Persistent strong growth of this vehicle market segment has the potential to play an important role in efforts aiming at reducing urban traffic congestions and improving air quality in cities. Developing a safe helmet for riders stands as the primary goal of manufacturers and policy makers. However, throughout the world numerous different standards are used to locally define power and speed thresholds as well as legal names for the vehicles generically called electric or pedal assisted bikes. As a result, in some countries moped helmet wearing policies apply to e-bikes while in others bicycle helmet wearing regulations (or lack thereof) apply. International harmonization of standards to clearly draw the line between bicycles and mopeds would facilitate developing clear national laws governing e-bike helmet standards and their road use in general.

7.2. Recommendations for further action and low-hanging fruits

The recommendations arising from this report are:

(a) It is of paramount importance to take measures to increase public awareness of the crucial safety benefits of wearing type-approved helmets while riding motorcycles - by conveying the right messages directly to the beneficiaries and/or through the media.

(b) Powered two-wheelers are in many developing countries the only economically viable alternative for personal and family mobility. Measures to improve the availability, quality and safety of public transport in these countries can contribute to slow the very dynamic growth in their motorcycle fleets. Such measures will in turn contribute to improving their currently deteriorating road safety records.

(c) Special attention needs to be dedicated to the most vulnerable population group in terms of motorcycle safety, namely children, and towards setting and enforcing age thresholds for their transport on motorcycles, while always maintaining the requirement of appropriate additional measures that contribute to their safe transport on the vehicles, such as child seats and helmets.

(d) Politicians should be made aware of the benefits of children wearing appropriate helmets. The policy agenda on road safety should address the protection of children transported on motorcycles to a greater extent. The production of helmets for children type-approved in accordance with UN Regulation No. 22 is possible. Steps should be taken to make helmets for children affordable for both manufacturers and consumers.

(e) All countries that do not have a helmet-wearing policy should introduce one. The steps to follow are outlined in section 2: Introducing helmet-wearing policies.

(f) Countries may consider acceding to the 1958 UN Agreement. A procedure to follow is outlined in section 3.6 and in Annex I. More information is available in the publication, "World Forum for Harmonization of Vehicle Regulations (WP.29) – How It Works, How to Join It".

(g) Countries may also consider applying UN Regulation No. 22 on helmets, in its current or one of the former versions, as described in section 3.5 and Annex I. Once the regulation No. 22 is applied, countries should ensure that the helmets used in the country comply with it.

(h) Helmets should be made more affordable in low income and low-middle income countries. Here are four possible avenues to explore, described more extensively in section 2.2:

1. Introduce a government subsidy programme, perhaps initially for children only;

2. Include a helmet in the sale of the vehicle;

3. Reduce the requirements the helmet has to meet through using an earlier version of UN Regulation No. 22;

4. Create conditions for the mass production of helmets.

(i) Efforts to internationally harmonize electric (pedal assisted) bike standards would be an important step towards application of appropriate national legislation and the development of helmets that are suitable for conditions experienced by e-bike riders and dangers they are exposed to.

(j) From a broader perspective, it is essential to initiate a more general transport policy debate, one that will lead to internationally harmonized traffic rules and new approaches towards infrastructure development that take into account the growing use of e-bikes.

(k) National statistical data on motorcycles in use, accidents involving motorcycles, and deaths and injuries related to motorcycles, needs to be improved, so that policies can be developed on the basis of solid knowledge. Annex II provides some examples of how such statistical work could be carried out.

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Annexes

I. The procedures for joining the 1958 Agreement and implementing UN Regulation No. 22

II. Statistics explained

III. European Union and UNECE definitions of L category vehicles

Annex I: The procedures for joining the 1958 Agreement and implementing UN Regulation No. 22

The 1958 Agreement is one of the three agreements administered by the World Forum for Harmonization of Vehicle Regulations (WP.29), serviced by the UNECE Sustainable Transport Division. The 1958 Agreement provides the legal and administrative framework for establishing international UN Regulations (annexed to the Agreement) with uniform performance oriented test provisions and administrative procedures for granting type approvals. The Regulations also cover the conformity of production and the mutual recognition of the type approvals granted by Contracting Parties.

All UN countries can join WP.29 and become Contracting Parties to the UN 1958 Agreement. Contracting Parties can apply the UN Regulations at the national level and propose amendments by participating in the discussions. Through the discussions countries have the opportunity to have their local needs reflected in requirements of the international Regulation.

UN Regulation No. 22 on helmets is only one of current the 135 UN Regulations annexed to the 1958 Agreement. The regulation is supervised and updated by the Working Party for Passive Safety (GRSP), which is one of the subsidiary Working Parties to WP.29.[24]

Harmonized regulations allow the benefits of economies of scale and the resulting spread of new technologies to accrue to a greater number of riders. UN Regulation No. 22 was adopted in response to the need to harmonize different national technical provisions on helmet design and testing. Since its adoption in 1972, UN Regulation No. 22 has been updated to reflect new scientific developments.

The original version UN Regulation No. 22

The original version of UN Regulation No. 22 (from 1972) contained the following requirements:

- *General requirements*:

  These addressed the coverage of the head and ensured an adequate field of vision and adequate hearing, provided for the possibility of ventilation holes, minimized projections (which may get caught when the helmet slides over a surface and thus increase the rate of rotation), and ensured the durability of materials. The requirements also stipulated a maximum mass of 1 kg.
- *Helmet mass*:

  On the one hand, the greater the mass of the helmet, the quicker the rider will tire. The additional mass might also stress the neck in a crash. On the other hand, adding more material, such as in the helmet liner, could provide better protection. Modern helmets range in mass from 1.35 kg to 2.05 kg, with an average of 1.66 kg.
- *Conditioning procedures*:

  These included cold, heat and moisture treatments, which replicated typical conditions of use.
- *A shock absorption test*:

  This was the most important test replicating an impact to the head in a crash. The principle was that the load transmitted to the head shall not exceed a limit that is considered safe.

[24] Other Working Parties include: Working Party on Noise (GRB), Working Party on Pollution and Energy (GRPE), Working Party on Lighting and Light Signalling (GRE), Working Party on Brakes and Running Gear (GRRF), and Working Party on General Safety Provisions (GRSG).

- *A penetration test*:

  In the beginning of standard helmet development, it was assumed that there was a risk of the helmet being penetrated by an object or projection during a crash. Subsequent accident investigations showed that this kind of penetration rarely happens and the test was dropped from UN Regulation No. 22.

- *A rigidity test of the helmet when compressed longitudinally and then laterally, and a test for chinstrap deformation*:

  A helmet is not sufficiently protective if it is not properly secured on the rider's head; an obvious reality but one that is apparently not understood by many riders. A comprehensive study of motorcycle crashes across Europe showed that around 12 per cent of helmets fell off during the course of an impact (European Union, 2001). Wearing a helmet that fits correctly dramatically increases the chances of surviving a crash. The shape of the human head is such that it is quite easy to remove a helmet by pulling upwards on the back. Though, it was a common opinion that the chinstrap should fasten tightly, presently it is understood that helmet loss is a more complex issue and not necessarily limited to the setting of the chinstrap (which, incidentally, should not be fastened tightly). Compatibility of head shape with the internal shape of the helmet is paramount. Premium manufacturers produce different liner shapes for different markets which reflect the varying physiology of the consumers in the various markets (Asia – North America – Europe).

- *A test for chinstrap tearing*:

  Clearly, if the strap tears and no longer holds the helmet in place, advantages are completely lost.

- *Tests for peak flexibility and non-flammability*:

  In 1972, there were many helmets with peaks, fitted to protect the face from rain and the eyes from sunlight (full-face helmets were comparatively rare). The concern was that in the event of a crash, the peak might collapse and injure the face, hence the flexibility test. Both tests were later dropped from the Regulation.

- *Size of head forms*:

  The head forms on which the helmets were mounted ranged from 50 cm to 64 cm in circumference, thereby covering most common head sizes.

The technical development of UN Regulation No. 22

In early versions of the regulation, there were elements for which a suitable test procedure was not yet developed. Therefore, the evaluations were made by inspection. This was the case in the "general requirements" section mentioned above. This approach has the disadvantage of being subjective and open to different interpretations. As a result, test procedures were developed and added to the regulation. For example, the potential for the helmet to create rotation of the head when in contact with another surface, such as the road, is now tested because the dangers of rotational accelerations to the brain are better understood. Rotational acceleration of the brain destroys the tiny ligaments that hold the brain in place within the skull, increasing the risk of severe brain damage.

Similarly, testing methods have been developed over time, becoming more precise and more stringent. It has partly been driven by the need to obtain repeatable results, particularly in different test centres, partly reflecting an improved understanding of crash dynamics and the biomechanics of impacts and injuries, and partly reflecting the improvement of real tests. Thus, for example, modern impact tests include letting the helmet fall onto the anvil rather than having a striker hit the stationary helmet. The chinstrap deformation test is now also dynamic, with a mass being dropped to pull suddenly on the chinstrap. Results from tests and research are crucial in the evolution of the safety of helmets.

Major developments in helmet design have necessitated new methods of testing. For example, there are now full-faced helmets with integrated visors and chin-guards. The visor offers protection, but at the same time allows the driver full visibility. These helmets have also been associated with the introduction of new methods of fastening the chinstrap, e.g. by means of a device similar to those used in car seatbelts. The impact absorption test introduced by the 02 series of amendments (April 1983) is a free fall test with a metal head form (with a three-directional accelerometer) that checks the helmet performance even during lateral impacts. This type of test can be administered and successfully passed by a full face or open face helmet type.

The most recent version of UN Regulation No. 22

All of the above described factors have led to considerable amendments to the original version of UN Regulation No. 22 over the last 40 years. Today, Regulation No. 22 is considered the most comprehensive regulation on protective helmets in the world.

The general requirements include:

- Requirements on the basic structure, visors, peaks and the need to identify non-protective chinstraps;
- Much more detailed requirements concerning the extent of the helmet's head coverage;
- The same requirements for hearing and ventilation;
- The introduction of shear testing for irregularities of over 2 mm in height, requirements to smooth projections, and controls on the interior surface of the helmet shell (i.e. no projections);
- For chinstraps there are requirements regarding protection from abrasion, the minimum width of the chinstrap, adjustment devices, positioning of the fastening/tensioning devices, and latching and release of fastening systems. The requirements also ban chin cups;
- The extent of peripheral vision, which should be tested by a field of vision test;
- Requirements for material durability;
- General specifications for the visor, e.g. removability, specifications for devices for lifting the visor out of the line of sight with one hand;
- Provisions for child helmets (introduced in 1983 with 02 series of amendments).

Specific tests for the helmet have been updated and new tests added as follows:

- Conditioning procedures have been extended to include ultraviolet conditioning and solvent conditioning (for hydrocarbons, cleaning fluids, paints, transfers or other extraneous additions that may affect the shell material);
- The impact-absorption test is based on the measurement of the deceleration of a head. The Head Injury Criterion (HIC) is calculated for five specific test points (including the protective chinstrap) using a guided free fall helmet drop test;
- The new test for surface friction measures the rotation-inducing forces created by projections, e.g. visor fittings, studs, etc., and friction with other surfaces;
- The rigidity test remains the same;
- The new dynamic test of the retention system assesses the displacement of the retention system under a dynamic and then, over time, a static load;
- The new retention (detaching) test checks whether the helmet is likely to "roll" forward and off the head if struck from behind;

- The new test for the micro-slip of the chinstrap checks how much slip occurs when the strap and fastening are placed under variable loads (as when wearing the helmet);
- The tear test of the strap has been replaced by an abrasion test in which after an abrading procedure the strap is tested under tension;
- For the new quick-release mechanisms, tests are performed for accidental operation, ease of release, and durability.

With the introduction of visors, a new series of tests was developed:

- Prior to any other tests a general ultraviolet conditioning test should be performed;
- The mechanical impact test checks for sharp splinters after impact;
- Light transmission through the visor is tested and there are specifications for tinted visors that may only be used in daytime;
- Light diffusion, i.e. the scatter of light towards the eye, is checked as are spectral transmittance and refractive powers;
- The scratch resistance test measures the light diffusion after the surface has been abraded, e.g. the "starring effect" from headlamps;
- Recognition of signal lights (not necessary if the transmittance value is very high);
- Mist retardant properties, if the visor has been so treated, are measured by the degree of light transmission lost due to misting. (Misting has always been a phenomenon with full-face helmets, which is why these kinds of coatings are used and why it must be easy to lift the visor out of the field of vision.).

To ensure easy availability of the following information to the helmet user, UN Regulation No. 22 requires the helmets to be labelled with:

- The size and maximum mass;
- Information on the proper attachment and fitting of the helmet;
- A reminder to replace the helmet after a violent impact;
- A warning against using of a helmet coming into contact with petrol, paints and solvents;
- The types of visors approved for use with the helmet.

Non-protective chinstraps must be marked, thus indicating that they have not been tested or have failed to meet the requirements.
Visors have to be labelled with the type of helmet to which they can be fitted and they shall be accompanied by information on cleaning, use at night and in poor visibility, and any mist retardant properties.

The helmet shall carry the type approval mark (see the image below). This mark shows which type approval authority granted the helmet type, the status of the Regulation when it was approved (in the first two digits of the approval number), subtypes and a serial number. The approval mark provides immediate evidence that the helmet has been type approved.

E = ECE Reg. No. 22; **2** = certified by French Authority;

051018 = ECE Reg. No. 22 **05** series of stringency, with Approval Number **1018** issued in France;

P = "Protective", i.e. chin bar tested and approved as a protective full-face helmet;

J – Although not visible in this example, would for instance signify "Jet" style open face approval;

320678 = Batch Test control number – identifies the production batch for which test results are available.

Administering UN Regulation No. 22

UN Regulation No. 22 has been developed by the inter-governmental World Forum on Harmonization of Vehicle Regulations (WP.29), which is advised by industry, consumers and experts. UN Regulations aim at harmonizing existing requirements to match the stringency level of the participating country that has the highest level of stringency in its national regulation.

Each new package of changes known as a "series of amendments" has added to the stringency of the UN Regulation. Although the existing version of the Regulation is the most stringent, other versions are also available. Any country, even if not a Contracting Party to the 1958 Agreement, can adopt on its national basis the most updated or, if the cost of meeting the most recent requirements is too high, any former, less stringent, versions of the Regulation. However, if a Contracting Party to the 1958 Agreement does so its type approval will not be recognized by the other Contracting Parties to the Agreement.

A future revision of the 1958 Agreement would allow recognition of type approval of Contracting Parties applying a previous version of UN Regulations. Thus the country can step onto the most suitable rung of the "ladder" and then advance upwards to more stringent levels of helmet requirements as their national conditions progress. Countries that do so, and, at the same time, accept all helmets that meet more recent versions of the Regulation, set a suitable minimum for their national legislation and still enjoy the benefit of having type-approved, more advanced technologies enter their market.

The procedures for implementing UN Regulation No. 22

Once a Regulation has been published a country may use it to develop its national rules. The country can use the text as a basis for a national regulation, with no further obligation, but in this case the advantages of mutual recognition and international type approval are not available to the country. Therefore, any testing associated with the regulation would have to be carried out at the national level.

In a variation of the first option, a country may apply the text of the UN Regulation and also accept type approval certificates from other countries that are Contracting Parties to the UN Regulation in question. This reduces the need for the country to have their own test facilities and manufacturers benefit from a reduced test burden.

A country that has become a Contracting Party to the Agreement and has signed a particular Regulation shall accept approvals based on that UN Regulation granted by other Contracting Parties. As a final step, the Contracting Party that applies the Regulation may also issue approvals.

The main advantage of all these methods of applying a UN Regulation is that the same provisions are used in different Contracting Parties regulatory environments. This facilitates trade and ensures the spread of the most advanced technical requirements. An additional advantage of entering the system is that the country benefits from mutual recognition, from being able to issue type approvals and, more generally, from being part of the decision-making process in WP.29.

A Contracting Party may decide to apply UN Regulation No. 22 but not to issue type approvals (usually because the necessary testing facilities do not exist in its territory). In this case, the Contracting Party is obliged to accept the type approvals or compliance tests issued by another Contracting Party for those UN Regulations.

Once a Contracting Party has applied a UN Regulation, it may grant type approvals for motor vehicle equipment and parts (including protective helmets) covered by that Regulation. To be able to grant type approvals, the Contracting Party must have the necessary technical competence to do so, and to ensure the conformity of production. This is both a matter of having the necessary administrative structures and having access to technical testing capabilities, as Contracting Parties may use technical services situated in another country.

If unable to accede to the 1958 Agreement, countries should consider basing national legislation on UN Regulation No. 22 or on one of its earlier versions so that the level of protection for motorcycle riders can be improved over time.

In using UN Regulation No. 22, two options could be considered:

<u>Option 1</u>: Adopt on a national basis at least the 02 series of amendments to UN Regulation No. 22 dating from April 1983. The impact absorption test introduced by this series of amendments calls for a free-fall test with a metal head form (with a tri-directional accelerometer) that evaluates the helmets' performance even in lateral impacts. This type of test can be conducted on a full-face or open-face style helmet that is made of energy absorbing material and has an outer shell made of plastic, such as polystyrene. According to the modern concept of motorcycle helmets, this type of protective helmet could significantly reduce the risk and severity of a head injury in a road crash.

<u>Option 2</u>: Phased approach — rungs of a "ladder of protection". It is suggested that countries adopt on a national basis the full text of the original version of the Regulation, including the 02 series of amendments <u>as an intermediate step</u> on the path to reach the 05 series of amendments. This would encourage countries to strive for the highest level of stringency of the Regulation. They may also decide to accede to the 1958 Agreement.

How to join and implement the UN 1958 Agreement

This section explains the procedure of acceding to the UN 1958 Agreement. A fully detailed description of the work of the World Forum and how countries can become participants is contained in the publication, "World Forum for Harmonization of Vehicle Regulations (WP.29) – How It Works, How to Join It".

As mentioned earlier, the 1958 Agreement is open to all United Nations Member States and regional economic integration organizations. The meetings of the World Forum are public and open to representatives of any UN Member State. Representatives may be full members or observers. Many non-ECE States are already Contracting Parties. To become a Contracting Party, States have to deposit an instrument of accession with the United Nations Secretary-General. There is no fee to accede the Agreement. The texts of all the 135 UN Regulations annexed to the 1958 Agreement are publicly available and therefore part of it; they are considered international law.

The official procedure for joining the World Forum is to send a letter signed by the authorized official notifying the secretariat of WP.29 of the desire to send representative(s) to the meetings and to participate in the activities of WP.29.[25]

If a country wishes to become a Contracting Party to an Agreement administered by WP.29, its consent to be bound by that agreement shall be in accordance with the provisions of that Agreement. Those provisions include signature, and notifications of ratification and acceptance.

Once a country has become a Contracting Party to the UN 1958 Agreement it may vote on new Regulations, but not on amendments to existing UN Regulations if it does not apply those Regulation. Contracting Parties are free to apply all, some or none of the UN Regulations. When a Contracting Party notifies the appropriate body that it is applying a UN Regulation it may vote on an amendment to that UN Regulation. When applying a UN Regulation the Contracting Party also needs to accept the type approval granted by other Contracting Parties according to that UN Regulation.

A Contracting Party may decide to apply Regulations but not to issue type approvals (e.g. because the necessary administrative and technical capacities do not exist in their territory). At this stage, the Contracting Party is obliged to accept the type approvals issued by another Contracting Party for those particular UN Regulations.

Once a Contracting Party applies a UN Regulation, it may grant type approvals for motor vehicle equipment and parts covered by that Regulation. To be able to grant type approvals, the Contracting Party must have the necessary technical competence and be able to ensure conformity of production. This depends on the existence of necessary administrative structures in the country and access to technical testing capabilities.

The type approval system

The UN type approval system is the basis of the 1958 UN Agreement. Contracting Parties apply the harmonized requirements of the UN regulations to test product types of vehicles and their equipment and parts before they enter the market.

Under the 1958 UN Agreement, all the countries signatories of a Regulation are committed to accept all products covered by an approval certificate according to that UN Regulation. This "mutual recognition" of the approvals is a basic requirement, one that enables the free trade of approved products, i.e. "approved once and sold everywhere", in all acceding countries.

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[25] The letter should be addressed to The Director, Sustainable Transport Division, UN Economic Commission for Europe, 8-14, Avenue de la Paix, CH-1211 Geneva 10, Switzerland.

Mutual recognition has several important advantages for both governments and industry. For the industry, it means that only one approval process and one set of expenses is required. Both governments and industry benefit from the freedom of trade that mutual recognition brings and consumers benefit from new technologies that are available at a low price.

Mutual recognition enables countries to benefit from the Regulation without having to set up expensive test facilities. This is particularly a benefit for low income countries. Whether Contracting Parties of the 1958 Agreement or not, they may ask technical services accredited with other Contracting Parties to perform tests on their behalf. This would avoid the need to set up specific test laboratories and premises. Similarly, the provisions in the 1958 Agreement on the conformity of production ensure that the quality of the products remain at a similar level to that of the type approved prototype.

Based on the described facts and procedures, it is clear that broad participation in and application of the UNECE agreements, UN Regulation No. 22 in particular, would strengthen the development of national legislation for helmets.

Creation of technical services and conformity of production procedures

Once a country is a Contracting Party to the 1958 Agreement, it should establish the necessary administrative structures to follow the work of the World Forum. When the Contracting Party applies UN Regulations, it needs to designate a competent authority to establish a type approval authority (T.A.A.) and to deal with the communication forms for approvals given by other Contracting Parties. Information provided by the communication forms are the basis for controlling products in the Contracting Party's home market.

When the Contracting Party starts issuing type approvals, it will need to expand the capacity of the administrative unit dealing with regulatory documents, so that it can receive and issue all the documentation required for administering the approval process and granting type approvals. To carry out approval testing, a competent test facility or technical service has to be designated. Setting up a technical service may sometimes require huge investments and complex certification or accreditation procedures. For example, for noise measurement, the tests need to be performed on a test track meeting ISO 10844: 2014[26] and for emissions testing a chassis dynamometer with appropriate gas collection and equipment for analysis is needed. The technical services designated to carry out the regulatory tests may, or may not, be part of a government department. A number of countries have designated agencies, sometimes from outside the country itself, to conduct the actual tests. Once the test report has been prepared by the technical services, it is submitted to the type approval authority, that in turn verifies the test report and, in case all requirements and especially the limit values are fulfilled, issues the approval certificate and number.

Once approvals have been issued, it is the responsibility of the manufacturer and of the type approval authority to organize, if necessary, periodical controls of the conformity of production with the help of its technical services. Similarly, should a query on the validity of an approval be raised at national level the type approval authority that issued the approval is responsible for initiating the appropriate tests of conformity. In the event that the Contracting Party finds the suspicions correct, it will initiate corrective actions or withdraw the approval until it is satisfied that necessary measures have been taken to restore conformity of production. Accordingly, all Contracting Parties applying that Regulation are informed about the withdrawal of a type approval.

[26] The International Organization for Standardisation (ISO) develops and publishes international standards. ISO Standard 10844:2014 gives specifications for test tracks for measuring noise emitted by road vehicles and their tyres.

Annex II: Statistics explained

1. Introduction

The statistics used in this report are not intended to give a representative picture of what has happened, nor a fool-proof prediction of what might happen in the future. Firstly, the data are not representative (i.e. randomly sampled) and so not adequate for such work; and secondly, the transport needs and culture in each country are different. What happens in one group of countries may not repeat itself in another.

That being said, the intention here is to provide a general view of the past and possible future trends, and a methodology that might be useful for countries seeking to understand their local situation.

2. Data

General data on population and Gross National Income (GNI) per capita is easily available from the World Bank.

However, data on national motorcycles fleets or the accidents associated with that fleet is not readily available online for all countries. The Eurostat database was used to acquire information on motorcycle fleets in European countries, while data about fleets in other countries was drawn from the International Road Federation World Road Statistics 2014, supplemented and validated through national vehicle fleet registries.

The UNECE database provides data on the number of motorcycles in use and the number of accidents leading to fatalities or injury for countries in the region. These countries include the 56 countries of Europe and Central Asia, plus Canada, Israel and the United States of America. In terms of data availability, these countries are well covered, but even so there are gaps and mistakes in the data series. For example one country had over 6 million motorcycles in circulation in years A and C, but in year B the number fell to a few hundred thousand; once the 6 million was added to this figure, year B fit perfectly into the trend. In some years, other countries known to have excellent statistics, have not submitted them to the UNECE.

Data for other countries have to be researched on a country by country basis, and few have complete data series that are easily available, e.g. on the internet. For these countries, therefore, one relies on research carried out by other authors. For example, the Asian Development Bank issues country Road Safety Action Plans that contain statistical information. Other more specific reports, for example on road building in Africa may also contain simple statistics required for the type of study in this report. Often the data take the form of a gross total of, say, fatalities and then later in the report there is a percentage breakdown by road user type, thus making a calculation possible.

For analytical purposes the countries included in the database, compiled for the purposes of this study, have been grouped according to the classification of economies used by the World Bank. These are (at 1 July 2011):

- Low income economies: those that had average incomes of 1,005 United States dollars or less in 2010;
- Lower-middle income economies: with an average income of 1,006 US dollars to 3,975 US dollars;
- Upper-middle income economies: with average incomes of 3,976 US dollars to US dollars 12,275;
- High-income economies: with average incomes of 12,276 US dollars or more.

The countries included in the database and analysed in this report are those for which data sets exist for the main variables. In the two lowest groups, the data is heavily weighted by the size of the Indian, Vietnamese, Indonesian and Philippine data. This is not necessarily a problem, as these countries represent typical low income countries that have seen a rapid rise in the use of motorcycles as a cheap form of transport. Where similar conditions (low income and great transport need) apply it would be reasonable to expect similar trends.

The countries used in the analysis are:

- Low income countries (GNI per capita < US$ 1,005)
  - India, Kyrgyzstan, Uganda, Viet Nam
- Low-middle income countries (US$ 1,006 < GNI per capita < US$ 3,975)
  - Indonesia, Moldova, the Philippines, Ukraine
- Upper-middle income countries (US$ 3,976 < GNI per capita < US $ 12,275)
  - Azerbaijan, Belarus, Brazil, Bulgaria, Kazakhstan, Macedonia (FYO), Malaysia, Poland, the Russian Federation, Romania, Thailand, Turkey
- High income countries (US$ 12,276 < GNI per capita)
  - Austria, Belgium, Canada, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Ireland, Israel, Italy, Latvia, Netherlands, Norway, Portugal, Slovenia, Spain, Sweden, Switzerland, the United Kingdom, the United States of America.

3. Preparation of the data

The collected data that were available had gaps in the series. These were filled by simple interpolation or by extrapolation, using the techniques available in Microsoft's Excel program. Where there were obvious mistakes, such as those referred to above, the data were corrected. Where the extrapolation produced obviously unrealistic figures (e.g. negative fatalities) the last known figure was used to extend the series into future years. As most curves increase, this is a conservative estimate of those trends.

Though these methods are not really statistical, it should be remembered that without them it would not have been possible to conduct any trend analysis. Furthermore, the data series concerned are general and, at least in the case of the vehicle fleet, slow to change. The intention is to provide a general indication of trends, based on the categorization of countries used by the World Bank, and therefore such methods will not significantly distort the findings. Should new and more representative data become available, it would be simple enough to repeat the analysis and update the prognostics.

4. Analysis

4.1 General

The overall aim of this analysis is to predict the number of deaths and injuries occurring to motorcycle riders if the current trends continue; and from there to estimate the number of fatalities and injuries that could be avoided by the use of helmets, as well as to estimate the benefit-cost ratios of avoiding fatalities and injuries by wearing helmets.

This section argues that:

- Deaths and injuries in motorcycle crashes can be substantially reduced by the use of safety helmets;
- The number of deaths and injuries is related to the number of motorcycles in circulation;

- The number of motorcycles in circulation depends on the level of wealth in the country.
- The monetary benefits incurred as a result of helmet use outweigh the costs of purchasing helmets in all income category countries.

4.2 Establishing trends

The period 1993–2012 was used to generate trends due to availability of data. The trends were based on the average values for each group of countries, calculated by the actual number of positive scores per year; so if one country did not have data for a given year, the number used to divide the total was reduced by one. The trends were then used to extend the data series to 2020. Verifications were made by using the trends on known data and by checking the feasibility of the prediction by comparing the percentage growth for an equivalent period in previous years.

4.3 GNI/capita and the fleet of vehicles

The analysis expressed the figures for the fleet of vehicles as a function of GNI/capita values. The resulting correlations had R^2 values of 0.90 or more. It is thus, reasonable to conclude that the fleet of motorcycles will rise as the average income rises.

4.4 Prediction of fatalities and injuries

4.4.1 Fatalities

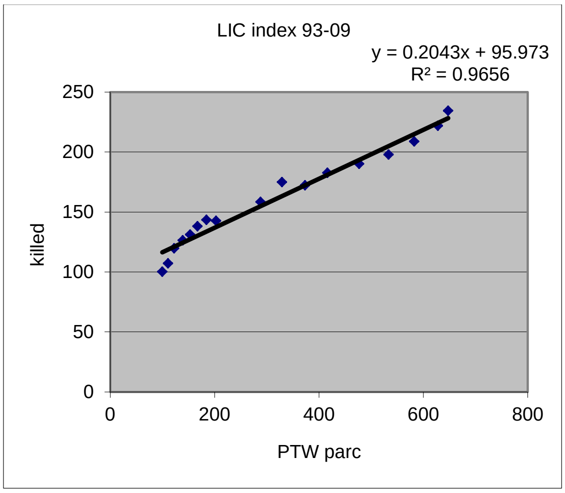
Based on the tables of the motorcycle fleet and the number of fatalities and injured, four different methods were used to generate alternative estimates for each country. These were then totalled, averaged and turned into indices for the purpose of deriving trends. The key year – 2008 – is the year for which the WHO (2009) provides authoritative figures for all countries.

Method 1 used the same period before and after 2008 to project the trend for deaths 1996 – 2008 up to the period 2008 – 2020. It, therefore, applies the past percentage changes to the future. The background to this method provided a feasibility check on the other methods; i.e. if figures for one group of countries had doubled in the first period then it would not be unreasonable if the same happened in the second period.

Method 2 first calculated the ratio of killed per 1,000 motorcycles. Both the fleet of motorcycles and the ratio were then extended by using the TREND function in Excel to provide a forecast for both variables. The expected number of fatalities was then calculated from these figures. The method uses simple trend analysis to predict the future values for key variables so that they can be used for calculation.

Method 3 predicts the fleet values using the TREND function. The killed over fleet regression equations for 1993 – 2009 were then used to calculate the potential future number of killed, except for the high income countries where the TREND function was used because of the obviously false results.

Figure 14 Examples of the fatalities over fleet regression equations for methods 3 and 4



Method 4 is based on regression analysis. The future figures for the fleet of motorcycles were the same as in Method 2. The fatality figures were expressed as a function of the fleet for the years 1993 – 2008 and the regression equations were calculated (in Method 3). The equations were then used to generate an estimate of the number of fatalities, starting from the WHO 2008 figures. (Note: in the case of the high income countries the regression equation gave very strange results (e.g. negative deaths) and the trend for these countries was finally established using the TREND function in Excel.) The predictions from these equations were then used to generate an index, based on 2008.

4.4.2 Injuries

The data on injuries is very limited and often inaccurate, e.g. injuries figures are the same as or even lower than fatalities, while reliable figures from some countries show that injuries are usually far greater, as would be expected, rendering therefore projections based on historical data quite unreliable. The number of severely injured riders, where severe injuries are considered as category 3 or higher injuries on the Maximum Abbreviated Injury Scale (MAIS 3+), were estimated according to the International Road Assessment Program (iRAP) ratio range of severe injuries to fatalities.

The MAIS[27] is a globally accepted trauma scale used by medical professionals. It provides an objective and reliable basis for data collection. The injury score is determined at the hospital with the help of a detailed classification key. The score ranges from 1 to 6. Injuries classified ≥3 on the MAIS scale are the most serious injuries, the types of injuries that cause significant long term damage and consequences. The scale facilitates international comparison of injury rates. It has been adopted and is used as a common injury classification and data reporting system within European Union countries (EC 2013).

[27] The UNECE acknowledges that the AIS (in all of its versions) is the property of the Association for the Advancement of Automotive Medicine (AAAM), owner of the Copyright. The so-called AIS (Abbreviated Injury Scale) is mentioned in this UNECE study for information purposes only.

5. *Predictions for killed and injured using the WHO 2008 figures as the starting point*

The results from all the methods were applied to the number of motorcycle riders killed in 2008, as given in the WHO Report. From this, individual country predictions were created, which were then totalled and averaged.

The intention was then that the lowest and highest changes in the index would be taken to identify the likely minimum and maximum trends for both killed and injured. However, some of the results had changes that were below 1.00. Desirable though this might be, when the high income country figures, i.e. the countries with the most active road safety measures, are taken into account, it is obvious that such low figures are not realistic. Therefore, only values above 1.00 were included in the minimum and maximum choices.

The maximum and minimum values selected were used to create a range of predicted deaths and injuries in 2015 and 2020.

Table 6

Estimated range for total lives saved and injuries avoided, per country income group

(Thousands of fatalities or injuries)

	Injuries - fatalities	Estimated total lives lost and injuries sustained				Expected reduction of fatalities and injuries in 2015 and 2020			
	2008	2015		2020		2015		2020	
		Min	Max	Min	Max	Min	Max	Min	Max
	Killed riders					Lives saved by helmet-wearing (42 per cent)			
LIC	53	68	174	78	260	28	73	33	109
LMIC	107	123	170	163	214	52	71	69	90
UMIC	16	19	68	30	106	8	29	12	44
HIC	15	18	21	18	21	7	9	8	9
Total	191	228	432	289	600	96	182	122	252
	Seriously injured riders					Serious injuries avoided by helmet-wearing (69 per cent)			
LIC	204	544	2,088	624	3,120	375	1,441	431	2,153
LMIC	928	984	2,040	1,304	2,568	679	1408	900	1,772
UMIC	41	152	816	240	1,272	105	563	166	878
HIC	460	144	252	144	252	99	174	99	174
Total	1,633	1,824	5,184	2,312	7,200	1,259	3,577	1,595	4,968

To generate an estimated figure for the number of lives that could be saved or injuries avoided by wearing a helmet, the percentages given in Liu et al (2008) were applied to the minimum/maximum predicted number of killed and injured. (Liu's conclusion is that helmets reduce the risk of head injury by 69 per cent and death by 42 per cent.)

6. *Estimation of potential monetary savings as a result of motorcycle helmet use and a benefit-cost analysis*

Predictions obtained for the number of fatalities were used to estimate the potential monetary savings of fatalities and serious injuries prevented by motorcycle helmet use. The iRAP economic appraisal model (Dandah and McMahon 2008) and the embedded sensitivity analysis were used to estimate the range of those potential monetary savings within the four income categories assessed in this study. As stated above, a serious injury is defined as a category 3 or higher injury based on the MAIS scale.

In addition, International Monetary Fund (IMF) individual countries GDP projections (in current USD) for the years 2015 and 2020 were used to calculate the per cent of GDP saved as a result of motorcycle helmet use, as described per individual income group in section 3 of chapter 1[28].

Table 7

Estimated range of potential monetary savings resulting from avoided fatalities and serious injuries, per country income group

	Injuries /fatalities (thousands)	Estimated total lives lost and severe injuries sustained (thousands)				Potential monetary savings resulting from helmet use (Billions of USD)			
	2008	2015		2020		2015		2020	
		Min	Max	Min	Max	Min	Max	Min	Max
	Killed riders					Monetary benefit of lives saved thanks to helmet-wearing (42 per cent)			
LIC	53	68	174	78	260	2.36	8.22	2.79	12.27
LMIC	107	123	170	163	214	9.11	16.58	12.08	21.01
UMIC	16	19	68	30	106	4.68	22.62	7.02	34.32
HIC	15	18	21	18	21	17.70	30.35	20.23	30.35
Total	191	228	432	289	600	33.85	77.76	42.12	97.95
	Seriously injured riders (MAIS3+)					Monetary benefit of serious injuries avoided by helmet-wearing (69 per cent)			
LIC	204	544	2,088	624	3,120	6.34	48.66	7.27	72.72
LMIC	928	984	2,040	1304	2,568	23.78	98.59	31.51	124.11
UMIC	41	152	816	240	1,272	12.27	131.73	19.37	205.35
HIC	460	144	252	144	252	50.26	175.90	50.26	175.90
Total	1,633	1824	5,184	2312	7,200	92.65	454.90	108.41	578.08
Grand Total						**126.5**	**532.66**	**150.53**	**676.03**

The results that were obtained were then used as inputs in the benefit-cost analysis of helmet use[29] for all country income group categories in 2015. As a first step, total projected aggregate USD monetary savings as a result injuries and fatalities prevented by helmet wearing in 2015 in countries analysed – per income category – were inferred from the above analysis in order to have a basis for a sensitivity analysis of benefit-cost ratios.

[28] International Monetary Fund, World Economic Outlook Database: http://www.imf.org/external/pubs/ft/weo/2015/01/weodata/download.aspx

[29] All estimates consider a one helmet per motorcycle rate.

Table 8

Total monetary savings as a result of injuries and fatalities prevented by helmet wearing in 2015 (billion USD)

	Low	Medium	High
LIC	8.70	32.79	56.88
LMIC	32.88	74.03	115.17
UMIC	16.95	85.66	154.35
HIC	67.96	137.11	206.25

A number of further inferences were made, as described below.

Table 9

Total Number of Powered Two Wheelers in countries analysed – per income category (million units)

	LIC	LMIC	UMIC	HIC
TOTAL PTW 2015	174.6	95.7	60.4	47

Powered-two-wheeler fleet estimates across income category countries were carried out using available motorcycle fleet data from the period 2002-2012. The individual countries annual motorcycle fleet rate changes over the decade were averaged and used to project the respective countries' 2015 motorcycle fleets.

Table 10

Estimated helmet price ranges in USD in analysed countries – per income category

	Low	Medium	High
LIC	50	100	150
LMIC	100	200	300
UMIC	200	400	600
HIC	500	750	1000

Price ranges of approved helmets (according to the latest version of UN Regulation No. 22) were obtained by researching prices of type approved helmets in countries included in the analysis.

Table 11

Total helmet price ranges in USD in analysed countries (one PTW one helmet) – per income category (billion USD)

	Low	Medium	High
LIC	8.73	17.46	26.19
LMIC	9.57	19.14	28.70
UMIC	12.09	24.17	36.26
HIC	23.50	35.25	47

The total cost of helmets is the total expenditure that would be incurred if all motorcycle riders (two per motorcycle) in the countries considered would purchase one helmet every second year.

The benefit-cost ratios for the four country income groups were determined as shown in the following tables:

Table 12
Low-income countries motorcycle helmet use Benefit-Cost ratio matrix

		Helmet cost		
		Low	Medium	High
Savings	Low	1	0.5	0.3
	Medium	3.8	1.9	1.3
	High	6.5	3.3	2.2

Table 13
Lower-middle income countries motorcycle helmet use Benefit-Cost ratio matrix

		Helmet cost		
		Low	Medium	High
Savings	Low	3.4	1.718	1.146
	Medium	7.8	3.9	2.579
	High	12	6	4

Table 14
Upper-middle income countries motorcycle helmet use Benefit-Cost ratio matrix

		Helmet cost		
		Low	Medium	High
Savings	Low	1.4	0.7	0.5
	Medium	7.1	3.5	2.4
	High	12.8	6.4	4.3

Table 15
High income countries motorcycle helmet use Benefit-Cost ratio matrix

		Helmet cost		
		Low	Medium	High
Savings	Low	3.6	1.8	1.2
	Medium	7.3	3.6	2.4
	High	11	5.5	3.7

The results of the benefit-cost analysis are explained and interpreted in section 3 of chapter 1. Motorcycle markets and accidents.

7. Statistical sources

- For countries in the UNECE: (Persons Killed or Injured in Road Traffic Accidents by Country, Category of User, Accident Type, Age Group and Time is available at http://live.unece.org/trans/main/wp6/wp6.html)
- Brazil: - DENATRAN (Departamento Nacional de Transito);
    - E. Vasconcellos and M. Sivak (2009). *Road safety in Brazil: challenges and opportunities*, Report No. UMTRI-2009-29.
    - K. Bhalla, S. Shahraz, J. Abraham, and P. Yeh (2009). *Estimating the global burden of road injuries - Preliminary results*, Harvard School of Public Health, Boston, MA, 02138.
- India: The *Indian yearbook 2007*
- Indonesia: Ministry of Transport, and Asian Development Bank, Regional road safety programme
- Japan: World Bank and *Yearbook* of the Japanese Automobile Manufacturers Association (JAMA)
- Malaysia: Asian Development Bank, Regional road safety programme, quoting MOT
- Philippines: Statistics office and Asian Development Bank, Regional road safety programme.
- Thailand: Asian Development Bank, Regional road safety programme, quoting MOT
- Uganda: J. Leyland, F. Tumwiine and J. Magola Wanume (2002). *Road safety activities in a road maintenance project: the case of the western Uganda road maintenance capacity building project*.
- Viet Nam: M.B. McDonnell, V.B.T. Van Bich Thi Tran, N.R. McCoy (2010). *Helmet Day,* SSRC USA quoting MOT.

Annex III: European Union and UNECE definitions of L category vehicles

Table 16
EU and UNECE definitions of L category vehicles

EU L category vehicle definitions[1]		UNECE L category vehicle definitions[2]	
Category and name	**Vehicle Description**	**Category**	**Vehicle Description**
L1e Light two-wheel powered vehicle	Two-wheel vehicles with a maximum design speed of not more than 45 km/h and characterised by an engine whose: • cylinder capacity does not exceed 50 cm^3 in the case of the internal combustion type, or • maximum continuous rated power is no more than 4 kW in the case of an electric motor	L_1	A two-wheeled vehicle with an engine cylinder capacity in the case of a thermic engine not exceeding 50 cm^3 and whatever the means of propulsion a maximum design speed not exceeding 50 km/h.
L2e Three-wheel moped	Three-wheel vehicles with a maximum design speed of not more than 45 km/h and characterised by an engine whose: • cylinder capacity does not exceed 50 cm^3 if of the spark (positive) ignition type, or • maximum net power output does not exceed 4 kW in the case of other internal combustion engines, or • maximum continuous rated power does not exceed 4 kW in the case of an electric motor	L_2	A three-wheeled vehicle of any wheel arrangement with an engine cylinder capacity in the case of a thermic engine not exceeding 50 cm^3 and whatever the means of propulsion a maximum design speed not exceeding 50 km/h.

EU L category vehicle definitions[1]		UNECE L category vehicle definitions[2]	
Category and name	**Vehicle Description**	**Category**	**Vehicle Description**
L3e Two-wheel motorcycle	Two-wheel vehicles without a sidecar fitted with an engine having a cylinder capacity of more than 50 cm^3 if of the internal combustion type and/or having a maximum design speed of more than 45 km/h	L_3	A two-wheeled vehicle with an engine cylinder capacity in the case of a thermic engine exceeding 50 cm^3 or whatever the means of propulsion a maximum design speed exceeding 50 km/h.
L4e Two-wheel motorcycle with side-car	Two-wheel vehicles with a sidecar fitted with an engine having a cylinder capacity of more than 50 cm^3 if of the internal combustion type and/or having a maximum design speed of more than 45 km/h	L_4	A vehicle with three wheels asymmetrically arranged in relation to the longitudinal median plane with an engine cylinder capacity in the case of a thermic engine exceeding 50 cm^3 or whatever the means of propulsion a maximum design speed exceeding 50 km/h (motor cycles with sidecars).
L5e Powered tricycle	Vehicles with three symmetrically arranged wheels fitted with an engine having a cylinder capacity of more than 50 cm^3 if of the internal combustion type and/or a maximum design speed of more than 45 km/h	L_5	A vehicle with three wheels symmetrically arranged in relation to the longitudinal median plane with an engine cylinder capacity in the case of a thermic engine exceeding 50 cm^3 or whatever the means of propulsion a maximum design speed exceeding 50 km/h.
L6e Light quadri-cycle	Quadricycles whose unladen mass is not more than 350 kg, not including the mass of the batteries in case of electric vehicles, whose maximum design speed is not more than 45 km/h, and whose • engine cylinder capacity does not exceed 50 cm^3 for spark (positive) ignition engines, or • maximum net power output does not exceed 4 kW in the case of other internal	L_6	A vehicle with four wheels whose unladen mass is not more than 350 kg, not including the mass of the batteries in case of electric vehicles, whose maximum design speed is not more than 45 km/h, and whose engine cylinder capacity does not exceed 50 cm^3 for spark (positive) ignition engines, or whose maximum net power output does not exceed 4 kW in the case of other internal combustion engines, or whose maximum continuous rated power does not exceed 4 kW in

EU L category vehicle definitions[1]		UNECE L category vehicle definitions[2]	
Category and name	**Vehicle Description**	**Category**	**Vehicle Description**
	combustion engines, or • maximum continuous rated power does not exceed 4 kW in the case of an electric motor. These vehicles shall fulfil the technical requirements applicable to three-wheel mopeds of category L2e unless specified differently.		the case of electric engines.
L7e Heavy quadri-cycle	Quadricycles other than those referred to in category L6e, whose unladen mass is not more than 400 kg (550 kg for vehicles intended for carrying goods), not including the mass of batteries in the case of electric vehicles, and whose maximum net engine power does not exceed 15 kW. These vehicles shall be considered to be motor tricycles and shall fulfil the technical requirements applicable to motor tricycles of category L5e unless specified differently.	L_7	A vehicle with four wheels, other than that classified for the category L6, whose unladen mass is not more than 400 kg (550 kg for vehicles intended for carrying goods), not including the mass of batteries in the case of electric vehicles and whose maximum continuous rated power does not exceed 15 kW.
Source: Regulation (EU) No. 168/2013 of the European Parliament and of the Council of 15 January 2013 on the approval and market surveillance of two- or three-wheel vehicles and quadricycles.		*Source:* Consolidated Resolution on the Construction of Vehicles (R.E.3) Revision 3 - Economic Commission for Europe, Inland Transport Committee, World Forum for Harmonization of Vehicle Regulations	

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Full face helmet. Photo from www.istockphoto.com/; Image ID – 12220358 (Cover page image 1);

Vintage helmet. Photo from www.istockphoto.com/; Image ID – 000079382481 (Cover page image 2);

Background motorcycle rider. Image from www.istockphoto.com/; Image ID – 2240225 (Cover page image 3)

Motorcycle riders without a proper helmet. Photo by Mr. Juan Ramos Peris (pp. 10);

A family on a motorcycle in the congested traffic of Karachi. Photo by Mr. Rik Nuytens (pp. 16);

A helmet visor type and a helmet approved according to UN Regulation No. 22. Photos by Mr. Nikola Šahović (pp. 32);

Pedelec riders with safety gear: Photo from http://www.gdv.de/2012/08/was-sie-ueber-den-versicherungsschutz-von-pedelecs-wissen-sollten/, by GDV Berlin (pp. 39);

UNECE motorcycle helmet type approval mark. Photo from https://commons.wikimedia.org/wiki/File:Casque_homologation.jpg, by Ŵishmaster (pp. 51);

Motorcycle accident. Photo from www.fotolia.com, number 15819626, by Tomas Svoboda (pp. 63).