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SafeFITS

Safe Future Inland Transport Systems

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United Nations Economic Commission for Europe

The United Nations Economic Commission for Europe (UNECE) is one of the five United Nations regional commissions administered by the Economic and Social Council (ECOSOC). It was established in 1947 with the mandate to help rebuild post-war Europe, develop economic activity and strengthen economic relations among European countries, and between Europe and the rest of the world.

During the Cold War, 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, the Commission acquired not only many new Member States, but also new functions. Since the early 1990s, it 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 countries of Europe, Central Asia and North America – 56 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. The Commission offers a regional framework for the elaboration and harmonization of conventions, norms and standards. In particular, UNECE 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 UNECE

The UNECE Sustainable Transport Division acts as the secretariat of the Inland Transport Committee 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 Inland Transport Committee and its 20 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 action to enhance traffic safety, environmental performance, energy efficiency and the competitiveness of the transport sector.

The Inland Transport Committee 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 and most well-known results of its ongoing work are reflected in the following outcomes:

- Fifty-eight 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.
- The Trans-European North-South Motorway, Trans-European Railway and the Euro-Asia Transport Links projects, which facilitate multi-country coordination of transport infrastructure investment programmes.
- The TIR system, which is a global customs transit facilitation solution.
- The tool called For Future Inland Transport Systems (ForFITS), which can assist national and local governments in monitoring carbon dioxide (CO2) emissions coming from inland transport modes and in selecting and designing climate change mitigation policies, based on their impact and adapted to local conditions.
- Transport statistics – methods and data – that are internationally agreed on.
- Studies and reports that help transport policy development by addressing timely issues, based on cutting-edge research and analysis.
- Special attention to Intelligent Transport Services, 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.

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ADR	European Agreement concerning the International Carriage of Dangerous Goods by Road
EuroNCAP	European New Car Assessment Programme
ForFITS	For Future Inland Transport Systems
IRF	International Road Federation
NCAP	New Car Assessment Programme
OECD	Organisation for Economic Co-operation and Development
RSPI	Road Safety Performance Indicators
SafeFITS	Safe Future Inland Transport Systems
UNDA	United Nations Development Account
UNECE	United Nations Economic Commission for Europe
WHO	World Health Organization

Executive summary

Within the United Nations Decade of Action for Road Safety 2011–2020, the United Nations Economic Commission for Europe (UNECE) initiated the Safe Future Inland Transport Systems (SafeFITS) project aiming to facilitate knowledge-based transport policy decision-making related to reducing road traffic injuries.

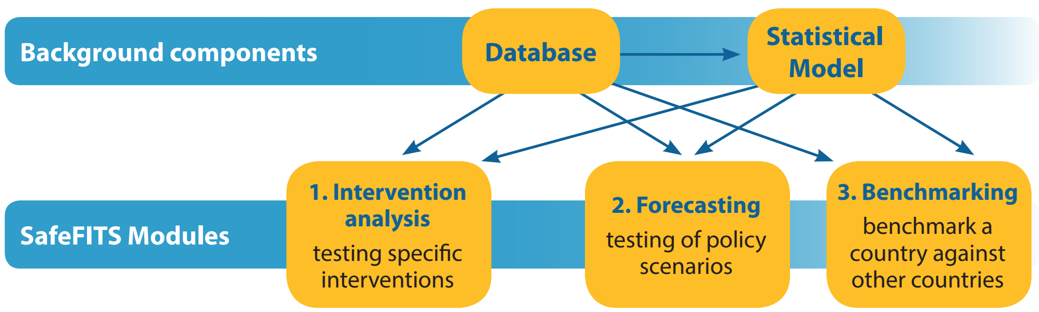
The objective of the SafeFITS project is to develop a road safety decision-making tool for national and local governments both in developed and developing countries, based on the related scientific knowledge and data available worldwide, with emphasis on recent academic research and project results. The tool is intended to assist governments and decision makers in deciding on the most appropriate road safety policies and measures so as to achieve tangible results. The model is based on historical road safety data and relations between several road safety parameters, and provides information on different road safety scenarios.

Within the first two phases of the project:

- A suitable methodological framework for the SafeFITS tool was designed, combining the five road safety pillars of the WHO Global Plan of Action (WHO, 2011) with five layers of the road safety management system, through an improved version of the SUNflower pyramid (SUNflower, 2002).
- A broad literature review was carried out and a list was drawn up of the most relevant relations (causalities) between different road safety indicators and effects.
- A list of available statistical data and the international sources considered necessary to describe and monitor road safety performance was developed.
- The SafeFITS conceptual framework was designed, which includes an outline of the model, architecture and a description of the data requirements.

In the last phase of the project, the SafeFITS statistical model was developed on the basis of actual data and included two background components and three modules:

The database consists of numerous data and indicators for 130 countries around the globe (with more than 2.8 million population) dealing with all layers of the road safety management system. World Health Organization reports on the global road safety status were the primary source of data, but were complemented with data from other international organizations (e.g. United Nations, Organisation for Economic Co-operation and Development, International Road Federation). The data were carefully checked and processed to include the latest available year and to address missing values.



The development of the statistical model took into account several challenges and particularities of road safety analyses. The task of road safety forecasting on the basis of policy scenarios, i.e. combining an explanatory approach on road safety with the time dimension at global level, was a challenge on its own, as there is no similar example in the literature.

The proposed approach is based on the calculation of composite variables and their introduction in a regression model (two-step approach), and the development of a model on the basis of short-term differences, accumulated to obtain medium- and long-term forecasts. Both these scientific choices have their limitations, but they were the optimal solutions for dealing with the complexity of the model to be developed on the basis of the available data.

The final model is robust, with satisfactory performance and acceptable prediction errors. The cross-validation undertaken is considered successful and can be implemented in the SafeFITS model. However, care should be taken that the limitations of the model are taken into account, and several recommendations are made for optimal use of the model (e.g. combinations of policy scenarios).

The output modules of the SafeFITS model allow for:

- Intervention analysis: allows users to examine the effects of single interventions at national or regional level.
- Forecasting analysis: allows users to define their own scenarios of measures (or combinations of measures) in a country and obtain medium/long term road safety forecasts for each scenario.
- Benchmarking analysis: allows users to benchmark a country against a group of countries (e.g. all countries, countries of similar economic or road safety performance).

Decision makers can better support road safety policy choices by exploiting the SafeFITS model in order to obtain forecasting and benchmarking estimates:

- For a "base case" scenario, solely on the basis of GNI and demographic indicators projections. This scenario serves as a reference case for assessing the effects of interventions.
- Policy scenarios with several interventions, in addition to GNI and demographic developments. This allows one to assess the cumulative impact of these interventions on the forecasted road safety outcomes, and the country's position globally or within a cluster of countries with similar economic and road safety performance.

Overall, the model can be used for the assessment of various policy scenarios of individual countries but also for road safety benchmarking and forecasting (i.e. monitoring the global progress towards the road safety targets).

At a next stage, a new wave of historical data may allow further validation and adjustment of the model. New data will allow better estimate future developments on the basis of longer historical trends, both as regards fatalities and as regards key economy, exposure and SPI indicators. Additionally, further changes in programmes and measures implemented in the various countries will allow accurate estimation of their effects on outcomes, improving the transferability of estimates in other countries as well. It is therefore suggested to closely monitor global developments in data availability and accuracy, so that the data are updated regularly and continuously, allowing the model to be improved with more, and more accurate, data.

1. INTRODUCTION

1.1 Background

Road accidents constitute a major social problem in modern societies, accounting for more than 1.25 million killed per year globally (WHO, 2015). Road traffic injuries are estimated to be the eighth leading cause of death globally, and more than half of the people killed in traffic accidents are people between the ages of 15 and 44.

In low- and middle-income countries, the rates of road traffic injuries are twice those of high-income countries and continue to increase. This can be partly attributed to rapid motorization in many developing countries, without any investment being made in road safety.

Current trends suggest that, unless action is taken, traffic injuries will become the fifth leading cause of death by 2030, with the disparity between high- and low-income countries further increased (WHO, 2015).

In order to guide countries in taking concrete, national-level action, the United Nations drew up a Global Plan for the Decade of Action for Road Safety 2011–2020. The Plan provides a context that explains the background and reasons behind the declaration of a special decade by the General Assembly and serves as a tool to support the development of national and local plans of action. It also provides a framework to allow coordinated activities at regional and global levels. It proposes several national road safety activities, grouped into five pillars: road safety management, safer roads and mobility, safer vehicles, safer road users and post-crash response.

General Assembly resolution 68/269 of 10 April 2014 on improving global road safety commended Member States that had developed national road safety plans in line with the Global Plan of Action and encouraged those which had not already done so to adopt such a plan. The resolution also recognized the importance of efficient movement of people and goods and of access to environmentally sound, safe and affordable transportation.

The 2030 Agenda for Sustainable Development adopted by the United Nations Sustainable Development Summit 2015, defined the Sustainable Development Goals (SDGs). The SafeFITS project supports United Nations Member States in achieving SDG targets that are directly related to road safety:

- SDG target 3.6 aims to reduce global road traffic deaths and injuries by 50% by 2020, and
- SDG target 11.2 aims to provide access to safe, affordable, accessible and sustainable transport systems for all by 2030.

The project For Future Inland Transport Systems (ForFITS), funded by the United Nations Development Account and finalized in 2013, aimed to facilitate knowledge-based transport policy decision-making related to CO2 reduction. The project developed the ForFITS tool, which estimates expected amount of CO2 generated by the inland transport modes for different transport policy options.

Within the above road safety context and using the ForFITS principles, the project Safe Future Inland Transport Systems (SafeFITS) aims to facilitate knowledge-based transport policy decision-making related to reducing road traffic injuries.

1.2 SafeFITS Objectives

The overall objective of the SafeFITS project is to develop a road safety decision-making tool for national and local governments both in developed and developing countries, based on the related scientific knowledge and data available worldwide, with emphasis on recent academic research and project results (e.g. SUNFLOWER NEXT, RIPCORD-iSEREST, DaCoTA, SafetyNet). The tool is intended to assist governments and decision makers in deciding on the most appropriate road safety policies and measures so as to achieve tangible results. The model is based on historical road safety data and relations between several road safety parameters, and provides information on different road safety scenarios.

1.3 Overview of the report

The final report of the SafeFITS project presents the following:

- Literature review of the most relevant road safety studies and projects that can be used for the development of the SafeFITS tool.
- Most relevant relations (causalities) identified between different road safety indicators / variables and effects.
- SafeFITS database with data on road safety indicators (fatalities and injuries, performance indicators, road safety measures, economy and background) for all countries, which were used for the estimation of new global causalities, through the development of statistical models.
- SafeFITS set of statistical models of global causalities, estimated on the basis of the database of road safety indicators, allowing "intervention", "forecasting" and "benchmarking" analyses within SafeFITS.
- SafeFITS tool, including three complementary modules, all serving very common purposes in road safety policy analysis:
  - An "intervention analysis" module, to allow the user to forecast the safety effects of a specific road safety measure or intervention for a given country and time period, all other things being kept constant.
  - A "forecasting" module, to allow the testing of combined scenarios of interventions (measures and programmes) at national level.
  - A "benchmarking" module, to allow the user to benchmark a country against other countries, by comparing the road safety outcomes in relation to the basic road safety indicators, and by identifying the priority areas that the country should focus on for improving its road safety.

The report, which is divided in two parts, is structured as follows:

Chapter 1 presents background information and introduces the SafeFITS project.

Part One comprises chapters 2 to 4.

Chapter 2 presents the methodology according to which the SafeFITS tool was based. It includes a description of the conceptual framework which was designed for the SafeFITS project, as well as the steps followed in order to meet the objectives of the project.

Chapter 3 presents the main results of the literature review concerning the causalities and relationships between the indicators of each pillar and the road safety outcomes.

Chapter 4 presents the results from the detailed review on causal relations linking the 19 priority indicators selected within the SafeFITS project to the outcome indicators (casualties and fatalities).

Part Two comprises chapters 5 to 9.

Chapter 5 presents an overview of the model, including a description of the SafeFITS tool and the analytical methods, in terms of the model formulations and steps of the analysis on which the SafeFITS model development is based.

Chapter 6 presents the architecture of the project database in terms of indicators, data sources and definitions. It also describes the procedures for the handling of missing values and other data limitations.

Chapter 7 presents the preliminary data analysis steps, which form the basis of the development of statistical models, as well as the final statistical model, including the development of global models and separate models for different groups of countries, and the validation of the models.

Chapter 8 presents and describes the SafeFITS tool in terms of the user input and model outputs for different modules through indicative screens ("wire-frames") of a future tool to be developed.

Chapter 9 summarizes and assesses the results of the SafeFITS project, the model limitations and future improvements, and discusses the next steps.

Part One

2. METHODOLOGY

2.1 Conceptual framework

The design of the methodological framework for the SafeFITS project combines the five road safety pillars of the WHO Global Plan of Action (WHO, 2011) with the concept of the SUNflower pyramid (SUNflower, 2002) and has been suitably adjusted in order to better serve the needs of the project.

As a result, the road safety management system within the project is described as a structure that includes five layers: economy and management, transport demand and exposure, road safety measures, road safety performance indicators, fatalities and injuries; and five pillars: road safety management, road infrastructure, vehicle, user and post-crash services. This structure is presented in table 2.1, along with example components for each layer/pillar combination.

The hierarchy of layers is as follows:

- The first layer, economy and management, reflects the structural, economic, cultural and regulatory characteristics (i.e. policy input) of each country, that are related to road safety performance.
- The second layer, transport demand and exposure, reflects the characteristics of the transportation system and the exposure of the population due to urbanization and urban sprawl, modal split (share of trips per mode), road network type, share of traffic (vehicle- and passenger-kilometres) of travel per mode and per road type etc., which are all related to road risk.
- The third layer, road safety measures (policy output), reflects the results of structural and economic characteristics.
- To link these three layers to the actual road accident outcomes, an intermediate (fourth) layer specifies the operational level of road safety in the country, containing road safety performance indicators (RSPI) on issues related to the five pillars (e.g. speeding, drinking and driving, road network and the main features of the vehicle fleet).
- Final outcomes expressed in terms of fatalities and injuries (road casualties) are then necessary to understand the scale of the problem. This information is found in the fifth layer and consists of different types of road risk indicators.

Table 2.1
Structure of the road safety management system for the SafeFITS project

LAYERS		PILLARS				
		1. Road safety management	**2. Road infrastructure**	**3. Vehicle**	**4. User**	**5. Post-crash services**
LAYERS	**1. Economy and management**	Economic Developments, Strategy and Targets, Regulatory framework (compliance with United Nations regulations)	Existence of motorways, of non-paved roads, of road tunnels, Existence of guidelines (for design, RSA etc.), Legislation on speeding	Number of registered vehicles, Vehicle age, Technical inspection legislation (maintenance, roadworthiness, overweight, ADR)	Requirements and regulations on drivers' licensing, Drivers' training, Medical exams of drivers, Legislation on alcohol / use of seatbelts / use of helmets	Trauma management sector level of development Number of hospitals / doctors / Intensive Care (IC) beds per population
	2. Transport demand and exposure	Transport Modal Split (road/rail, passenger/freight, private/public), Share of urban areas, Weather conditions	Exposure with regard to road type, Length of road per road type, Share of Motorway length out of the total road network, Number of railway level crossings	Exposure with regard to vehicle type, Share of PTW, HGV / carriage of dangerous goods vehicles in the vehicle fleet	Exposure with regard to age and gender	
	3. Road safety measures	Assessment of measures, Data collection and analysis, International comparisons, Vehicle taxation, Road pricing	Treatment of High Risk Sites, Road Safety Audits, Tunnel Road Safety Management, Improvement of signage, Installation of road restraint systems, Lighting, Speed limits in urban areas, Traffic Calming	Renewal rate of vehicle fleet, Measures for second-hand vehicles, Vehicle related roadside controls, Automated driving	Enforcement, campaigns, Road safety education, Training	e-call, First aid training, Existence and organization of trauma centres
	4. Road safety performance indicators	Safety targets, stakeholders' involvement, detail of analysis for intervention selection, economic evaluation	Number of RSAs conducted, Percentage of High Risk Sites treated	Global NCAP score, Mean age of the vehicle fleet per vehicle type, Existence of safety equipment, e-safety	Speeding / Drink and drive infringements, Seatbelts use, Helmets use, Driver distraction, Driver fatigue	Emergency response time, Type of field treatment, Speed of treatment in hospital, Number of ambulances per population, Number of good Samaritans per population
	5 Fatalities and injuries	Fatalities / injuries per million inhabitants, fatalities / injuries per million passenger cars, fatalities / injuries per 10 billion passenger-km	Fatalities / injuries in motorways, in 2-lane rural roads, in urban roads	Share of motorcycle fatalities out of the total fatalities	Share of pedestrian / bicyclist / motorcyclist fatalities out of the total fatalities, drink-driving-related fatalities	Death rate, Hospitalization in IC Unit, Total length of hospitalization

2.2 Methodological steps

A literature review of existing research on accident casualties was undertaken for each of the pillars. It summarized the causal relationships between policies or measures and road safety outcomes, emphasizing the complexity of these relations and the difficulty of generalizing the results. The statistical data that were considered necessary to describe and monitor road safety performance were also defined and the available data sources reviewed.

Based on the above findings, 19 indicators were proposed as priority indicators to be included in the SafeFITS model. A focused literature review was then carried out to determine specific quantified causal relations and equations linking these indicators with the road safety outcomes. As a result, 125 detailed causalities were identified, derived from some 95 different scientific studies, journal articles, reports, etc.

From the outcome of the literature review, several challenges in the development of the SafeFITS model were identified:

The relationships between indicators and road safety outcomes are complex and in some cases random. The literature suggests that the effect of an indicator (e.g. economy, transport demand, measure or intervention) may vary considerably among countries and time periods, and several contextual effects (known as modifying conditions) may affect the size and type of the relationship between indicator and road safety outcome. Consequently, the problem is multidimensional, and transferability of known causalities in a global context is not recommended.

Current knowledge on causalities is incomplete, as very few results are available for several key indicators. And since most existing causalities identified in the literature are based on analyses from industrialized countries, it is highly unlikely that these estimates can be safely transferred to emerging economies.

Data are lacking on several indicators and road safety outcomes at the international level. There are very few databases with global road safety data and performance indicators, and in these databases there are several limitations due to lack of data for several countries, especially developing countries. For example, safety performance indicators, which are known to significantly associate with road safety outcomes, are only partially available, even for industrialized and well-performing countries.

The main approaches adopted in the SafeFITS methodology are as follows:

- The methodology allows as many dimensions of the problem (road safety outcomes and indicators) as possible to be taken into account.
- The model is based on new causalities, estimated from original statistical data analyses, taking into account existing data for all Member States of the United Nations.
- An original database was created, bringing together data from different international sources for all countries, and appropriate techniques were applied in order to address the lack of data in the statistical analyses.

3. LITERATURE REVIEW OF ACCIDENT CAUSALITIES

3.1 Introduction

In the last two decades, road safety research worldwide has made important progress in analysing road safety policies and measures and assessing their effectiveness. These data and information regarding the relationship between road fatalities and injuries on the one hand and economic and social development, transport system development, infrastructure characteristics and conditions, road user behaviour, vehicle related factors, emergency response and post-crash care conditions etc., on the other, should constitute the foundation of every road safety decision-making tool aiming to provide information on future road safety outcomes based on historical road safety data.

Chapter 3 presents the main results of the pertinent literature review for each of the five pillars (road safety management, road infrastructure, vehicle, user and post-crash services). It focuses on the causalities and relationships between each of the two layers of the road safety management system, economy and management and road safety measures, and the road safety outcomes (road casualties).

The chapter concludes with a general synthesis for all five pillars, together with a comprehensive review synthesis table (table 3.1).

3.2 Road safety management

The road safety management pillar refers mainly to policy aspects such as the regulatory framework and compliance with United Nations legal instruments, the existence of national road safety strategic plans, possibly with quantified targets, the modal split of travel, as well as measures such as road pricing and vehicle taxation.

From the literature review, it could be seen that the safety impact of many of the various components within this pillar has not been documented in the existing literature as "high" (see table 3.1). However, according to research, based on common expectations, "these measures are potentially among the most drastic that can be taken to affect the number of accidents" (Elvik et al., 2009).

In most cases this discrepancy is attributed to the increased complexity of the road safety management measures, making the estimation of their safety effects difficult to quantify. Also, in many cases, the effect of the examined measures on road casualties is indirect, which creates the need for a multiple step approach to identifying the causal relationship. This creates a barrier to the related research, which limits the effectiveness and the generalization of the results.

Moreover, some of these measures are concerned with the design of the institutional framework for road safety policy, whose causal relationship with the number of accidents and injuries is extremely complex. Therefore, it is difficult, and perhaps not always possible or meaningful, to quantify the effects of such measures on accidents and injuries.

However, the safety impact of road safety management measures should not be underestimated. Although a quantified high impact has not been provided in the existing research, it is generally accepted that the institutional framework and road safety policy measures are a prerequisite for the effective implementation of measures in the other four pillars.

3.3 Road infrastructure

Research on the causalities of road casualties (fatalities and injuries) within the road infrastructure pillar is possibly the most extensive of all the five pillars. Several studies and research programmes have examined the effects of road infrastructure management issues and of road infrastructure measures on road casualties. A review was carried out of the most relevant studies, handbooks, manuals and research projects that provide standardized and accurate methods or tools for estimating the safety effects of infrastructure-related initiatives and measures.

From the literature review it can be seen that possibly the most important element in the economy and management layer is the existence of motorways, whereas in the road safety measures layer, several measures are identified as being of high importance: namely, the treatment of high-risk sites, the improvement of road alignment and sight distance, the reconstruction and rehabilitation of roads, the cross-section improvements and roadside treatments, treatments in intersections (channelization, roundabouts) and interchanges, the installation/improvement of road restraint systems, treatments in horizontal curves, anti-skid treatments, construction of bypass roads, traffic-calming measures, upgrading of pedestrian crossings and protection of railway level crossings.

A characteristic of the examined studies that is considered very useful in the development of the SafeFITS tool is the nature of the produced results: either microscopic or macroscopic, or in some cases both microscopic and macroscopic.

Specifically, a number of studies deal with the development of specific accident prediction models (APMs) or crash modification factors (CMFs) that predict accident frequency (or relative change in accident frequency, in the case of CMFs) based on the values of geometric characteristics (e.g. curve radius, lane width, or shoulder width) or traffic attributes (e.g. annual average daily traffic (AADT)).

Such models and factors are very useful for estimating the safety effects of a specific treatment applied in a specific location of the road, but are much less useful in summarizing the broad picture of expected overall improvement in the road safety performance of a whole country or even a subnational jurisdiction if a large number of such measures – along with measures in the other four pillars – are applied.

On the other hand, several other studies present results of a more macroscopic nature, presenting the safety impact of each measure or initiative in a broader and more generalized way.

3.4 Vehicle

Improving vehicle safety is a key strategy used in addressing international and national road casualty reduction targets and in achieving a safer road traffic system. It addresses the safety of all road users and currently comprises measures to help avoid a crash or reduce injury in the event of a crash (crash protection). Improvements to vehicle safety results from legislation, consumer information, the initiatives of individual manufacturers and product liability considerations (SafetyNet, 2009-c).

Relevant policies and measures fall into the following basic categories:

1. Vehicle design, protective devices and safety equipment. This includes three distinct types of measures:
    - active safety measures, which are intended to reduce the number of accidents, such as ABS, daytime running lights;
    - passive safety measures, which are intended to reduce the severity of injuries in the event of accidents, such as vehicle crashworthiness assessment, pedestrian friendly car front;
    - telematics and eSafety, such as Adaptive Cruise Control, Alcohol interlock.
2. Vehicle inspection measures and procedures, concerning either periodic or roadside technical inspection.

Several studies have examined the effects of vehicle-related interventions and measures on road casualties, with the first category of measures being more extensively studied than the second. From the results of the literature review, it can be stated that the most important elements in the economy and management layer are the application of vehicle safety standards (e.g. Vehicle Type Approval), and the existence of regulations for hazardous goods transport and for periodic vehicle inspection. In the road safety measures layer, the measures and vehicle equipment presenting the larger effect on road safety are probably vehicle crashworthiness assessment programmes (e.g. EuroNCAP, USNCAP, Global NCAP), airbags and child restraints.

When examining studies dealing with the safety impact of vehicle-related policies and measures, two levels of effects are distinguished (Elvik et al., 2009) – the individual level, which is the effect on the individual vehicle or the individual user of a specific type of vehicle equipment, and the aggregate level, which is the effect on the total number of accidents or injuries in a society that results from the measure. There is no simple relationship between the effects of a measure at the individual level and the effects of the same measure at the aggregate level.

In a large part of the literature, the effects of vehicle-related measures are studied at the individual level; thus, conclusions about these measures' overall safety impact, which are of interest to the SafeFITS project, are not readily available. Nonetheless, it is clear that many measures involving vehicle design and safety equipment have contributed significantly to reducing the number of fatalities and injuries in traffic.

An interesting issue that requires consideration is the safety impact of advanced technologies of Heavy Goods Vehicles (HGV), such as:

- Advanced Emergency Braking Systems (AEBS) - Much research is being carried out on such technologies, and very large estimates of the safety potential of such systems have been claimed following laboratory studies, but at an individual level. However, their usefulness in addressing high-risk crash scenarios, as well as their feasibility, has yet to be determined (SafetyNET, 2009-d).
- Lane Departure Warning System (LDWS) - Research results on the safety effect of LDWS are contradictory. It has been claimed (ROSEBUD, 2006) that an LDWS enables drivers to react, on average, 0.5 seconds earlier than

without the system, with the effect of a 25% reduction in all accidents. However, it should be taken into account that 25% of accidents related to lane departure of HGVs are a very small part of the total number of accidents that are of interest to the SafeFITS project. In other references (SafetyNET, 2009-d), it is suggested that, since times to collision in safety-critical lane changes are normally much less than one second, a driver does not have sufficient time to respond to a warning before crashing, and lane change and merging crashes can probably only be avoided by intervening systems. But these have their own problems: how to detect driver intentions and how to intervene. This may be by taking over the steering from the driver or by providing feedback through the steering wheel. The technical and operational feasibility of such systems has still to be demonstrated.

- Electronic Stability Control (ESC) - Several research efforts (SafetyNet, 2009-c), (SafetyNet, 2009-d), (Elvik et al., 2009) have examined the safety impact of ESC in cars and have reported accident reductions ranging from 12% to 40% (at individual level), depending on the type of accident. However, research on the safety effect of such systems specifically for HGVs has not yet been sufficiently investigated.
- Under-run protection - Energy-absorbing front, rear and side under-run protection has been estimated to reduce deaths in car to lorry impacts by about 12% (SafetyNET, 2009-c), (PROMISING, 2001). The measure has been identified as having an acceptable C/B ratio (ROSEBUD, 2006); however, no exact figures for its safety effects were identified through the meta-analysis methodology (Elvik et al., 2009).

3.5 User

Existing research on the causalities of road accidents related to the "User" pillar of the road safety management system is extensive and a large number of policies, initiatives and measures have been applied and assessed. Several different ways to categorize such measures can be found in the literature: according to user type (e.g. motorcyclists, pedestrians, cyclists, young drivers, older drivers), according to the nature of the measures (e.g. training, legislation, enforcement, education).

After examining the results of the literature review, no single policy or intervention can be identified as being of significantly greater importance. Instead, several components of a diverse nature (e.g. related to training, licensing, legislation, enforcement) may exhibit significant effects in reducing road fatalities and injuries.

The distinction between the individual level and the aggregate level of effects that was mentioned above for the "Vehicle" pillar is also valid for many user-related measures. Thus, conclusions about the overall safety impact of some measures, which are of interest to the SafeFITS project, were in many cases not readily available.

3.6 Post-crash services

Post-crash services (or post-impact care) refer to the framework aiming to reduce the severity of injury consequences after a road accident has occurred. The type of help needed by victims of road accidents obviously varies according to the severity of the injuries. In cases of minor injury, patients will often not be hospitalized and will treat themselves or seek the help of a general practitioner. Optimal medical and psychological follow-up care at this level is very important to alleviate pain and distress.

In major injuries, clinical experts (ETSC, 1999) have schematically defined the required post-impact care as a chain consisting of different links. Help starts with action taken by the victims themselves or more often by bystanders. The subsequent links in the chain are access to the emergency medical system, the help provided by the emergency services, the delivery of medical care before arrival at the hospital, hospital trauma care and rehabilitative psychosocial care, for those victims that have suffered debilitating injury.

Following examination of the review results, it can be stated that the most important elements in the economy and management layer are the existence of a lead organization for the pre-hospital emergency care system, and the availability of improvements in general medical care and medical technology.

In the road safety measures layer, possibly the most important measures are an efficient land ambulance service and the operation of Automatic Crash Notification (e-call).

However, the available research on the causal relationship between the performance and characteristics of the trauma management system and road accident outcomes is limited and in most cases the safety impact is not quantitatively defined through the application of scientifically solid procedures. Therefore, the results are based to a significant degree on the expectations and general impressions of medical and transport experts who participated in the preparation of the literature.

In cases where these expectations were contradictory among the examined reports (e.g. the impact of first-aid training for commercial and public transport drivers), subjective judgment was applied for identifying the most suitable result.

3.7 Literature review synthesis

The review was organized taking into account the five pillars that form the road safety management system (WHO, 2011) and schematically presented in table 2.1 of the present report.

The characteristics of the literature that were considered useful for the SafeFITS project are synoptically presented in table 3.1. Specifically, the following information has been compiled:

- General reference information: Title of the reference, issue date and author/publisher.
- Information (geographical origin and date) on the data used for identifying the causal relationships.
- Information on each study's methodology (e.g. meta-analysis, expert consultation, statistical modelling), form of results (e.g. recommendations, CBA results, percentage of accident or fatalities reduction, etc., and nature of results (macroscopic or microscopic - see also the related discussion below).
- Overall assessment of the reliability and usefulness of each reference for the SafeFITS tool development, using a three-level qualitative scale (high/medium/low). The assessments are based on subjective expert judgment, taking into account factors such as the applied methodology, the date of used data, the validity of assumptions of each study and the relevance of the study results to the needs of the project.
- Specific rating of the usefulness of each reference for identifying causal relationships within each pillar and for these two layers of the road safety management structure of table 2.1. (i.e. economy and management – abbreviated as "Mng" - and road safety measures – abbreviated as "RSM" in table 3.1). For this rating a three-level qualitative scale (high/medium/low) has also been applied.

Table 3.1
Examined literature on accident causalities, with reliability and usefulness assessment

REFERENCES				DATA USED		STUDY			ASSESSMENT		USEFULNESS RATING WITHIN EACH PILLAR									
											Road Safety Management		Road Infrastructure		Vehicle		User		Post-Crash Services	
No	Title	Issue Date	Author / Publisher	Countries	Years	Methodology	Form of Results	Nature of Results	Reliability	Useful-ness	Mng	RSM	Mng	RSM	Mng	RSM	Mng	RSM	Mng	RSM
1	Sustainable Transport - Priorities for Policy Reform	1996	World Bank	Worldwide	1950 - 1996	Review of literature - Summary of past experience	Policy suggestions	Macroscopic	medium	low	L									
2	Reducing the Severity of Road Injuries through Post Impact Care	1999	European Transport Safety Council (ETSC)	Europe	Not specified	-	Recommendations	Not applicable	medium	low									L	L
3	PROMISING research project - "Cost-benefit analysis of measures for vulnerable road users"	2001	PROMISING Consortium	Europe	Not specified	Review of existing literature and Cost - Benefit Analysis	CBA results	Macroscopic	medium	low				M		L		L		
4	Implementing the Recommendations of the World Report on Road Traffic Injury Prevention	2004	Bliss, T. / World Bank	Worldwide	Not applicable	-	Framework and Guidelines	Not applicable	medium	medium	M									
5	A Review of the Impact of Medical Care and Technology in Reducing Traffic Fatalities	2004	Noland, R.	USA, United Kingdom and international datasets	1970 - 1996	Various Statistical Models	Depending on the model, changes in: (1) Fatalities, (2) Average length of in-patient stay in hospital, and (3) Average acute care days in hospital	Macroscopic	high	medium									M	
6	Prehospital trauma care systems	2005	World Health Organization (WHO)	Worldwide	Not applicable	-	Recommendations	Not applicable	high	medium									M	M
7	ROSEBUD research project - "Examples of assessed road safety measures - a short handbook"	2006	ROSEBUD Consortium	Europe	1967 - 2006	Review of existing literature and Cost - Benefit or Cost - Effectiveness Analysis	CBA or CEA results	Macroscopic	medium	low				M	L	L	L	L		
8	Helmets: a road safety manual for decision-makers and practitioners	2006	World Health Organization (WHO)	Worldwide	Not applicable	-	Recommendations	Not applicable	high	medium							M	L		
9	SUPREME research project - "Handbook for measures at the Country level" and "Handbook for measures at the European level"	2007	SUPREME Consortium.	25 EU Member States plus Norway and Switzerland	Not specified	Review of existing literature by experts and Questionnaires	- Outline on effects - Outline on cost	Macroscopic	medium	low	L	L		L		L	L	L	L	L
10	Drinking and Driving: a road safety manual for decision-makers and practitioners	2007	World Health Organization (WHO)	Worldwide	Not applicable	-	Recommendations	Not applicable	high	medium							M	L		
11	CEDR Report - "Best Practice on Cost Effective Road Safety Infrastructure Investments"	2008	Conference of European Directors of Roads (CEDR)	Europe (primarily)	1980 - 2007	Review of existing literature, Questionnaire Survey and Expert Consultation Process	- Crash reduction % - CBA results - Strengths and Weaknesses - Implementation barriers	Macroscopic	high	medium				M						

REFERENCES				DATA USED		STUDY			ASSESSMENT		USEFULNESS RATING WITHIN EACH PILLAR									
											Road Safety Management		Road Infrastructure		Vehicle		User		Post-Crash Services	
No	Title	Issue Date	Author / Publisher	Countries	Years	Methodology	Form of Results	Nature of Results	Reliability	Useful-ness	Mng	RSM	Mng	RSM	Mng	RSM	Mng	RSM	Mng	RSM
12	RIPCORD - ISEREST research project - "Road Infrastructure Safety Protection - Core Research and Development for Road Safety in Europe; Increasing Safety and Reliability of Secondary Roads for a Sustainable Surface Transport"	2008	RIPCORD - ISEREST Consortium	Austria, Portugal, The Netherlands, Germany	2003 - 2005	Generalised Linear Model (GLM) using a Negative Binomial Distribution	Accident Prediction Models	Microscopic	medium	low				L						
13	The Handbook of Road Safety Measures (2nd Edition)	2009	Elvik, R., Hoye, A., Vaa, T. and Sorensen, M. / Emerald Group Publishing Ltd	Europe, USA, Canada and Australia	1939 - 2009	Formal Meta-Analysis of existing literature	- Crash reduction % - CBA results	Micro- and Macroscopic	high	high	L	M	L	H	M	H	H	H	L	M
14	Country Guidelines for the Conduct of Road Safety Management Capacity Reviews and the Specification of Lead Agency Reforms, Investment Strategies and Safe System Projects	2009	Bliss, T. and Breen, J. / World Bank	Worldwide	Not applicable	-	Framework and Guidelines	Not applicable	high	high	H	H								
15	Post Impact Care (web text)	2009	SafetyNet Consortium	Europe	Not applicable	-	Recommendations	Not applicable	high	medium									M	M
16	Vehicle Safety (web text)	2009	SafetyNet Consortium	Europe	Not applicable	-	Crash, fatalities or injuries reduction %	Macroscopic	high	medium					M	M				
17	eSafety (web text)	2009	SafetyNet Consortium	Europe	Not applicable	-	Crash, fatalities or injuries reduction %	Macroscopic	high	high						H				
18	Seat-belts and child restraints: a road safety manual for decision-makers and practitioners	2009	World Health Organization (WHO)	Worldwide	Not applicable	-	Recommendations	Not applicable	high	low							L	L		
19	RISMET research project - "Road Infrastructure Safety Management Evaluation Tools" - Deliverable 4 and 5	2011	RISMET Consortium	Europe	1990 - 2008	Regression analysis for the effect of the use of safety management tools to road safety performance.	Regression Analysis Table	Macroscopic	medium	low		L		L						
20	RISMET research project - "Road Infrastructure Safety Management Evaluation Tools" - Deliverables 6.1 and 6.2	2011	RISMET Consortium	Germany, Portugal, Austria, Norway, The Netherlands	2005 - 2007	Poisson Regression, Poisson-Gamma Regression and Poisson Log-Normal Regression	Accident Prediction Models	Microscopic	medium	low				L						
21	IRDES research project - "Improving Roadside Design to Forgive Human Errors" - Deliverables Nr.2 and Nr.3	2011	IRDES Consortium	Italy, Sweden, Austria	2001 - 2010	Empirical Bayes before - after study, Before - after study with comparison group, vehicle - infrastructure interaction simulation	- Safety Performance Functions - Crash Modification Factors	Microscopic	medium	low				L						

											USEFULNESS RATING WITHIN EACH PILLAR									
REFERENCES				DATA USED		STUDY			ASSESSMENT		Road Safety Management		Road Infrastructure		Vehicle		User		Post-Crash Services	
No	Title	Issue Date	Author / Publisher	Countries	Years	Methodology	Form of Results	Nature of Results	Reliability	Useful-ness	Mng	RSM	Mng	RSM	Mng	RSM	Mng	RSM	Mng	RSM
22	2BESAFE research project - "2-wheeler Behaviour and Safety"	2011	2BESAFE Consortium	Europe and Australia	Not specified	Review of existing literature, Questionnaire Survey and Expert Consultation Process	Expert assessment using a five-scale rating	Macroscopic	medium	medium			M	M		L	L	M		M
23	Sharing Road Safety: Developing an International Framework for Crash Modification Functions	2012	OECD / ITF	Worldwide	Not applicable	Range of Replications technique	Discussion on methodological issues	Not applicable	medium	low				L						
24	Road Safety Management Capacity Reviews and Safe System Projects Guidelines	2013	Bliss, T. and Breen, J. / World Bank	Worldwide	Not applicable	-	Framework and Guidelines	Not applicable	high	high	H	H								
25	Countermeasures that work: A Highway Safety Countermeasure Guide For State Highway Safety Offices - 7th Edition	2013	National Highway Traffic Safety Administration (NHTSA)	USA	1984 - 2013	Review of existing literature and expert assessments	Expert assessment using a five-scale star rating	Macroscopic	high	high						M	H	H		
26	Saving lives with Sustainable Transport. Traffic safety impacts of sustainable transport policies	2013	EMBARQ program, World Resources Institute.	UK (London)	2001 - 2006	Before - After Analysis	Average annual injury accidents reduction	Macroscopic	high	low	L	L								
27	Democratising Car Safety: Road Map for Safer Cars 2020	2015	Global NCAP	Worldwide	Not applicable	-	Recommendations	Not applicable	medium	medium						M				
28	The Highway Safety Manual	2010 and 2014	American Association of State Highway and Transportation Officials (AASHTO)	USA	1960 - 2008	Formal Meta-Analysis of existing literature with involvement of several expert panels	- Safety Performance Functions - Crash Modification Factors	Micro- and Macroscopic	high	high				H						
29	The Cochrane Injuries Group Reviews: "Prevention of road traffic injuries"	various	The Cochrane Collaboration (various authors)	Depending on review	Depending on review	Formal Meta-Analysis of existing literature	Crash, fatalities or injuries reduction %	Macroscopic	high	medium				L		M	M	L		

Note: Rating of usefulness within each layer – pillar combination: L – low, M – medium, H – high

From the review of the literature, the following conclusions can be drawn, which are considered important for the SafeFITS project:

- Only limited information is available originating from studies in middle and low-income countries on accident causalities. Many of these studies are not methodologically robust or they lack high-quality road safety data. Taking into account the significant differences between developed and developing countries in all aspects of road transport (from motorization level, common transport modes and exposure, to enforcement and use of restraining equipment), it can still be a challenge to identify and quantify causal relations connecting policy actions and measures to road fatalities and injuries in middle and low-income countries.
- In some cases the causal relations are complex and several secondary factors can be affected by a measure, thus complicating the estimation of the measure's effect on accidents. An example of this is the implementation of driver education in schools, so as to increase road safety. It was found that although the purpose of the measure was to reduce accident involvement through better driver training, instead it resulted in early licensing and could finally increase the proportion of young people involved in accidents (Roberts and Kwan, 2001).
- In many cases, the intercorrelation of road safety measures and policies applied simultaneously may affect the safety effects overall. The effects may be cumulative, or perhaps a beneficial measure, if applied on its own, may have an adverse effect when combined with other measures. This issue has not yet been sufficiently explored.
- Similarly, several policies and measures have an indirect effect on road casualties. Taking exposure control as an example, in order to quantify the effect of measures affecting traffic volume on road casualties, it is important to know both the effect of the measures on traffic volume and the relationship between traffic volume and the number of accidents, which has been estimated as a "1% increase of volume resulting in 0.88% increase in the number of accidents" (Elvik et al., 2009). This multiple step approach to identifying the causal relationship often creates a barrier to relevant research, thus limiting the usefulness of the research results for the SafeFITS project.
- In certain cases, the causal relationships identified in the literature were found to be incompatible with each other. The incompatibility usually refers to the magnitude of the examined road safety effect, and not to the direction of the effect (negative or positive), and can be attributed to a large number of reasons (e.g. methodological weaknesses, study biases, data used, context of the study). This further complicates the identification of quantified accident causalities.
- Another point of interest, particularly evident in the road infrastructure pillar is the **nature of the causality results: microscopic** (in-depth) or **macroscopic**. Specifically, a number of studies deal with the development of specific accident prediction models (APMs) or crash modification factors (CMFs). Such models and factors are useful for estimating the safety effects of a specific infrastructure treatment applied in a specific location of the road network, but cannot be used to summarize the broad picture of expected overall improvement in road casualties after the implementation of interventions of a greater scale. Furthermore, the safety impact of an infrastructure-related treatment may vary significantly according to the specific treatment characteristics: for example, according to Elvik et al., 2009, increasing curve radius in a horizontal curve can have an estimated impact in accident number ranging from a 50% reduction (in the case of increasing a <200m radius to 200-400m) to a 10% increase (when reconstructing a >1,000m radius curve as a straight segment).
- Another important issue when analysing studies dealing, for instance, with the safety impact of the use of safety equipment, is the distinction between individual versus aggregate level of safety effects (Elvik et al., 2009). The individual level refers to the effect on the individual user of a specific type of safety equipment; the aggregate level refers to the effect on the total number of accidents or injuries in a society that results from the measure. There is no simple relationship between the effects of a measure at the individual level and the effects of the same measure at the aggregate level.

  An interesting example is the effect of seat belt wearing legislation (Elvik et al., 2009). The probability of front seat fatalities is reduced by around 40%–50% when seat belts are worn. Increased use of seat belts is therefore expected to reduce the number of fatalities.

  However, a 10% increase in seat belt use will not necessarily reduce the number of total fatalities by 5%, and there are many reasons for this. The number of fatalities is also influenced by several other factors and is also subject to random fluctuations. More importantly, it is not certain that those who start using seat belts when this becomes mandatory are a representative sample of all drivers. If the first drivers to use seat belts are those with the lowest accident involvement rate, the decrease in the total number of fatalities will be smaller than the percentage increase in seat belt use would suggest.

Many studies examine the effects of measures regarding the use of safety equipment at the individual level. Thus, conclusions about the measures' overall safety impact, which is of interest to the SafeFITS project, are not readily available, and care should be exercised in interpreting the results.

Many of the causal relationships adequately quantified in the literature refer not to the total number of accidents or injuries in a society, but only to the accidents affected by the examined measure or policy. For example, the safety impact of Graduated Driving Licence (GDL) programmes refers only to accidents involving young drivers. Similarly, accident reduction percentages attributed to the installation of automated speed cameras refer only to accidents occurring in those sections where the speed cameras were installed. Therefore, the overall effect of such measures on the total fatalities, injuries and accidents in a country cannot be directly obtained from the existing literature and are difficult to estimate.

The above issues indicate that the development of a model linking the layers of economy and management and road safety measures to the road safety outcomes cannot safely be based only on the causal relationships as identified in the literature, since in many cases the relationships have not been adequately quantified, and especially in middle and low-income countries, the reliability of the identified relationships can be limited.

On the basis of the above, a detailed review of selected causalities was undertaken in order to further explore the data and information available on those indicators for which stronger evidence appears to exist on their effects on road safety outcomes.

More specifically, the next step of the investigation examined whether there are sufficiently robust causalities for a selected set of indicators (from all layers and pillars of the SafeFITS conceptual framework) for developing a model based on the causalities of a selected set of indicators.

4. FOCUSED REVIEW OF DETAILED CAUSALITIES

4.1 Review of detailed causalities for the priority indicators

Following the literature review of the most relevant road safety studies and projects for the development of the SafeFITS model and the identification of the required statistical data, the following 19 priority indicators were proposed for inclusion in the model:

1. GDP per capita (indicator I01).
2. Country has a national road safety strategic plan (indicator I02).
3. Country has time-based, quantified national road safety targets (indicator I03).
4. Country has a clearly empowered agency leading road safety (indicator I04).
5. Country has a defined allocation of expenditure for dedicated road safety programmes (indicator I05).
6. Share of trips / traffic per mode (indicator I06).
7. Country has a target to eliminate high-risk roads (indicator I07).
8. Number of passenger cars per 1,000 inhabitants (indicator I08).
9. Share of powered two-wheelers in the vehicle fleet (indicator I09).
10. Country has a comprehensive helmet use law (indicator I10).
11. Country has systematic policies and practices in place for Road Safety Audits of new road projects (indicator I11).
12. Number of enforcement controls (speed, alcohol, seat belt, helmet etc.) per 1,000 population (indicator I12).
13. Roadside police alcohol tests per 1,000 population (indicator I13).

14. Roadside police speed checks per 1,000 population (indicator I14).
15. Share of High Risk Sites treated (indicator I15).
16. Percentage of rural road network not satisfying design standards (indicator I16).
17. Helmet wearing rates for powered two-wheelers (indicator I17).
18. Seat belt wearing rates on front seats of cars (indicator I18).
19. Mean EMS response time (indicator I19).

A detailed review was performed to identify quantifiable causal relations linking the 19 priority indicators to the outcome indicators (casualties and fatalities). The references examined per pillar were scrutinized in order to identify such relations, and further, more detailed references were sought (e.g. research papers in journals, conferences and workshops, other relevant publications), in which such causal relations could possibly be established. In the following paragraphs and in tables in appendix A, the results are summarized for each of the priority indicators.

4.1.1 GDP per capita

According to the review, the identified associations of GDP changes to fatality rates in the relevant literature, which were considered useful for the development of the SafeFITS tool, are the models proposed by Kopits and Cropper and by Yannis et al.

At a first glance the models may seem contradictory: the Kopits and Cropper model suggests a non-linear relation, with increasing fatality rates as GDP increases at low GDP per capita levels, and decreasing fatality rates as GDP increases at higher levels. Therefore in high-income EU countries one would expect a decrease in fatality rates as a result of GDP increase. Instead, Yannis et al. identified a statistically significant annual increase of fatality rates as GDP increases, and a statistically significant annual decrease of fatality rates as GDP decreases.

It should, however, be pointed out that the Kopits and Cropper study focuses on long-term GDP changes, with resulting changes in motorization levels, whereas the EU model by Yannis et al. is better suited for periods of short-term economic recessions in already developed countries.

4.1.2 Country has a national road safety strategic plan

A single analysis of the effects of a road safety programme in Malaysia was identified, reporting an average 5% reduction in fatalities per year during the first six years. However, this research cannot establish a quantifiable causal relation on its own. Instead, more comprehensive research efforts based on data from multiple countries (DaCoTA, 2012; Papadimitriou and Yannis, 2013) indicated that road safety management indicators were not found to be significant predictors of the mortality and fatality risk rates.

As stated by Elvik et al. (2009), an important characteristic of such measures is that the objectives are very complex and often conflicting, and improving road safety is often not the only objective, and in many cases, not the most important.

Furthermore, the measures themselves are often complex and several variations may exist. Since the effects largely depend on the way these measures are designed, implemented and used, it is often very difficult to make generalizations. However, research, based on common expectations, has suggested that "these measures are potentially among the most drastic that can be taken to affect the number of accidents" (Elvik et al., 2009). In most cases this discrepancy is attributed to the increased complexity of the road safety management measures, making the estimation of their safety effects very difficult to quantify.

4.1.3 Country has time-based, quantified national road safety targets

The existing studies examining the effect of road safety targets on road safety are few and their results are ambiguous or even contradictory. The problem in determining the effects of road safety targets on road safety is complex.

Firstly, there are relatively few units of observation (i.e. few countries have set quantified targets), while there are many factors affecting road safety for each unit of observation. It is therefore difficult to rule out the effects of confounding factors (Elvik et al., 2009).

Secondly, a quantified road safety target does not, by itself, directly influence road safety. The causal mechanism includes the actual implementation of effective road safety programmes (Elvik, 2001). Therefore, in many cases, although quantified road safety targets were set, no significant road safety outcome was recorded because the required road safety programmes were not implemented effectively.

The only existing comprehensive studies of the effects of quantified road safety targets in road fatalities are those by Elvik (2001) and Wong et al. (2006), which have produced similar results. The average of the above results, a 0.85% per year reduction in fatalities, is proposed as a best estimate for high-income countries. Although in both studies statistically significant associations were identified, the results are not adequate to establish a solid causal relationship, and this reduction estimate should be used with caution.

Meta-analysis studies and multivariate statistical-mathematical models were not identified for indicator I03. And no studies whatsoever were identified for middle- and low-income countries, possibly because setting quantified road safety targets is not common practice in such countries.

4.1.4 Country has a clearly empowered agency leading road safety

From the review of the literature, it is evident that a quantitative causal relation linking the existence of a clearly empowered agency leading road safety and road safety outcomes has not yet been established, and it is generally accepted that it is very difficult to determine the specific effects of road safety management initiatives, due to their complex nature, the different variations and the different ways they are designed, implemented and used. Thus, the impact of the existence of such an agency cannot be quantitatively determined.

4.1.5 Country has a defined allocation of expenditure for dedicated road safety programmes

From the review of the literature, it is also evident that a quantitative causal relation linking the existence of a defined allocation of expenditure (budget) for dedicated road safety programmes and road safety outcomes has not yet been established (same as for agency leading road safety). Thus, the impact of this indicator cannot be quantitatively determined.

4.1.6 Share of trips/traffic per mode

In table A.6 (appendix A) of the present report, the relations regarding indicator I06 ("Share of trips/traffic per mode") are comparatively presented. From the review it is evident that existing relevant studies have varying assumptions and cannot be directly compared to each other. As far as studies of individual effects are concerned, the study of Allsop and Turner could be useful for SafeFITS. However, the data are old and refer to a restricted geographical area (London).

4.1.7 Country has a target to eliminate high-risk roads

From the review of the research, it can be seen that no quantitative causal relation has yet been established linking a national target to eliminate high-risk roads with road safety outcomes. It is difficult to determine the specific effects of road safety management initiatives. This is due to their complex nature, the different variations and the different ways in which they are designed, implemented and used.

4.1.8 Number of passenger cars per 1,000 inhabitants

From the literature review, it can be deduced that the statistical models that describe the relation of motorization rate to road fatalities are not universal. Instead there are significant differences in the identified patterns and the magnitude of effects between countries or groups of countries. These differences could possibly be attributed to other factors influencing road safety, such as legislation, and road safety budget and strategy, and can be found in the models (Yannis et al., 2007a) (Yannis et al., 2011).

Especially in the latter, it becomes evident that, although some of the examined countries exhibit a breakpoint in road fatalities within a narrow range of motorization rate values (implying perhaps similar social and economic conditions and/or similar road safety culture), this range differs among certain subgroups in the examined countries.

4.1.9 Share of powered two-wheelers in the vehicle fleet

According to the review, the only identified association of the percentage of powered two-wheelers (PTWs) in the vehicle fleet to fatality rates that was considered useful in the context of the SafeFITS project is the group of statistical models proposed by Yannis et al., 2007a. However, significant differences in the identified patterns and the magnitude of effects between countries or groups of countries can be identified, and the generally applied distinction between high-income and middle- and low-income countries seems insufficient for the needs of the SafeFITS model.

4.1.10 Country has a comprehensive helmet use law

Table A.10 (appendix A) presents all of the abovementioned relations regarding indicator I10 ("Country has a comprehensive helmet use law"). Indicators I09 and I10 are useful only in estimating the effects on PTW fatalities alone. According to IRTAD data (OECD, 2013), these represent approximately 10% to 30% of annual fatalities in IRTAD countries.

In order to homogenize and compare results between different studies of individual effects, the following assumptions were made:

1. Only safety effects expressed in PTW fatalities per 10,000 registered PTWs were taken into account, since the introduction or repeal of helmet laws (associated with the examined differences in helmet use rates) was found to significantly affect PTW registrations and thus exposure to risk. Specifically, the repeal of helmet laws was found to have a positive effect on PTW registrations and PTW vehicle-kilometres, and examination of changes in fatalities alone (i.e. not taking registrations into account) would probably lead to an overestimation of the adverse safety effect.
2. To compare results from studies examining the positive effects of helmet law introductions to the results from studies analysing the negative effects of helmet legislation repeals, the latter were reversed. For example the 75% increase in PTW fatalities per 10,000 registered PTWs reported for Louisiana (NHTSA, 2003) after repeal of the universal helmet law, was considered to correspond to a (100-175) / 175 = 43% reduction, assuming a hypothetical reverse scenario of a universal helmet law introduction.

Based on the above, a comparison of the results of individual effects studies for high-income countries reveals a minimum 10% reduction of PTW fatalities per 10,000 registered PTWs (Mounce et al., 1992) for Texas 1989 law and a maximum 43% reduction of PTW fatalities per 10,000 registered PTWs, for Louisiana (NHTSA, 2003), with a best estimate of a 20% reduction proposed for the purposes of the SafeFITS project.

The formal meta-analysis approach of Elvik et al. (2009) proposes, as a best estimate, a 26% reduction in fatalities after the introduction of a comprehensive helmet use law. But although the methodology applied in Elvik et al. (2009) for the estimate deduction is more rigorous and comprehensive, the original studies that were analysed are older, mostly from between the 1960s and the 1990s.

Regarding the reviewed mathematical-statistical models on the effects of the indicator I09, it was found that the models by Houston and Richardson (2008) are based on a larger database than the model developed by Branas and Knudson (2001) and by Morris (2006). They control for more possibly correlated parameters and address more reliably the issue of partial coverage helmet laws by using a trichotomous independent variable for helmet legislation (none, partial and comprehensive). Furthermore, the models are available for three different types of fatality rates (per 10,000 registered motorcycles, per 100,000 population and per 10 billion vehicle miles of travel (VMT)).

However, the models were based entirely on United States data and no comparable international studies were identified during the review. Although the results are comparable to the results of South-European studies, application of these models to other high-income countries and even more so to low- and middle-income countries should be done with caution, and further validation of the results will be required.

4.1.11 Country has systematic policies and practices in place for road safety audits of new road projects

Generally, the effects of performing road safety audits (RSAs) can be estimated comparing accidents during the first years of operation on roads that have been audited to similar roads that were not audited. Unfortunately, very few such studies were identified in the literature, and none was identified on the overall effects of establishing RSA policies and practices at a nationwide level. A further difficulty in evaluating the effects of RSAs, also mentioned in ROSEBUD (2006), is that the effects of road safety audits depend on the implementation of the recommendations made by the auditor.

It can be seen from the literature that only studies examining the individual effects of specific RSA programmes in high-income countries were identified, the results of which range from a minimum of 12.5% to a maximum of 70% reduction of accidents in audited traffic schemes, as compared with non-audited ones. However, these accident reduction ratios refer only to specific road sections that were audited, and do not represent an overall nationwide accident reduction that can be attributed to the implementation of systematic RSA policies and practices.

4.1.12 Number of enforcement controls (e.g. speed, alcohol, seat belt, helmet) per 1,000 population

From the review it was found that limited quantitative information on the absolute level of enforcement, and "low" or "heavy" traffic police activity is not always numerically defined. Or, in cases where numbers do exist, they are measured in different ways from one study to another.

And most studies examining the effect of enforcement on road safety focus on specific enforcement types (e.g. speeding, seat belt and helmet use). Causal relations linking the overall enforcement intensification with fatalities, casualties or accidents are very limited in the literature.

No studies were identified that examine the road safety effect of enforcement in middle- and low-income countries. For studies of individual effects, the results of Newstead et al. (2001) from Queensland, Australia, could possibly be used, but taking into account the significant limitations concerning the estimation of the number of controls per hour and the population of the area estimated in the middle of the implementation period.

A more generalized estimation, based on meta-analysis, has been presented in ESCAPE (2001). This approximate summary relationship between the extent of enforcement and the change in the number of injury accidents is probably the most useful for SafeFITS quantitative relation that can be identified in the existing literature, despite the assumptions that were required for its development.

An attempt to statistically model the effects of enforcement on road safety has been made by Yannis et al. (2007). However, the strong regional variations that were discovered and the analysis of data only from one single (small) country, i.e. Greece, restrict the generalization of the research results.

4.1.13 Roadside police alcohol tests per 1,000 population

From the review of existing studies on the safety effects of alcohol enforcement, it is evident that although a large number of relevant studies have been published, it is difficult to identify consistent quantitative relations due to the diversity of the results. A difficulty encountered are the variations in police methods applied in alcohol controls that may influence road safety effects.

Another issue that further complicates the establishment of a causal relation and is not addressed in all but one of the examined studies (Diamantopoulou and Cameron, 1998) is that there is evidence that suggests that some drink-drivers faced with intense enforcement, heightened by intense publicity, may change their travel behaviour and use relatively unsafe minor roads.

Whether or not the effects of enforcement can persist over many years is a question that remains to be answered. And no studies were identified that examine the road safety effect of enforcement in middle- and low-income countries.

As far as studies of individual effects are concerned, no direct comparison of the relations can be performed, since in all eight identified relations (see table A.13), both the level of enforcement and the nature of the results are measured in different – not comparable – ways. As a best estimate possibly depicting the overall effect on the total number of casualties, the estimation presented by Elvik (1999) is proposed, which indicates that a three times increase in alcohol enforcement efforts can result in a 1.15% reduction of casualties.

Probably the most useful information on the effects of alcohol enforcement on road safety can be retrieved from meta-analysis studies, such as ETSC (2003), (Elder et al., 2002) and Elvik et al. (2009).

The most comprehensive such study is the analysis included in Elvik et al. (2009), according to which the implementation of alcohol testing is related to a 9% reduction of total accidents in affected road sections (-13% for Australia).

Finally, interesting attempts to statistically model the effects of alcohol enforcement on road safety have been made by Henstridge et al. (1997) for Australia and by Yannis et al. (2008) for Greece. However, both models originate from countries with unique characteristics as far as the effect of alcohol enforcement is concerned, and in both studies strong regional variations were discovered.

4.1.14 Roadside police speed checks per 1,000 population

There is limited quantitative information on the absolute level of speed enforcement, and "low" or "heavy" traffic police activity is not always numerically defined. Or, in cases where numbers do exist, they are measured in different ways from one study to another.

And no studies examining the road safety effect of speed enforcement in middle- and low-income countries were identified.

For individual effects, no direct comparison of the relations can be performed, since in all eight identified relations (see table A.14), either the level of enforcement or the nature of the results are measured in different and incomparable ways.

As a best estimate possibly depicting the overall effect on the total number of casualties, the estimation presented by Elvik (1999) is proposed, which indicates that a three times increase in speed enforcement efforts can result in a 3.94% reduction of casualties.

A more generalized estimation, based on meta-analysis, but lacking the information on the "amount" of speed enforcement, has been presented in Elvik et al. (2009). According to this, a stationary visible speed enforcement programme can result in a 17% reduction in the number of accidents in the affected road sections (95% confidence intervals: -31% to -2%).

An attempt to statistically model the effects of speed enforcement on road safety has been made by Yannis et al. (2007). However, the strong regional variations that were discovered and the analysis of data only from a single (small) country, i.e. Greece, restrict the generalization of the research results.

4.1.15 Share of high-risk sites treated

According to the review of the literature, only studies examining the individual effects of specific high-risk sites treatment programmes in high-income countries were identified, the results of which differ between urban and rural areas. They also range from a minimum of 41.8% to a maximum of 48.2% reduction in accidents in rural areas and a minimum of 27.0% to a maximum of a 31.2% reduction in accidents in urban areas. As a best estimate of effects, a 43% reduction in injury accidents in rural areas and a 30% reduction in urban areas is proposed, which is also the best estimate provided by the meta-analysis of Elvik et al. (2009).

This accident reduction ratio, however, refers only to the specific high-risk sites that were treated, and does not represent an overall nationwide accident reduction that can be attributed to the implementation of high-risk site programmes and can be related to the share of high-risk sites treated.

Thus the impact of the percentage of high-risk sites that are treated, and therefore the final results of the identification of causalities for this indicator I15 (see table 4.2), are marked as n/a ("not available").

4.1.16 Percentage of rural road network not satisfying design standards

A causal relationship linking the percentage of rural road network not satisfying design standards to road safety outcomes cannot be established from the existing research. And the identified trends in accident reduction are of insufficient detail and reliability to be exploited within the SafeFITS project.

4.1.17 Helmet wearing rates for powered two-wheelers

Table A.17 (appendix A) presents all the relations regarding indicator I17 ("Helmet wearing rates for powered two-wheelers").

Most of the studies refer to various States in the United States. Two refer to other high-income countries, and only one to middle- and low-income countries, in which there is no comparable information for fatalities, but only on fatalities among injured and hospital admitted powered two-wheelers (PTWs). Therefore, the safety effects estimated in middle- and low-income countries are not comparable to those estimated in high-income countries.

Another interesting observation is the large differences in observed helmet wearing rates between high-income and middle- and low-income countries. In most of the examined studies in high-income countries, observed helmet wearing rates range from approximately 50%-60%, when no helmet laws are effective, to over 95% after the implementation of helmet laws. On the other hand, in middle- and low-income countries, very low helmet wearing rates were reported, such as 4.5% (Thailand).

In order to homogenize and compare results between different studies of individual effects, the following assumptions were made:

1. Only safety effects expressed in PTW fatalities per 10,000 registered PTWs were taken into account, since the introduction/repeal of helmet laws (associated with the examined differences in helmet use rates) was found to significantly affect PTW registrations and thus exposure to risk. Specifically, the repeal of helmet laws was found to have a positive effect on PTW registrations and PTW vehicle-kilometres, and examination of changes in fatalities alone (i.e. not taking registrations into account) would probably lead to an overestimation of the adverse safety effect.
2. To compare results from studies examining the positive effects of helmet law introductions to the results from studies analysing the negative effects of helmet legislation repeals, the latter were reversed. For example the 75% increase in PTW fatalities per 10,000 registered PTWs reported for Louisiana (NHTSA, 2003) after repeal of the universal helmet law was considered to correspond to a (100-175) / 175 = 43% reduction, assuming a hypothetical reverse scenario of a universal helmet law introduction.

Based on the above, regarding individual effect studies for high-income countries, the following can be stated:

- The minimum effect was reported in the State of Texas (USA) (Mounce et al., 1992), with a corresponding decrease in PTW fatalities per 10,000 registered PTWs of 0.19 percentage points per 1 percentage point increase in helmet wearing rates (increase by 54 percentage points in helmet use resulted in a 10% decrease in fatalities).
- The maximum effect was reported in the State of Louisiana (USA) (NHTSA, 2003) with a corresponding decrease in PTW fatalities per 10,000 registered PTWs of 0.89 percentage points per 1 percentage point increase of helmet wearing rates (decrease by 48 percentage points in helmet use resulted in a 75% increase in fatalities).
- A proposed best estimate of the effect, estimated as the average of the four comparable studies, is a 0.58 percentage point decrease in PTW fatalities per 10,000 registered PTWs per 1 percentage point increase in helmet wearing rates.

4.1.18 Seat belt wearing rates on front seats of cars

Table A.18 (appendix A) presents all the relations regarding indicator I18 ("Seat belt wearing rates on front seats of cars").

No studies were identified that examine the road safety effect of seat belt wearing rates in middle- and low-income countries. By homogenizing and comparing the results of individual effects studies for high-income countries, the following remarks were made:

The minimum effect was reported in the State of Delaware (USA) (NHTSA, 2008), where an increase of fatalities of 0.06 percentage points per 1 percentage point increase of seat belt wearing rates was observed (increase by 18.9 percentage points in seat belt use resulted in an increase of +1.2% in fatalities).

The maximum effect was reported in the State of Washington (USA) (Salzberg and Moffat, 2004) with a corresponding decrease of fatalities of 1.34 percentage points per 1 percentage point increase of seat belt wearing rates (increase by 10 percentage points in seat belt use resulted in a decrease -13,4% in fatalities).

A proposed best estimate of the effect, estimated as the average of the six comparable studies is a decrease of fatalities of 0.52 percentage points per 1 percentage point increase of seat belt wearing rates.

The more rigorous meta-analysis methodology of Elvik et al. enhances the validity of the estimates, however the results are based on older studies, mostly from the 1970s to the 1990s.

4.1.19 Mean emergency medical service (EMS) response time

Table A.19 (appendix A) presents the relations regarding the indicator I19 ("Mean EMS response time"). Although existing studies strongly indicate that a reduction in EMS times improves road safety performance, the effects have not been quantitatively estimated. The only relation that could potentially be useful is that mentioned in the study by Bernard-Gely (1998), that the consequences of an accident can be reduced by 1% for every minute saved in EMS response time.

However, as no details were available regarding the development of the above relation (e.g. data origin, limitations, possible biases), it was decided not to be taken into account in the SafeFITS project.

4.2 Synthesis of identified relations – detailed causalities

The previous paragraphs presented the results of a focused literature review aiming to determine specific detailed causalities and equations linking the priority indicators to fatalities and injuries. Over 200 references were examined and a total of 125 detailed causalities were identified from approximately 95 different studies, journal articles, reports, etc.

Table 4.1 presents the total number of identified detailed causalities per indicator, further categorized according to country type (high-income vs. medium- and low-income), and according to type of study. The table also includes studies that attempted to develop a causal relationship but finally concluded that such a relationship was not statistically significant.

From a detailed review of the literature, several quantitative relations that link the model's priority indicators to road safety outcomes (fatalities and injuries) were identified, as shown in table 4.2.

Table 4.1
Total number of identified detailed causalities per indicator

No.	Indicator	Number of identified detailed relations					
		Total	High-income countries	Middle- and low-income countries	Studies of individual effects	Meta-analysis studies	Statistical - multivariate models
I01	GDP per capita	3	2	1	1	0	2
I02	Country has a national road safety strategic plan	2	1	1	1	0	1
I03	Country has time-based, quantified national road safety targets	7	7	0	6	0	1
I04	Country has a clearly empowered agency leading road safety	1	1	0	0	0	1
I05	Country has a defined allocation of expenditure for dedicated road safety programmes	1	1	0	0	0	1
I06	Share of trips / traffic per mode	4	3	1	2	0	2
I07	Country has a target to eliminate high-risk roads	0	0	0	0	0	0
I08	Number of passenger cars per 1,000 inhabitants	2	1	1	0	0	2
I09	Share of powered two-wheelers in the vehicle fleet	2	1	1	1	0	1
I10	Country has a comprehensive helmet use law	24	23	1	15	4	5
I11	Country has systematic policies and practices in place for Road Safety Audits of new road projects	3	3	0	3	0	0

No.	Indicator	Number of identified detailed relations					
		Total	High-income countries	Middle- and low-income countries	Studies of individual effects	Meta-analysis studies	Statistical - multivariate models
I12	Number of enforcement controls (speed, alcohol, seat belt, helmet etc.) per 1,000 population	7	7	0	2	4	1
I13	Roadside police alcohol tests per 1,000 population	20	20	0	8	7	5
I14	Roadside police speed checks per 1,000 population	8	8	0	4	3	1
I15	Share of High Risk Sites treated	12	12	0	9	3	0
I16	Percentage of rural road network not satisfying design standards	1	1	0	0	1	0
I17	Daytime helmet wearing rates for motorcycles	12	11	1	12	0	0
I18	Seat belt wearing rates on front seats of cars	13	13	0	7	6	0
I19	Mean EMS response time	3	3	0	3	0	0
TOTAL		125	118	7	74	28	23

Table 4.2
Preliminary list of detailed causalities with increased usefulness for SafeFITS

Model priority indicator				Detailed causalities with increased usefulness for SafeFITS		
No.	Description	Layer	Pillar	Study Type	High-income countries	Low- and Middle-income countries
I01	GDP per capita	Economy and Management	Economy and Management	Indiv. effects studies - minimum	n/a	n/a
				Indiv. effects studies - maximum		
				Indiv. effects studies - best estimate		
				Meta-analysis studies	n/a	n/a
				Statistical - Mathematical Models	Yannis et al. (2014): short term GDP flunctuatons Kopits and Croper (2005): long-term trends	Kopits and Croper (2005)
I02	Country has a national road safety strategic plan	Economy and Management	Economy and Management	Indiv. effects studies - minimum	n/a	yes => -5% in fatalities per year
				Indiv. effects studies - maximum		
				Indiv. effects studies - best estimate		
				Meta-analysis studies	n/a	n/a
				Statistical - Mathematical Models	n/a	n/a

Model priority indicator				Detailed causalities with increased usefulness for SafeFITS		
No.	**Description**	**Layer**	**Pillar**	**Study Type**	**High-income countries**	**Low- and Middle-income countries**
I03	Country has time-based, quantified national road safety targets	Economy and Management	Economy and Management	Indiv. effects studies - minimum	yes => -0.77% in fatalities per year	n/a
				Indiv. effects studies - maximum	yes => -0.92% in fatalities per year	
				Indiv. effects studies - best estimate	yes => -0.80% in fatalities per year	
				Meta-analysis studies	n/a	n/a
				Statistical - Mathematical Models	n/a	n/a
I04	Country has a clearly empowered agency leading road safety	Economy and Management	Economy and Management	Indiv. effects studies - minimum	n/a	n/a
				Indiv. effects studies - maximum		
				Indiv. effects studies - best estimate		
				Meta-analysis studies	n/a	n/a
				Statistical - Mathematical Models	n/a	n/a
I05	Country has a defined allocation of expenditure for dedicated road safety programmes	Economy and Management	Economy and Management	Indiv. effects studies - minimum	-14% in public transport => +4% in number of injuries (urban environment only)	n/a
				Indiv. effects studies - maximum		
				Indiv. effects studies - best estimate		
				Meta-analysis studies	n/a	n/a
				Statistical - Mathematical Models	n/a	n/a
I06	Percentage of traffic per mode	Transport demand and Exposure	Economy and Management	Indiv. effects studies - minimum		n/a
				Indiv. effects studies - maximum		
				Indiv. effects studies - best estimate		
				Meta-analysis studies	n/a	n/a
				Statistical - Mathematical Models	n/a	Bhalla et al. (2007) - after further elaboration
I07	Country has a target to eliminate high-risk roads	Economy and Management	Road Infrastructure	Indiv. effects studies - minimum	n/a	n/a
				Indiv. effects studies - maximum		
				Indiv. effects studies - best estimate		
				Meta-analysis studies	n/a	n/a
				Statistical - Mathematical Models	n/a	n/a

Model priority indicator				Detailed causalities with increased usefulness for SafeFITS		
No.	Description	Layer	Pillar	Study Type	High-income countries	Low- and Middle-income countries
I08	Number of passenger cars per 1000 inhabitants	Economy and Management	Vehicle	Indiv. effects studies - minimum	n/a	n/a
				Indiv. effects studies - maximum		
				Indiv. effects studies - best estimate		
				Meta-analysis studies	n/a	n/a
				Statistical - Mathematical Models	Yannis et al. (2011) and Yannis et al. (2007a) - model selection according to country's socioeconomic conditions	Yannis et al. (2007a) - model for Turkey
I09	Share of powered two-wheelers in the vehicle fleet	Transport demand and Exposure	Vehicle	Indiv. effects studies - minimum	n/a	n/a
				Indiv. effects studies - maximum		
				Indiv. effects studies - best estimate		
				Meta-analysis studies	n/a	n/a
				Statistical - Mathematical Models	Yannis et al. (2007a) - model selection according to country's socioeconomic conditions	Yannis et al. (2007a) - model selection according to country's socioeconomic conditions
I10	Country has a comprehensive helmet use law	Economy and Management	User	Indiv. effects studies - minimum	yes => -10% in PTW fatalities per 10,000 registered PTWs	n/a
				Indiv. effects studies - maximum	yes => -43% in PTW fatalities per 10,000 registered PTWs	
				Indiv. effects studies - best estimate	yes => -20% in PTW fatalities per 10,000 registered PTWs	
				Meta-analysis studies	yes => -26% in PTW fatalities	n/a
				Statistical - Mathematical Models	Houston and Richardson (2008)	n/a
I11	Country has systematic policies and practices in place for Road Safety Audits of new road projects	Road Safety Measures	Road Infrastructure	Indiv. effects studies - minimum	n/a	n/a
				Indiv. effects studies - maximum		
				Indiv. effects studies - best estimate		
				Meta-analysis studies	n/a	n/a
				Statistical - Mathematical Models	n/a	n/a
I12	Number of enforcement controls (speed, alcohol, seat belt, helmet etc.) per 1,000 population	Road Safety Measures	User	Indiv. effects studies - minimum	198 controls per 1,000 population annually => 14.9% reduction in fatal accidents (network wide)	n/a
				Indiv. effects studies - maximum		
				Indiv. effects studies - best estimate		
				Meta-analysis studies	ESCAPE (2001): Figure 3.2.12.1	n/a
				Statistical - Mathematical Models	Yannis et al. (2007b) - after consideration of the model's transferability	n/a

Model priority indicator				Detailed causalities with increased usefulness for SafeFITS		
No.	**Description**	**Layer**	**Pillar**	**Study Type**	**High-income countries**	**Low- and Middle-income countries**
I13	Roadside police alcohol tests per 1,000 population	Road Safety Measures	User	Indiv. effects studies - minimum	Not comparable results	n/a
				Indiv. effects studies - maximum		
				Indiv. effects studies - best estimate	3 times increase in alcohol enforcement => -1.15% in total casualties	
				Meta-analysis studies	yes => -9% in total accidents in affected road sections (all countries) yes => -13% in total accidents in affected road sections (Australia and New Zealand)	n/a
				Statistical - Mathematical Models	Henstridge et al. (1997) and Yannis et al. (2008) - after consideration of the models' transferability	n/a
I14	Roadside police speed checks per 1,000 population	Road Safety Measures	User	Indiv. effects studies - minimum	Not comparable results	n/a
				Indiv. effects studies - maximum		
				Indiv. effects studies - best estimate	3 times increase in speed enforcement => -3.94% in total casualties	
				Meta-analysis studies	stationary visible enforcement => -17% in total accidents in affected road sections	n/a
				Statistical - Mathematical Models	Yannis et al. (2007b) - after consideration of the model's transferability	n/a
I15	Share of High Risk Sites treated	Road Safety Performance Indicators	Road Infrastructure	Indiv. effects studies - minimum	n/a	n/a
				Indiv. effects studies - maximum		
				Indiv. effects studies - best estimate		
				Meta-analysis studies	n/a	n/a
				Statistical - Mathematical Models	n/a	n/a
I16	Percentage of rural road network not satisfying design standards	Road Safety Performance Indicators	Road Infrastructure	Indiv. effects studies - minimum	n/a	n/a
				Indiv. effects studies - maximum		
				Indiv. effects studies - best estimate		
				Meta-analysis studies	n/a	n/a
				Statistical - Mathematical Models	n/a	n/a

Model priority indicator				Detailed causalities with increased usefulness for SafeFITS		
No.	Description	Layer	Pillar	Study Type	High-income countries	Low- and Middle-income countries
I17	Daytime helmet wearing rates for motorcycles	Road Safety Performance Indicators	User	Indiv. effects studies - minimum	1 percentage point increase in helmet wearing rates => 0.19 percentage points decrease in PTW fatalities per 10,000 registered PTWs	n/a
				Indiv. effects studies - maximum	1 percentage point increase in helmet wearing rates => 0.89 percentage points decrease in PTW fatalities per 10,000 registered PTWs	
				Indiv. effects studies - best estimate	1 percentage point increase in helmet wearing rates => 0.58 percentage points decrease in PTW fatalities per 10,000 registered PTWs	
				Meta-analysis studies	n/a	n/a
				Statistical - Mathematical Models	n/a	n/a
I18	Seat belt wearing rates on front seats of cars	Road Safety Performance Indicators	User	Indiv. effects studies - minimum	1 percentage point increase in seat belt wearing rates => 0.06 percentage points increase in fatalities	n/a
				Indiv. effects studies - maximum	1 percentage point increase in seat belt wearing rates => 1.34 percentage points decrease in fatalities	n/a
				Indiv. effects studies - best estimate	1 percentage point increase in seat belt wearing rates => 0.52 percentage points decrease in fatalities	n/a
				Meta-analysis studies	< +25% in seat belt use => -7% in fatalities +25% to +50% in seat belt use => -8% in fatalities > +50% in seat belt use => -21% in fatalities	n/a
				Statistical - Mathematical Models	n/a	n/a
I19	Mean EMS response time	Road Safety Performance Indicators	Post-Crash Services	Indiv. effects studies - minimum	n/a	n/a
				Indiv. effects studies - maximum		
				Indiv. effects studies - best estimate		
				Meta-analysis studies	n/a	n/a
				Statistical - Mathematical Models	n/a	n/a

However, the following limitations should be pointed out:

1. Although literature on accident causalities is extensive, there is very limited available information originating from studies in middle and low-income countries. Many of the studies from middle and low-income countries suffer from methodological weaknesses or lack of high quality road safety data, and thus the identified causalities have limited reliability.
2. In some cases, a quantitative relation to estimate an overall (local or nationwide) accident reduction that can be attributed to the specific indicator is not available, although there is an obvious influence in road safety outcomes. Examples of such cases are indicators I11 ("Country has systematic policies and practices in place for Road Safety Audits of new road projects") and I15 ("Share of High Risk Sites treated"). In both cases, there are several studies that estimate accident reduction ratios that refer to specific implementation of road safety audits/inspections or specific high-risk sites treatments programmes. However, these accident reduction ratios cannot be related to the above indicators on a more generalized scale.
3. Some indicators – mainly from the economy and management layer – are characterized by complex and sometimes conflicting objectives. Improving road safety is often not the only objective, and in many cases, not the most important.

   Furthermore, the measures themselves are often complex and several variations may exist. Since the effects largely depend on the way these measures are designed, implemented and used, it is often very difficult to generalize about their effects.
4. In some cases (e.g. indicators I13 and I14), in order to produce comparable results between different studies, the detailed causalities identified above have been based on logical assumptions (e.g. the average number of speed or alcohol controls that can be performed during a police officer's shift), which could possibly influence the estimated effects.
5. Finally, attention should be paid to the geographic origin of detailed causalities. The implementation of a quantitative relation developed using data from a specific geographical area in a different context should be done with caution and with proper verification of the results.

The detailed review of selected causalities largely confirmed the findings on the literature review of all causalities, presented in chapter 2. Because of these limitations, a dedicated analysis methodology was developed in order to meet the SafeFITS objectives. Thus, new causalities were estimated from original statistical data analyses, which took into account as many dimensions of the problem as possible. The methodology developed and the respective results are presented in the following chapters.

Part Two

5. OVERVIEW OF THE SafeFITS MODEL

5.1 Introduction

The SafeFITS model is based on international road safety data and statistical relations between several road safety indicators. It is expected to provide information on different road safety scenarios based on the chosen policies and measures.

The model is based on the hierarchical structure of road safety management systems as proposed by both the SUNflower pyramid (SUNflower, 2002; SUNflower+6, 2005) and the Global Plan of Action (WHO, 2011), which was adjusted for the specific purposes of the SafeFITS project. This structure includes five layers:

- Economy and management
- Transport demand
- Road safety measures
- Road safety performance indicators
- Fatalities and Injuries.

SafeFITS includes two background components and a tool with three modules:

- Database with data on road safety indicators (i.e. fatalities and injuries, performance indicators, road safety measures, economy and background) for all countries, as well as projections of key economic indicators (see chapter 6), which is used for developing and implementing statistical models.
- Statistical models of global causalities, estimated on the basis of the database of road safety indicators, allowing "intervention", "forecasting" and "benchmarking" analyses.
- SafeFITS tool, including three complementary modules, all serving very common purposes in road safety policy analysis:
- The intervention analysis module allows the user to forecast the safety effects of a specific road safety measure or intervention for a given country and time period, all other things kept constant.
- The forecasting module enables combined scenarios of interventions (measures and programmes) to be tested at national level.
- The benchmarking module allows the user to benchmark a country against other countries by comparing the road safety outcomes in relation to the basic road safety indicators, and by identifying the priority areas that a country should focus on so as to improve its road safety outcomes.

An overview of the SafeFITS model is presented in figure 5.1.

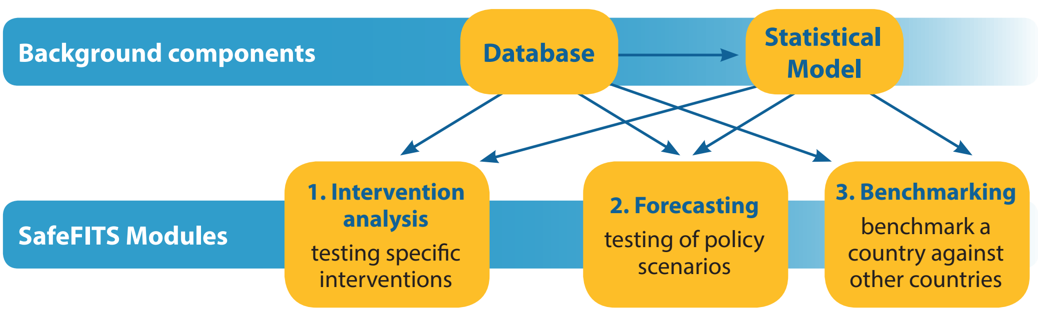


Figure 5.1
Overview of background components and modules of SafeFITS

5.2 Methodology

The model is based on several key hypotheses, all outlined on the basis of existing knowledge and validated experience on the complex and particular causalities in road safety systems. These allow the formulation of the various mathematical equations.

In the hierarchical structure of road safety management systems, there are several meaningful indicators in each layer of the system. For efficient forecasting of road safety outcomes, a maximum number of indicators should be taken into account.

As the efficient forecasting of future developments needs to take into account previous developments, one should make explicit consideration of the time dimension. For example, countries for which fatalities have been increasing in the last few years are more likely to exhibit the same trend in the coming years (and vice versa).

The analytical methods and respective model equations are detailed in the following sections.

5.2.1 Estimation of composite variables

The SafeFITS model includes these five distinct layers. Each layer may comprise several different indicators, from the five pillars: road safety management, road user, vehicle, road, post-crash care. In order to reduce the number of dimensions of the analysis, while exploiting as much information as possible, it is suggested to analyse composite variables (i.e. combinations of indicators), instead of individual indicators.

Each layer can be described by a composite variable (denoted as [Composite Variable] in the following), estimated as a function of several indicators. Overall, for a set of countries (i) fatalities and injuries specific indicators are considered, (j) specific safety performance indicators, (k) road safety measures indicators, (l) transport demand and exposure indicators, and (m) economy and management indicators. More specifically, each composite variable is defined as a linear combination of indicators (Box :

Box 5.1
Estimation of composite variables in SafeFITS

$$\text{[Fatalities and Injuries]} = \alpha_1 * \text{(Fatalities and Injuries Indicator 1)} + \alpha_2 * \text{(Fatalities and Injuries Indicator 2)} + \ldots + \\ + ai * \text{(Fatalities and Injuries Indicator i)} + e; \tag{1a}$$

$$\text{[RSPI]} = \beta_1 * \text{(RSPI Indicator 1)} + \beta_2 * \text{(RSPI Indicator 2)} + \ldots + \beta_j * \text{(RSPI Indicator j)} + v; \tag{1b}$$

$$\text{[Road Safety Measures]} = \gamma_1 * \text{(Road Safety Measures Indicator 1)} + \gamma_2 * \text{(Road Safety Measures Indicator 2)} + \ldots + \\ + \gamma_k * \text{(Road Safety Measures Indicator k)} + w; \tag{1c}$$

$$\text{[Transport demand and exposure]} = \delta_1 * \text{(Transport demand \& exposure Indicator 1)} + \delta_2 * \\ *\text{(Transport demand \& exposure Indicator 2)} + \ldots + \delta_l * \text{(Transport demand and exposure l)} + y; \tag{1d}$$

$$\text{[Economy and management]} = \varepsilon_1 * \text{(Economy and management Indicator 1)} + \varepsilon_2 * \\ * \text{(Economy and management Indicator 2)} + \ldots + \varepsilon_m * \text{(Economy and management Indicator m)} + z. \tag{1e}$$

Note: (i) fatalities and injuries indicators, (j) specific safety performance indicators, (k) road safety measures indicators, (l) transport demand and exposure indicators and (m) economy and management indicators, **α, β, γ, δ, ε** parameters to be estimated, and **e, v, w,** y, **z** error terms expressing the uncertainty in the estimation of the composite variables.

Indicators in each case include elements from all five pillars. For example, the composite variable [Economy and management] may be a function of indicators (GDP per capita), (country has a national road safety strategy: yes / no) and (country has defined allocation of expenditure for road safety).

Several methods exist for calculating composite variables, ranging from simple weighting and standardization techniques to statistical techniques (for details see Al Haji, 2005; OECD, 2008; Bax, 2012). Techniques such as factor analysis[1] are most appropriate for the estimation of composite variables.

5.2.2 Linking road safety outcomes with indicators through composite variables

The next step estimates the effect of indicators on road safety outcomes, through the composite variables.

The common method for statistically associating composite variables is Structural Equation Modelling (SEM),[2] in which composite variables are simultaneously estimated on the basis of indicators and correlated with each other. However, SEM is a very demanding technique, with one of its prerequisites being the presence of a large sample of observations. In the SafeFITS database, more than 100 countries are considered. This, however, is not an adequate sample for an SEM. Moreover, the use of SEMs for forecasting is questionable, as their main purpose is descriptive and explanatory on complex relationships in large datasets.

Consequently, in SafeFITS another approach is opted for, known as the "two-step" approach: first, calculate the composite variables externally on the basis of a factor analysis technique or similar, and then develop a regression model linking the composite variables.

This approach has been successfully implemented for linking road safety outcomes with road safety management and performance indicators in Europe (Papadimitriou and Yannis, 2013).

More specifically, after a factor analysis, each [Composite Variable] "score" for country (i) can be calculated on the basis of the specific indicators it includes, as shown in box 5.1. A regression analysis may then link road safety outcomes with the composite variables (i.e. the "score" of each country on each composite variable, calculated with the factor analysis coefficients on the values of the related indicators). The relationship between the composite variables is described by the following equations (in the simple case of a linear or logarithmic model):

Box 5.2
Statistical model formulation between composite variables[3]

$$[\text{Fatalities \& Injuries}]_i = A_i + K_i * [\text{Economy \& Management}]_i + L_i * [\text{Transport demand \& Exposure}]_i + \\ + M_i * [\text{Road Safety Measures}]_i + N_i * [\text{RSPI}]_i + \varepsilon_i; \qquad (2a)$$

or

$$\log([\text{Fatalities \& Injuries}]_i) = A_i + K_i * [\text{Economy \& Management}]_i + L_i * [\text{Transport demand \& Exposure}]_i + \\ + Mi * [\text{Road Safety Measures}]_i + N_i * [\text{RSPI}]_i + \upsilon_i. \qquad (2b)$$

*Note: With (i) countries, **A, K, L, M, N** parameters to be estimated, and **ε, υ** error terms[4] expressing the uncertainty in the estimation of the relationship.*

[1] Factor analysis refers to a family of techniques aiming to reduce the dimensionality of a data set, by describing variability among observed, correlated variables in terms of a potentially lower number of unobserved variables called "factors". For example, it is possible that variations in six observed variables / indicators mainly reflect the variations in two unobserved (underlying or composite) variables. Factor analysis searches for such joint variations in response to unobserved latent variables. The observed variables/ indicators are modelled as linear combinations of the potential factors, plus "error" terms.

[2] Structural equation models are used to assess unobservable 'latent' constructs. They invoke a measurement model that defines latent (composite) variables using one or more observed variables (indicators), and a structural model that imputes relationships between latent (composite) variables. The links between constructs of a structural equation model may be estimated with independent regression equations or through more involved approaches.

[3] Logarithmic function of the statistical model refers to natural logarithm.

[4] In the case of a linear model, ε is assumed to follow a normal probability distribution with mean 0 and variance σ2, while in the case of a logarithmic model – very common in road safety analysis – υ is assumed to follow a Poisson-family probability distribution with mean λ.

5.2.3 The time dimension

The relationships between road safety outcomes and indicators depend on the underlying trends in the evolution of outcomes. The hierarchy of road safety management systems described above depicts a "snapshot" of the system in a given year (SUNflower, 2002, 2006). However, if fatalities exhibit a decreasing trend over the last decade, this trend is expected to continue in the future (Commandeur et al., 2013; Dupont et al., 2014). Consequently, it is necessary to account for this trend, so that the effects of indicators may be truly attributed to the changes in the values of the indicators and not to the existing underlying trend.

In theory, there are two approaches for modelling road safety developments (Antoniou et al., 2016):

- A short-term analysis, which may correlate short-term (e.g. annual) differences in road safety outcomes with short-term differences in other indicators (e.g. GDP, vehicle-kilometres of travel) (see Yannis et al., 2014).
- A macroscopic analysis, which uses a regression of road safety outcomes and other indicators over the examined time period.

An optimal and methodologically recommended approach, especially when there is interest in a group (panel) of countries, would be to combine short-term and long-term analysis in a model aggregating the estimates of individual countries.

A detailed presentation of these techniques and their applications is beyond the scope of the present report (see Antoniou et al, 2016). However, these techniques do not fully fit the purpose of SafeFITS, and adjustments are needed for a number of reasons.

First, the purpose of SafeFITS is strongly explanatory; it aims to forecast the outcomes on the basis of as many interventions as possible (policy scenarios), while most analyses of road safety developments over time aim to forecast future developments only on the basis of past developments.

Second, to perform a classical time series development analysis, historical data for at least a decade would be necessary for all Member States of the United Nations, but such data are not available in any of the international databases.

Consequently, in SafeFITS the time dimension will be taken into account by implementing a medium-term forecasting approach, on the basis of the developments over the last few years, for which data are available. These developments will be taken into account to forecast future developments over the next few years. By applying the same approach on the future forecasted outcomes, long-term forecasts may be eventually obtained.

The key variable that will be taken into account in the forecasts to account for past and future developments is GDP. Several recent studies have shown that, in the absence of mobility and exposure data (e.g. vehicle- and passenger-kilometres of travel), GDP is considered an appropriate indicator for modelling and forecasting road safety developments (Kopits and Cropper, 2005; Antoniou et al., 2016). Terms are introduced in the models, relating the road safety outcomes of year to those of previous years and to GDP (or its development over the same period) (Yannis et al., 2014).

Consequently, equation (2c) can be expressed as follows, in case the fatality rate per population is used as the road safety indicator of interest, and the difference between τ years is considered:

Box 5.3
Time-dependent statistical model formulation[5]

$$\begin{aligned}&\log((\text{Fatalities per Population})_{it}) = A_i + \log((\text{Fatalities per Population})_{i\,(t-\tau)}) + B_i * GDP_{it} +\\ &+ K_i * [\text{Economy \& Management}]_{it} + L_i * [\text{Transport demand \& Exposure}]_{it} + M_i * [\text{Road Safety Measures}]_{it} +\\ &+ N_i * [RSPI]_{it} + \varepsilon_i;\end{aligned} \qquad (3a)$$

or

$$\begin{aligned}&\log((\text{Fatalities per Population})_{it}) = A_i + \log((\text{Fatalities per Population})_{i\,(t-\tau)}) + B_i * (GDP_{it} - GDP_{i\,(t-\tau)}) +\\ &+ K_i * [\text{Economy \& Management}]_{it} + L_i * [\text{Transport demand \& Exposure}]_{it} + M_i * [\text{Road Safety Measures}]_{it} +\\ &+ N_i * [RSPI]_{it} + \varepsilon_i.\end{aligned} \qquad (3b)$$

[5] Logarithmic function of the statistical model refers to natural logarithm.

6. ARCHITECTURE OF THE DATABASE

6.1 Introduction

The database covers the structure of the road safety management system as adopted in the context of the SafeFITS model development. This structure includes the five layers and five pillars referred to in chapter 2. The relevant data were explored in international databases, such as those of the World Health Organization (WHO), the United Nations, the World Bank, the International Road Federation (IRF) and the Organisation for Economic Co-operation and Development (OECD), aiming to select representative indicators for each layer and collect reliable and the most recent data for the greatest possible number of Member States.

Data were collected for 130 countries – countries with a population higher than 2.8 million inhabitants – to ensure a sufficient road safety outcomes sample for statistical analysis. The indicators of the database alongside the corresponding sources are presented in appendix B.

6.2 Economy and management layer

This layer includes data concerning the basic characteristics of each country, economic indicators and indicators describing the road safety management structure. More specifically:

6.2.1. Basic characteristics of countries

Population

The data were retrieved from the World Bank database and concern the period 1960–2050, with the figures from 2015 and later being projections. For the statistical model, data for 2013 were used. Data were extracted regarding the percentage of population under 15 years old, the percentage of population over 65 years old and the percentage of urban population of the total population. The population density was calculated as the rate of total population per kilometre of the total area of each country.

Area in km^2

The data set consists of data for 130 countries for 2013, and wherever data for 2013 were not available, the latest available data were used. These data were extracted from the World Bank database.

6.2.2. Economy

GNI per capita in United States dollars

The gross national income (GNI) per capita is the dollar value of a country's final income in a year divided by its population using the World Bank Atlas methodology (WHO, 2015). The GNI is the gross domestic product (GDP) plus net receipts of primary income (employee compensation and investment income) from abroad. The data set consists of data for 130 countries for 2010 and 2013 from the World Bank database.

GDP per capita in 2010 United States dollars

GDP is the monetary value of all the finished goods and services produced within a country in a specific time period, usually calculated on an annual basis. It is thus one of the primary indicators of a country's economic performance, as well as an indicator of standard of living. GDP per capita is the output of GDP divided by the population of the country.

The data set includes data for 130 countries for the period from 2010 to 2030, with all values from 2015 and later being projections. The data were extracted from the Economic Research Service (ERS) International Macroeconomic Data Set of the United States Department of Agriculture (USDA).

6.2.3. Road safety management indicators

Existence of road safety lead agency

This indicator concerns whether there is a lead agency, i.e. an institution (either stand alone, or within a Ministry) that coordinates road safety at national level. The information is indicated as "yes" or "no", which are represented by 1 and 0 respectively in the SafeFITS database. Data for 2013 were retrieved from the WHO report 2015 and were available for 130 countries. Wherever 2013 data were not available, the latest available data were used.

The lead agency is funded

This indicator concerns whether the road safety lead agency of the country is funded. The information is indicated as "yes" or "no", which are represented by 1 and 0 respectively in the SafeFITS database. Countries with no road safety lead agency are indicated as "no". Data for 2013 were retrieved from the WHO report 2015 and were available for 130 countries. Wherever 2013 data were not available, the latest available data were used.

Existence of national road safety strategy

This indicator concerns whether a road safety strategy at national level exists in each country. The information is indicated as "yes" or "no", which are represented by 1 and 0 respectively in the SafeFITS database. Countries where national strategy development is underway but has not yet been approved or endorsed by government are indicated as "no", while countries with multiple national strategies on road safety are represented as "yes". Data for 2013 were retrieved from the WHO report 2015 and were available for 128 countries. Wherever 2013 data were not available, the latest available data were used.

The national road safety strategy is funded

This indicator concerns whether the national road safety strategy of each country is funded. The information is indicated as "not funded", "partially funded" or "fully funded", which are represented by 0, 0.5 and 1 respectively in the SafeFITS database. Countries where no national road safety strategy exists are indicated as "no". Data for 2013 were retrieved from the WHO report 2015 and were available for 128 countries. Wherever 2013 data were not available, the latest available data were used.

Existence of road safety fatality targets

This indicator concerns whether the countries have defined a fatality reduction target for a specific time period, which is expressed either as an absolute number of fatalities or as a fatality rate per population. The information is indicated as "yes" or "no", which are represented by 1 and 0 respectively in the SafeFITS database. Data for 2013 were retrieved from the WHO report 2015 and were available for 107 countries.

6.3. Transport demand and exposure layer

This layer includes characteristics related to the amount of travel per mode in each country, e.g. share of traffic per mode (passenger cars, powered 2-wheelers, public transport, pedestrians and cyclists etc.), vehicle- and person-kilometres of travel, time spent in traffic per mode.

6.3.1. Roads

Road network density

The data for the length of the road network were extracted from the IRF database for 2013 for the 130 countries examined. The road network density was calculated as the ratio of length of the road network per 1 km2 of the total area.

Percentage of motorways

The data set consists of data regarding the length of motorways as a percentage of the total road network for 2013 or the latest available year. Data for 61 countries were extracted from the IRF database.

Percentage of paved roads

The data set consists of data regarding the length of paved roads as a percentage of the total road network for 2013 or the latest available year. Data for 98 countries come from the IRF database and for the remaining countries data from the CIA database.

6.3.2. Vehicles

Number of vehicles in use in total and by type of vehicle

The number of vehicles in use was retrieved from the IRF database. Data were available for 113 countries out of the 130 countries examined. The ratio of the vehicle fleet per population was calculated for the purposes of the statistical analysis.

In addition, data for each vehicle type by country are included in the data set, i.e. passenger cars, buses or motor coaches, vans and lorries, powered two wheelers. Data for the number of passenger cars in use were available for 120 countries, for the number of buses and motor coaches for 115 countries, for the vans and lorries for 112 countries and for the powered two wheelers for 105 countries. The data refer to 2013 or the latest available year. The indicators included in the statistical analysis were the percentages of the total vehicle fleet.

6.3.3. Traffic

Traffic volume

The traffic volume in millions of vehicle kilometres was extracted from the IRF database. The data set consists of data for 64 countries. The number of vehicle kilometres by type of vehicle was available for fewer countries, mostly for the developed ones. Data refer to 2013 or the latest available year.

Inland surface passengers transport

The total number of passenger kilometres, as well as the road and rail passenger kilometres separately, were extracted from the IRF database. Data on road passenger transport were available for 50 countries, while data for rail passenger transport were available for 81 countries. Data refer to 2013 or the latest available year. The ratio of rail/road passenger transport was calculated for the statistical analysis.

Inland surface freight transport

The total number of tonne-kilometres, as well as the road and rail tonne-kilometres, separately, were retrieved from the IRF database. Data on road freight transport were available for 61 countries, while data for rail freight transport were available for 81 countries. The ratio of road passenger/freight transport was calculated for the statistical analysis.

6.4 Road safety measures layer

This layer includes indicators regarding legislation and interventions made by authorities in relation to the various pillars: road user, vehicles, roads, post-crash care. More specifically:

6.4.1. Roads

Road safety audits on new roads

The data set consists of data regarding whether road safety audits of new road infrastructure projects are carried out. The information is indicated as "yes" or "no", which are represented by 1 and 0 respectively in the SafeFITS database. Data for 2013 were retrieved from the WHO report 2015 and were available for 128 countries.

Existence of speed law

The information is indicated as "yes" or "no", which are represented by 1 and 0 respectively in the database. Data for 2013 were retrieved from the WHO report 2015 and were available for 130 countries.

Maximum speed limits on urban roads

The information is indicated as "no speed limits", ">50 km/h" or "≤50 km/h", which are represented by 0, 1 and 2 respectively in the SafeFITS database. Countries where no relative legislation exists are represented by the value "0". Data for 2013 were retrieved from the WHO report 2015 and were available for 127 countries.

Maximum speed limits on rural roads

The information is indicated as "no speed limits", "100-120 km/h", "70-90 km/h" or "≤70 km/h", which are represented by 0, 1, 2 and 3 respectively in the SafeFITS database. Countries where no relative legislation exists are represented by the value "0". Data for 2013 were retrieved from the WHO report 2015 and were available for 127 countries.

Maximum speed limits on motorways

The information is indicated as "no speed limits", "equal or lower than 100 km/h", "between 100 and 120 km/h" or "equal or higher than 120 km/h", which are represented by 0, 1, 2 and 3 respectively in the SafeFITS database. Countries where no relative legislation exists are represented by the value "0". Data for 2013 were retrieved from the WHO report 2015 and were available for 128 countries.

6.4.2. Vehicles

Existence of ADR Law

This indicator concerns whether the European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR) is applicable in the country. The information is indicated as "yes" or "no", which are represented by 1 and 0 respectively and comes from the UNECE website.

Vehicle standards

These indicators concern whether the legislation regarding the vehicle standards applied in each country includes the following United Nations standards: seat-belts, seat-belts anchorages, frontal impact, side impact, electronic stability control, pedestrian protection and child seats. The data are based on international regulations or in some countries, such as the United States, Canada, the Republic of Korea, China, India and Brazil. And the national regulations are considered to be equivalent to the United Nations standards (WHO, 2015). The information is indicated as "yes" or "no", which are represented by 1 and 0 respectively in the SafeFITS database. Data for 2013 were retrieved from the WHO report 2015 and were available for 130 countries.

New cars subjected to NCAP

This indicator concerns whether countries have established a New Car Assessment Programme in order to evaluate the new car designs for road safety performance. The information is indicated as "yes" or "no", which are represented by 1 and 0 respectively in the SafeFITS database. Data for 2010 were retrieved from the WHO report 2013 and were available for 109 countries.

6.4.3. Road User

Existence of drink-driving law

This indicator concerns whether a national law on drink-driving exists in a country. The information is indicated as "yes" or "no", which are represented by 1 and 0 respectively in the database. Data for 2013 were retrieved from the WHO report 2015 and were available for 130 countries.

BAC limits

Blood alcohol concentration (BAC) limits refer to the maximum amount of alcohol legally acceptable in the blood of a driver on the road – i.e. the blood alcohol level above which a driver may be punished by law. The information is indicated as "yes" or "no", which are represented by 1 and 0 respectively in the SafeFITS database. Countries where no relative legislation exists or the permitted alcohol level is not defined by BAC are represented by the value "0".

In the following countries, the consumption of alcohol is legally prohibited: Afghanistan, Bangladesh, Iran (Islamic Republic of), Kuwait, Libya, Mali, Mauritania, Morocco, Pakistan, Qatar, Saudi Arabia, Senegal, Somalia, Sudan, the United Arab Emirates and Yemen

Data for 2013 were retrieved from the WHO report 2015 and were available for 128 countries. Wherever 2013 data were not available, the latest available data were used. Thus, three separate variables were created for the following types of drivers:

- allowed BAC limits for general population
- allowed BAC limits for young/novice drivers
- allowed BAC limits for commercial drivers.

Existence of a national seat-belt law

This indicator concerns whether a national law for the obligatory use of seat-belts exists in a country. The information is indicated as "yes" or "no", which are represented by 1 and 0 respectively in the SafeFITS database. Data for 2013 were retrieved from the WHO report 2015 and were available for 129 countries.

The national seat-belt law applies to all occupants

This indicator concerns whether the national seat-belt law applies to all occupants of the vehicles. The information is indicated as "yes" or "no", which are represented by 1 and 0 respectively in the SafeFITS database. Countries where no relative legislation exists are represented by the value "0". Data for 2013 were retrieved from the WHO report 2015 and were available for 129 countries.

Existence of a national child restraint law

This indicator concerns whether a national law for the obligatory use of child restraints systems exists in each country. The information is indicated as "yes" or "no", which are represented by 1 and 0 respectively in the database. Data for 2013 were retrieved from the WHO report 2015 and were available for 129 countries.

Existence of a national helmet law

This indicator concerns whether a national law for the obligatory use of helmet exists in each country. The information is indicated as "yes" or "no", which are represented by 1 and 0 respectively in the SafeFITS database. Data for 2013 were retrieved from the WHO report 2015 and were available for 129 countries.

The national law requires helmet to be fastened

The information is indicated as "yes" or "no", which are represented by 1 and 0 respectively in the SafeFITS database. Countries where no relative legislation exists are represented by the value "0". Data for 2013 were retrieved from the WHO report 2015 and were available for 129 countries.

The national helmet law defines specific helmet standards

The information is indicated as "yes" or "no", which are represented by 1 and 0 respectively in the SafeFITS database. Countries where no relative legislation exists are represented by the value "0". Data for 2013 were retrieved from the WHO report 2015 and were available for 129 countries.

Existence of a national law regarding mobile phone use while driving

The information is indicated as "yes" or "no", which are represented by 1 and 0 respectively in the SafeFITS database. Data for 2013 were retrieved from the WHO report 2015 and were available for 129 countries.

The law on mobile phone use applies to hand-held phones

The information is indicated as "yes" or "no", which are represented by 1 and 0 respectively in the SafeFITS database. Countries where no relative legislation exists are represented by the value "0". Data for 2013 were retrieved from the WHO report 2015 and were available for 129 countries.

The law on mobile use applies to hands-free phones

The information is indicated as "yes" or "no", which are represented by 1 and 0 respectively in the SafeFITS database. Countries where no relative legislation exists are represented by the value "0". Data for 2013 were retrieved from the WHO report 2015 and were available for 129 countries.

Existence of penalty point system

A penalty point or demerit point system is one in which a driver's licensing authority, police force, or other organization issues cumulative demerits or points to drivers on conviction for road traffic offences. The information is indicated as "yes" or "no", which are represented by 1 and 0 respectively in the SafeFITS database. Data for 2010 were retrieved from the WHO report 2013 and were available for 124 countries.

6.4.4. Post-crash care

Training in emergency medicine for doctors

This indicator concerns whether doctors in each country are trained in emergency medicine. The information is indicated as "yes" or "no", which are represented by 1 and 0 respectively in the SafeFITS database. Data for 2013 were retrieved from the WHO report 2015 and were available for 128 countries.

Training in emergency medicine for nurses

This indicator concerns whether nurses in each country are trained in emergency medicine. The information is indicated as "yes" or "no", which are represented by 1 and 0 respectively in the SafeFITS database. Data for 2013 were retrieved from the WHO report 2015 and were available for 124 countries.

6.5 Road safety performance indicators layer

6.5.1. Traffic law enforcement

The data set consists of data on the assessment of law enforcement on specific issues, as provided by the WHO report 2015. The values of each variable range between 0 and 10, where 0 is "not effective" and 10 is "highly effective". Countries where no relative legislation exists are represented by the value "0". Four separate variables were created with the following legislation issues:

- assessment of effectiveness of seat-belt law enforcement
- assessment of effectiveness of drink-driving law enforcement
- assessment of effectiveness of speed law enforcement
- assessment of effectiveness of helmet law enforcement.

6.5.2. Road user

Seat-belt wearing rates in front seats

The data set consists of data on the percentage wearing rate of seat belts in a country by front occupants of passenger cars. Data for 2013 were retrieved from the WHO report 2015 and were available for 56 countries. Wherever 2013 data were not available, the latest available data were used.

Seat-belt wearing rate in rear seats

The data set consists of data on the percentage wearing rate of seat belts in a country by rear occupants of passenger cars. Data for 2013 were retrieved from the WHO report 2015 and were available for 44 countries. Wherever 2013 data were not available, the latest available data were used.

Helmet wearing rate-driver

The data set consists of data on the percentage wearing rate of helmets in each country by drivers of motorcycles. Data for 2013 were retrieved from the WHO report 2015 and were available for 45 countries. Wherever 2013 data were not available, the latest available data were used.

6.5.3. Post-crash care

Estimated percentage of seriously injured patients transported by ambulance

The data set consists of data for 124 countries. The information is indicated as "no ambulance services", "≤10%", "11-49%", "50-74%" or "≥75%", which are represented by 0, 1, 2, 3 and 4 respectively in the SafeFITS database. Data for 2013 were retrieved from the WHO report 2015. Wherever 2013 data were not available, the latest available data were used.

Number of hospital beds per population

The data set consists of data for 127 countries on the number of hospital beds per 1,000 population. Data come from the World Bank Database and refer to 2012 or the latest available year.

6.6 Fatalities and Injuries layer

Reported number of road traffic fatalities

The data set consists of road traffic fatality data for 124 countries, as reported by their national authorities. Data come from the IRF and WHO databases. They refer to 2013 or the latest available year.

From the comparison between the two databases, it was found that the WHO database has adjusted the number of fatalities reported by the national data sources to the 30-days definition, while the IRF database publishes fatality data as defined by the national authorities. Therefore, these databases could not be used in a complementary way and the estimated number of fatalities by WHO was selected for the purposes of the SafeFITS project.

Estimated number of road traffic fatalities

The data set consists of road traffic fatality data for 129 countries, as estimated by WHO. Data for 2013 were retrieved from the WHO report 2015, and for 2010, data come from the WHO report 2013. Wherever data were not available, the latest available data were used.

According to WHO, the countries are divided into four groups, based on the quality of death registration data. More specifically, the first group includes the countries with good death registration data, the second one includes the countries with other sources on information on causes of death, the third group includes the countries with population less than 150,000 and the last one concerns the countries without eligible death registration data. For each group a different estimation methodology is used, which is considered to address underreporting issues and thus, making fatality data comparable across the countries (WHO, 2015).

Estimated road traffic fatality rate per 100,000 population

The data set consists of data for 129 countries, as estimated by WHO. Data for 2013 were retrieved from the WHO report 2015 and for 2010 data come from the WHO report 2013. Wherever data were not available, the latest available data were used.

Distribution of road traffic fatalities by road user type

The data set consists of road fatality data for 102 countries for the following road user types:

- drivers/passengers of 4-wheeled vehicles
- drivers/passengers of 2- or 3- wheelers
- cyclists
- pedestrians
- other/unspecified road users.

Data for 2013 were retrieved by the WHO report 2015 and wherever data were not available, the latest available data were used.

Distribution of road traffic fatalities by gender

Data for the percentages of road fatalities by gender were retrieved from the WHO report 2015. Data are available for 108 countries and refer to 2013 or the latest available year.

Percentage of road traffic fatalities attributed to alcohol

The data set consists of data for 73 countries, as provided by the WHO report 2015. Wherever data were not available, the latest available were used.

Data on the number of non-fatally injured persons were available for a small number of countries. However, these data are not comparable in order to be used in the development of the SafeFITS model due to different definitions used by national and data collection methodology. Consequently, the layer of road safety outcomes includes only road fatality data and thus, the term "fatalities" will be used from now on when referring to this layer.

6.7 Data handling on missing values

An issue that should be handled during the data preparation was the imputation of the missing values. First, for those variables and countries that there were available time-series, the latest available data were used for 2013. For the remaining countries, for which there were no available data, their substitution with the known mean value was selected.

The three groups of countries, based on their road safety and economic performance (see section 7.3) were divided into six regions. Thus, the missing values of each indicator of the countries were filled with the known mean value of the indicator in the available countries in their regions (see appendix C, table C.3). Wherever the available data were not sufficient, the mean of each of the three groups (low, middle and high performance) was used.

7. DATA ANALYSIS AND MODEL DEVELOPMENT

7.1 Introduction

For the SafeFITS model development a "two-step" approach is adopted: first, the composite variables are calculated externally on the basis of a factor analysis technique or similar, and as a next step a regression model is developed, which links the composite variables with road safety outcomes.

7.2 Calculation of composite variables

In statistics, an exploratory factor analysis is used in the early investigation of a set of data to determine whether the factor analysis model is useful in providing a parsimonious way of describing and accounting for the correlations between the observed data. For the purpose of this research, this type of analysis will determine which indicators are most highly correlated with the composite variables of interest, and how many factors are needed to give an adequate description of the data. In an exploratory factor analysis, no constraints are placed on which indicators "load" on which factor (composite variables), while in a confirmatory factor analysis a predefined number of factors is tested.

The factor "loadings" express the correlations of the indicators with the factor, whereas the factor score coefficients are the parameters of the linear equation calculating the score (value) of the factor on the basis of the values of the indicators (i.e. the parameters to be estimated referred in box 5.1).

The factor analyses were implemented on each one of the layers of the road safety system However, it was concluded that this type of analysis, and consequently the calculation of composite variables, is not meaningful for road safety outcomes (fatalities).

More specifically, for fatalities and injuries layer, it was investigated whether it would be useful to estimate a composite variable to be the primary dependent variable of the SafeFITS statistical models.

Preliminary factor analysis was not very successful in estimating a single factor (composite variable); the indicators in the database were shown to result in more than two factors in all trials. After several modelling trials, it was decided to use the indicator of the fatality rate per population as the main dependent variable for two reasons: first, it is the most common indicator, available for all countries, also with adequate historical data; and second, it is known to strongly correlate with GDP and road safety performance indicators (RSPI).

For the estimation of composite variables for the other four layers, three approaches were tested: general factor analysis; factor analysis per layer; and factor analysis, constrained to yield one factor per layer.

General factor analysis, including all indicators of all layers together

This exploratory approach allows the factor analysis algorithm to identify the number of factors, which then have to be interpreted and "labelled" on the basis of their content (indicators).

Factor analysis per layer

This exploratory approach allows the factor analysis algorithm to identify the number of factors in each layer.

Factor analysis, constrained to yield one factor per layer

This approach lies within the family of "confirmatory" rather than exploratory factor analysis, and is in full accordance with the conceptual framework of the SafeFITS model, with one factor (composite variable) per layer.

All three approaches yielded an acceptable solution in terms of number and robustness of the estimated factors. The general factor analysis yielded 11 factors, out of which the 4 first ones included most of the indicators in the database, and the remaining ones included 2-3 indicators each. The factor analysis per layer resulted in 2 or 3 factors per layer, all together including most of the indicators of the layer.

The confirmatory factor analysis, constrained to produce 1 factor per layer, was also successful, and included indicator "loadings" higher than 0.3 (which was the threshold set) for most of the indicators of the layer, allowing to include almost all indicators in that single factor.

In order to decide on the best option for SafeFITS, the results (factors) from all three approaches were tested as explanatory variables in statistical models, and the performance of the models compared. It was found that the best performing statistical models, in terms of statistical significance of the factors (composite variables) and in terms of model prediction accuracy, resulted from the factors of the confirmatory approach. This approach is also closer to the initial idea on which the SafeFITS modelling was based. In one particular case, that of "transport demand and exposure", there appeared to be value in including a second composite variable (factor) due to considerable additional variance explained, but the option was eventually not pursued as there was no real added value in the subsequent modelling results.

A further issue examined was the treatment of categorical variables. Methodologies such as polychoric correlation were tested, but no significant differences were found in the results obtained from the analyses. Consequently, it was chosen to insert the categorical variables in the analysis without any further process, since through this methodology the relationship between the indicator and road safety outcomes would be more straightforward and better applicable within the context of the intervention analysis.

The results of the factor analyses eventually selected for SafefITS are presented in the following sections for each of the five layers.

7.2.1. Factor analysis for the estimation of composite variable on economy and management

First, a factor analysis for all the indicators collected allows one to determine the way the specific indicators form a composite variable on the economy and management layer.

All nine indicators collected were introduced in this factor analysis. Table 7.1 presents a matrix of loadings and respective component scores for each indicator. The loadings indicate how much each indicator is correlated with the factor. Small loadings (e.g. lower than 0.3) are conventionally not taken into account, to draw attention to the pattern of the larger loadings.

Table 7.1
Indicator loadings and coefficients on the estimated factor (composite variable) on economy and management

Indicator label	Definition	Component	
		Loadings	Score coefficients
EM1_Popdensity	Population per area	0.091	0.029
EM2_lt15yo	Percentage of popualtion under 15 years old	**-0.778**	**-0.250**
EM3_gt65yo	Percentage of popualtion over 65 years old	**0.714**	**0.229**
EM4_UrbanPop	Percentage of urban population	**0.709**	**0.228**
EM5_LeadAgency	Existence of a road safety lead agency	0.284	0.091
EM6_LeadAgencyFunded	The lead agency is funded	0.226	0.073
EM7_NationalStrategy	Existence of national road safety strategy	**0.697**	**0.224**
EM8_NationalStrategyFunded	The strategy is funded	**0.626**	**0.201**
EM9_FatalityTargets	Existence of fatality reduction target	**0.692**	**0.222**

Results from the confirmatory factor analysis indicate that this factor represents 34.7% of the overall variance in the data.

Indicators relating to the demographic distribution (population <15 or >65 years old, population living in urban areas) are those with the highest loadings, complemented with some elements of the road safety management system (national strategy, fatality reduction targets, etc.).

The scores of each country on the composite variable can be computed on the basis of the factor scores coefficients estimated by the factor analysis. The following equation presents this linear equation:

Box 7.1
Composite variable on economy and management

*[Comp_EM] = **-0.250** (EM2_lt15yo) + **0.229** (EM3_gt65yo) + **0.228** (EM4_UrbanPop) + **0.224** (EM7_NationalStrategy) +*
*+ **0.221** (EM8_NationalStrategyFunded) + **0.222** (EM9_FatalityTargets)*

7.2.2. Factor analysis for the estimation of composite variable on transport demand and exposure

A factor analysis for all the transport demand and exposure indicators collected allows us to determine the way the specific indicators form a composite variable on the transport demand and exposure layer.

All 10 indicators collected were introduced in this factor analysis. Table 7.2 presents the matrix of loadings and respective component scores for each of the indicators.

Table 7.2
Indicator loadings and coefficients on the estimated factor (composite variable) on transport demand and exposure

Indicator label	Definition	Component	
		Loadings	Score coefficients
TE1_RoadNetworkDensity	Road network per area	**0.497**	**0.161**
TE2_Motorways	Percentage of motorways of total road network	**0.460**	**0.149**
TE3_PavedRoads	Percentage of paved roads of total road network	**0.734**	**0.238**
TE4_VehiclesPerPop	Total number of vehicles in use	**0.839**	**0.272**
TE5_PassCars	Number of passenger cars in use	**0.825**	**0.267**
TE6_VansLorries	Number of vans and lorries in use	-0.132	-0.043
TE7_PTW	Number of powered two wheelers in use	**-0.681**	**-0.221**
TE8_Vehkm_Total	Total number of vehicle kilometers in millions	0.269	0.087
TE9_RailRoad	Ratio rail/road passenger kilometers	0.136	0.044
TE10_PassengerFreight	Roads transport – passenger kilometers/freight kilometers	**-0.360**	**-0.117**

Results from this confirmatory factor analysis indicate that this factor represents 30.8% of the overall variance in the data.

Regarding this factor, indicators related to the vehicle fleet distribution (vehicles per population, share of passenger cars and PTW) are those with the highest loadings, complemented with some elements of the road network (density, share of motorways and paved roads etc.) and modal split (passenger vs. freight).

The share of PTW has a negative loading and coefficient, suggesting that countries that have higher values in the other indicators (e.g. share of passenger cars) tend to have lower values on the share of PTW.

The scores of each country on the composite variable can be computed on the basis of the factor scores coefficients estimated by the factor analysis. The following equation presents this linear equation:

Box 7.2
Composite variable on transport demand and exposure

[Comp_TE] = ***0.161*** *(TE1_RoadNetworkDensity) +* ***0.149*** *(TE2_Motorways) +* ***0.238*** *(TE3_PavedRoads) +*
+ ***0.272*** *(TE4_VehiclesPerPop) +* ***0.267*** *(TE5_PassCars) -* ***0.221*** *(TE7_PTW) -* ***0.117*** *(TE10_PassengerFreight)*

7.2.3 Factor analysis for the estimation of composite variables on measures

All the 39 measures collected were introduced in this factor analysis. Table 7.3 presents the matrix of loadings and coefficients for each of the indicators.

Table 7.3
Indicator loadings and coefficients on the estimated factor (composite variable) on measures

Indicator label	Definition	Component	
		Loadings	Score coefficients
ME1_RSA	Road Safety Audits on new roads	0.245	0.025
ME2_ADR	Existence of ADR law	0.681	0.069
ME3_SpeedLaw	Existence of national speed law	0.229	0.023
ME4_SpeedLimits_urban	Maximum speed limits on urban roads	0.443	0.045
ME5_SpeedLimits_rural	Maximum speed limits on rural roads	0.200	0.020
ME6_SpeedLimits_motorways	Maximum speed limits on motorways	0.634	0.064
ME7_VehStand_seatbelts	Vehicle standards-seat belts	0.877	0.088
ME8_VehStand_SeatbeltAnchorages	Vehicle standards-seat belt anchorages	0.906	0.091
ME9_VehStand_FrontImpact	Vehicle standards-frontal impact	0.908	0.092
ME10_VehStand_SideImpact	Vehicle standards-side impact	0.904	0.091
ME11_VehStand_ESC	Vehicle standards-Electronic Stability Control	0.891	0.090
ME12_VehStand_PedProtection	Vehicle standards-Pedestrian Protection	0.862	0.087
ME13_VehStand_ChildSeats	Vehicle standards-child seats	0.896	0.090
ME14_DrinkDrivingLaw	Existence of national drink-driving law	0.126	0.013
ME15_BAClimits	BAC limits less than or equal to 0.05 g/dl	0.670	0.068
ME16_BAClimits_young	BAC limits lower than or equal to 0.05g/dl for young/novice drivers	0.670	0.068
ME17_BAClimits_commercial	BAC limits lower than or equal to 0.05g/dl for commercial drivers	0.645	0.065
ME18_SeatBeltLaw	Existence of national seat-belt law	0.297	0.030
ME19_SeatBeltLaw_all	The law applies to all occupants	0.570	0.057
ME20_ChildRestraintLaw	Existence of national child restraints law	0.628	0.063
ME21_HelmetLaw	Existence of national helmet law	0.236	0.024
ME22_HelmetFastened	Law requires helmet to be fastened	0.334	0.034
ME23_HelmetStand	Law requires specific helmet standards	0.379	0.038
ME24_MobileLaw	Existence of national law on mobile phone use while driving	0.375	0.038
ME25_MobileLaw_handheld	The law applies to hand-held phones	0.350	0.035
ME26_MobileLaw_handsfree	The law applies to hands-free phones	-0.295	-0.030
ME27_PenaltyPointSyst	Demerit/Penalty Point System in place	0.378	0.038
ME28_EmergTrain_doctors	Training in emergency medicine for doctors	0.178	0.018
ME29_EmergTrain_nurses	Training in emergency medicine for nurses	0.399	0.040

Results from this confirmatory factor analysis indicate that this factor represents 34.2% of the overall variance in the data.

Indicators related to the vehicle standards – e.g. Vehicle_SeatBelts, Vehicle_ElStabilityControl and Vehicle_Pedestrian – are the variables with the highest loadings, followed by the BAC limits, the speed limits and the measures on ADR.

Several other indicators are included with lower loadings. Speed law (M3) and seatbelt law (ME18) were (marginally) not included in the factor, but specific elements of speed and seatbelt legislation had higher loadings and were included. This may be due to the fact that as almost all countries have speed and seat-belt legislation, there is no real variability on this variable, but variability exists on specific aspects of the related laws.

The scores of each country on the composite variable can be computed on the basis of the factor scores coefficients estimated by the factor analysis. The following equation presents this linear equation:

Box 7.3
Composite variables on road safety measures

[Comp_ME] = ***0.069*** *(ME2_ADR) +* ***0.045*** *(ME4_SpeedLimits_urban) +* ***0.064*** *(ME6_SpeedLimits_motorways) +*
+ ***0.088*** *(ME7_VehStand_seatbelts) +* ***0.091*** *(ME8_VehStand_SeatbeltAnchorages) +* ***0.092*** *(ME9_VehStand_FrontImpact) +*
+ ***0.091*** *(ME10_VehStand_SideImpact) +* ***0.090*** *(ME11_VehStand_ESC) +* ***0.087*** *(ME12_VehStand_PedProtection) +*
+ ***0.090*** *(ME13_VehStand_ChildSeats) +* ***0.068*** *(ME15_BAClimits) +* ***0.068*** *(ME16_BAClimits_young) +*
+ ***0.065*** *(ME17_BAClimits_commercial +* ***0.057*** *(ME19_SeatBeltLaw_all) +* ***0.063*** *(ME2_ChildRestraintLaw) +*
+ ***0.034*** *(ME22_HelmetFastened) +* ***0.038*** *(ME23_HelmetStand) +* ***0.038*** *(ME24_MobileLaw) +*
+ ***0.035*** *(ME2_MobileLaw_handheld) +* ***0.038*** *(ME27_PenaltyPointSyst) +* ***0.040*** *(ME29_EmergTrain_nurses)*

7.2.4 Factor analysis for the estimation of composite variables on RSPI

Within the last factor analysis, the nine RSPI collected were used. Table 7.4 presents a matrix of loadings for each of the indicators. The factors indicate the extent to which the indicator correlates with the corresponding factor and the respective coefficients of the linear equation. All the RSPI load on the factor with a high loading.

Table 7.4
Indicator loadings and coefficients on the estimated factor (composite variable) on RSPI

Indicator label	Definition	Component	
		Loadings	Score coefficients
PI1_SeatBeltLaw_enf	Effectiveness of seat-belt law enforcement	**0.756**	**0.144**
PI2_DrinkDrivingLaw_enf	Effectiveness of drink-driving law enforcement	**0.812**	**0.155**
PI3_SpeedLaw_enf	Effectiveness of speed law enforcement	**0.795**	**0.152**
PI4_HelmetLaw_enf	Effectiveness of helmet law enforcement	**0.837**	**0.160**
PI5_SeatBelt_rates_front	Seat-Belt wearing rate-Front	**0.811**	**0.155**
PI6_SeatBelt_rates_rear	Seat-Belt wearing rate-Rear	**0.766**	**0.146**
PI7_Helmet_rates_driver	Helmet wearing rate-driver	**0.784**	**0.150**
PI8_SI_ambulance	Estimated % seriously injured patients transported by ambulance	**0.667**	**0.127**
PI9_HospitalBeds	Number of hospital beds per 1,000 population	**0.607**	**0.116**

Results from this confirmatory factor analysis indicate that this factor represents 58.2% of the overall variance in the data.

The factor brings together all the elements of enforcement (alcohol, speed, helmet, seal belt), as well as variables related to the use of safety equipment (seat belt front and rear, helmet use) and the post-impact care (percentage of serious injuries transported by ambulance; hospital beds per population).

The scores of each country on the composite variable can be computed on the basis of the factor scores coefficients estimated by the factor analysis. The following equation presents these coefficients:

Box 7.4
Composite variables on road safety performance indicators

[Comp_PI] = ***0.144*** *(PI1_SeatBeltLaw_enf) +* ***0.155*** *(PI2_DrinkDrivingLaw_enf) +* ***0.152*** *(PI3_SpeedLaw_enf)+*
+ ***0.160*** *(PI4_HelmetLaw_enf) +* ***0.155*** *(PI5_SeatBelt_rates_front) +* ***0.146*** *(PI6_SeatBelt_rates_rear) +*
+ ***0.150*** *(PI7_Helmet_rates_driver)+* ***0.127*** *(PI8_SI_ambulance) +* ***0.116*** *(PI9_HospitalBeds)*

7.2.5. Summary

Four new composite variables are created on the basis of 43 indicators. More specifically, the new variables are the following:

- Comp_EM: the composite variable (factor) on economy and management, including 6 related indicators.
- Comp_TE: the composite variable on transport demand and exposure including 7 related indicators.
- Comp_ME: the composite variable on measures, including 21 related indicators.
- Comp_PI: the composite variable on safety performance indicators including 9 related indicators.

In general, this type of confirmatory factor analysis provides a single variable that more or less represents the whole set of indicators for all countries. Countries with the same value for the composite variable may have different values for the specific indicators.

In other words, different combinations of source variables can result in the same composite variable score. Consequently, given a specific value of the composite variable, it is not possible to derive the values of the indicators.

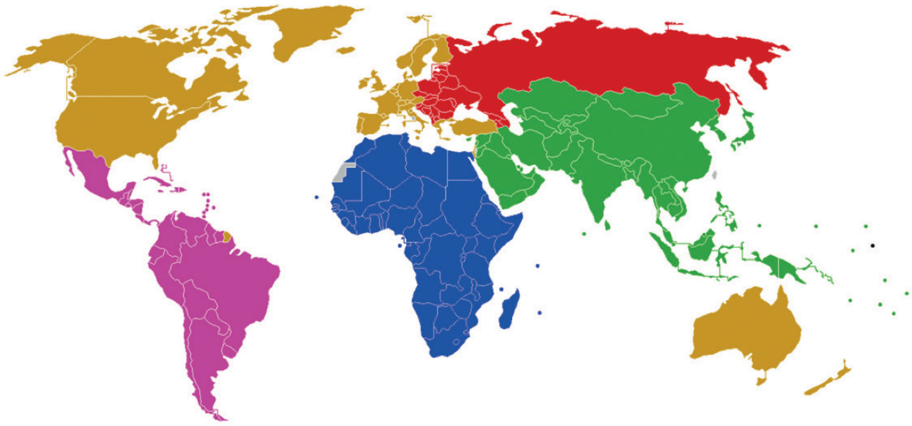
However, such composite variables bringing together a considerable number of indicators are opted for, in order to meet the primary objective of SafeFITS, which is to allow for the testing of numerous interventions for policy scenarios.

7.3 Identification of groups of countries

For a better understanding of the indicators and a better statistical analysis, countries grouping was attempted. The hypothesis is that groups of countries of similar geographical (and therefore also possibly cultural), economic or road safety characteristics may be better described by dedicated analyses. For example, there are several socioeconomic indicators that are very similar within geographical regions; there are many RSPI that would be applicable only in emerging economies (e.g. share of paved roads). Two types of grouping were explored, as described in the following sections.

7.3.1. Geopolitical grouping

Countries were initially grouped according to the United Nations Regional Groups as follows (see also figure 7.1 and appendix C, table C.1).



- African Group – 54 Member States
- Asia-Pacific Group – 53 Member States
- Eastern European Group – 23 Member States
- Latin American and Caribbean Group – 33 Member States
- Western European and Others Group – 28 Member States.

Figure 7.1
Geographical country grouping – the United Nations global regions

However, statistical analysis would have been unfeasible, because several regions include fewer than 30 countries. It was therefore decided to merge some groups and test the following groups of countries based on geopolitical criteria:

- African and Asia-Pacific countries
- Eastern European and Latin American - Caribbean countries
- Western European and Other countries.

A first set of models was attempted to be developed, but no statistically significant results were found (see section 7.6). A different classification of the countries was therefore chosen, which was based not only on geopolitical criteria but also on the economic performance, the motorization level and the road safety level of the countries.

7.3.2. Road safety and economic performance grouping

Figure 7.2 shows the countries scattered according to the GNI per capita and the Fatalities/Vehicles (F/V) rate according to the initial geopolitical grouping. Road safety performance and economic performance are not fully accordant to geopolitical criteria, despite some general patterns. More specifically, good road safety performing countries come from several regions, but very poorly performing countries most often come from the same region.

Another classification of the countries was suggested, based on the economic and road safety performance of the countries (see appendix C, table C.2.). This grouping is demonstrated in figure 7.3

1. Low performance: 33 African countries and 8 Asia-Pacific countries with GNI per capita ranging between \$270 and \$2,710 and the F/V rate being higher than 0.228.
2. Middle performance: 8 African countries, 19 Asia-Pacific countries, 9 Eastern European countries and 1 1 from the group of Western European and Others with GNI per capita ranging between \$950 and \$26,260 and the rate F/V ranging between 0.032 and 0.250.
3. High performance: 8 Eastern European countries, 7 Latin American and Caribbean, 6 Asian countries and 21 Western and other countries with GNI per capita ranging between \$6,290 and \$102,610 and the rate F/V ranging between 0.005 and 0.059.

Both groupings were tested within the development of statistical models, as described in section 7.6.

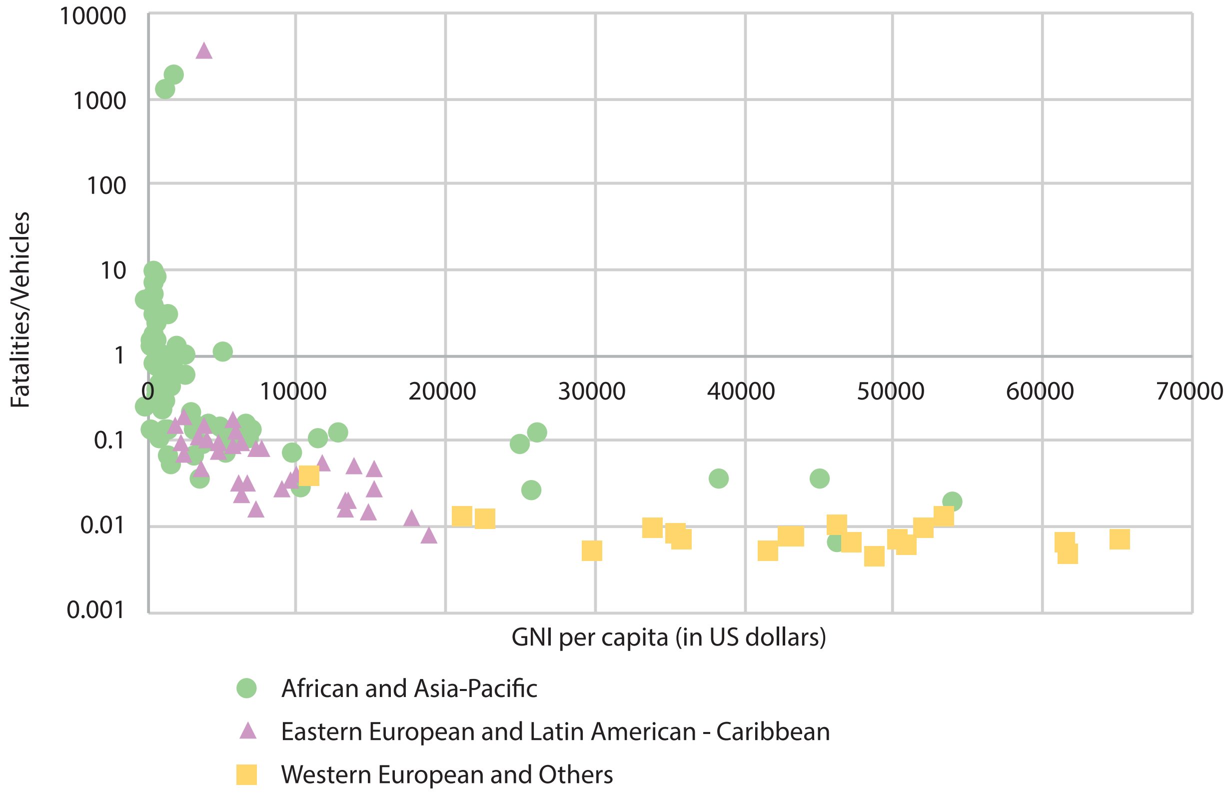


Figure 7.2
Road safety and economic performance of the geopolitical groups of countries

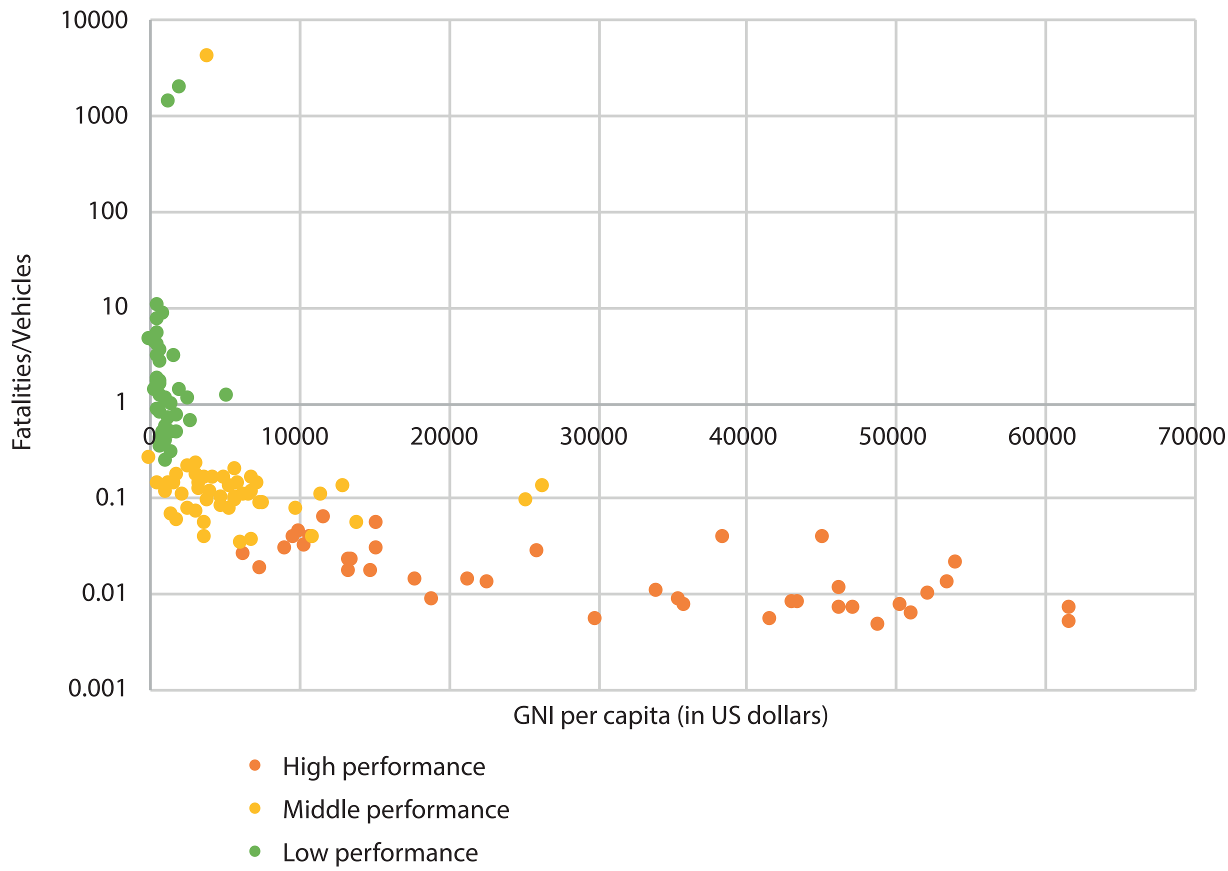


Figure 7.3
Grouping of countries based on economic and road safety performance

7.4 Development of statistical models

In the next steps of the analysis, linear regression is implemented to identify relationships between explanatory composite variables with the dependent variable, which is fatality per population. The selected explanatory variables include the new composite variables that have been developed above, based on the respective factor analyses.

The model specification presented in box 5.3 was tested; this model specification is in accordance with recent research on modelling road safety developments (Yannis et al., 2013, Antoniou et al., 2015) and is also considered most appropriate for the purposes of SafeFITS.

Several alternative model specifications were tested for the selection of the final model. The model quality was assessed on the basis of the following criteria:

- Statistical significance of variables: for a parameter estimate of the model to be statistically significant at a 95% confidence level, a T-test or Wald test higher than 1.64 is required, corresponding to a p-value lower than 0.050.
- Likelihood ratio test: the difference between the deviance (-2loglikelihood) of the null model (with intercept i.e. constant term only) and the final model (with all variables) should be statistically significant following a chi-square distribution with degrees of freedom equal to the difference in estimated parameters between the two models.
- Mean prediction error, calculated as the absolute difference between the observed and predicted values of the model.
- Mean percentage prediction error, calculated as the percentage of the difference between the observed and predicted values of the model.

7.4.1. Final model

The SafeFITS model is based on the three-year development of fatality rate and GDP, together with the various composite variables, as shown below:

$log(Fatalities\ per\ Population)t_i = A_i + log(Fatalities\ per\ Population)_{(t-3)} + K_i * logGDPt_i + L_i * [Comp\_EM] + Mi * [Comp\_TE]_i + + Ni * [Comp\_ME]_i + P_i * [Comp\_PI]_i + \varepsilon_i$

The best performing model for the purposes of SafeFITS is presented in table 7.5. It is a model whose dependent variable the logarithm of the fatality rate per population for 2013 and the main explanatory variables are the respective logarithm of fatality rate in 2010 (so the development of fatality rate over 2010-2013 is modelled), and the respective logarithm of GDP per capita for 2013, together with the four composite variables: economy and management, transport demand and exposure, measures and RSPI.

Table 7.5
Parameter estimates and fit of the final generalized linear model

Parameter	B	Standarderror	95% confidence interval		Hypothesis test		
			Lower	Upper	Wald chi-square	df	p-value
(Intercept)	1.694	0.2737	1.157	2.230	38.291	1	<0.001
Comp_ME	-0.135	0.0646	-0.261	-0.008	4.358	1	0.037
Comp_TE	-0.007	0.0028	-0.013	-0.002	7.230	1	0.007
Comp_PI	-0.007	0.0030	-0.013	-0.001	5.652	1	0.017
Comp_EM	0.007	0.0051	-0.003	0.017	2.009	1	0.156
LNFestim_2010	0.769	0.0462	0.678	0.859	276.322	1	<0.001
LNGNI_2013	-0.091	0.0314	-0.153	-0.030	8.402	1	0.004
(Scale)	0.038						
Likelihood ratio	1,379.00						
df	6						
p-value	<0.001						

The modelling results can be analysed as follows:

An increase in the GNI results in a decrease of the change in the fatality rate. This is intuitive and in accordance with previous research findings.

A higher fatality rate in 2010 is associated with a higher fatality rate in 2013. This is also intuitive, as countries with higher fatality rates in the past are expected (all other things kept equal) to exhibit similar fatality rates in the future. In fact, for a more accurate interpretation of the effect of road safety developments, this can be translated as follows: if fatalities have been increasing (i.e. the fatality rate of 2013 is higher than the fatality rate of 2010), an increase over the next three years is also expected, and, of course, vice versa.

All the parameter estimates of the composite variables on measures or RSPI have a negative sign, suggesting that an increase in the composite variable score (i.e. an increase in one or more of the indicators forming the composite variable) results in a decrease in the fatality rate.

All the parameter estimates are statistically significant at a 95% confidence level (p-values <0.050), and the Likelihood Ratio Test leads to accept the model, as its value is significant for an equal chi-square test with 6 degrees of freedom.

7.4.2. Model assessment

A comparison of the observed and the predicted values is shown in figure 7.4. For a perfectly fitting model, all points would lie on the diagonal, as the predicted value would be equal to the observed. The distance from the diagonal shows the prediction error for this country.

It can be seen that the model is very satisfactory for the good performing countries (low fatality rate) and quite satisfactory for the medium performing countries. The prediction error increases for the countries that had a high fatality rate in the first place, which is not surprising (as these countries also exhibit many missing values in several indicators, compromising the implementation of the model).

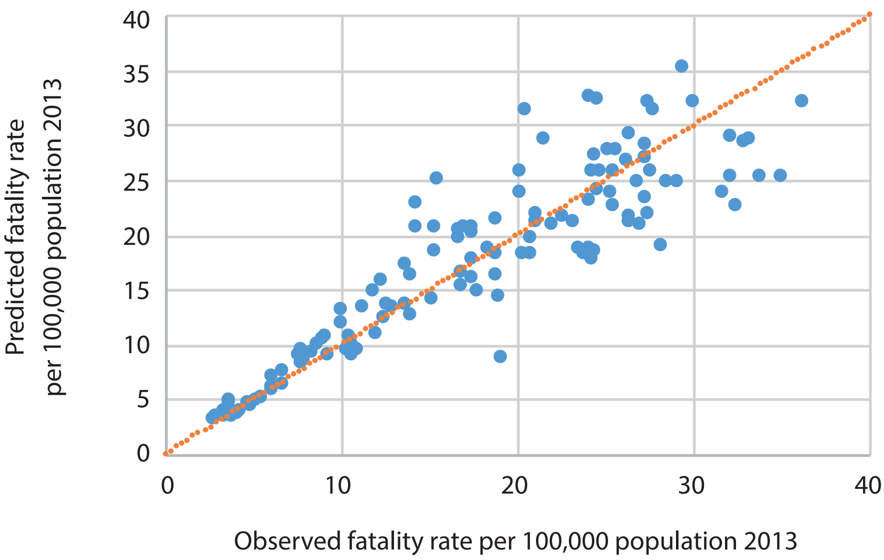


Figure 7.4
Observed vs. predicted fatality rates of year 2013

The mean absolute prediction error is estimated at 2.7 fatalities per population (maximum prediction error at 10.9 fatalities per population), whereas the mean percentage prediction error is estimated at 15% of the observed value (minimum is 0% and maximum is 60%; however, 115 out of the 128 countries have less than a 30% prediction error).

One issue that needs to be taken into account when interpreting the model is multicollinearity, i.e. the presence of correlated variables. The implementation of confirmatory factor analysis (instead of exploratory factor analysis) does not guarantee that the estimated composite variables are not correlated. In this case, the introduction of correlated variables in a model may result in some underestimation of the standard errors of the parameter estimates, and in some inaccuracy in the magnitude of the parameter estimates.

The correlation matrix of the composite variables was calculated, and it was confirmed that some correlations between the composite variables exist. For example, it is well known (e.g. from the SUNflower framework) that road safety measures are correlated with performance indicators. Of course, the various indicators within a composite variable are also by definition correlated.

In order to address this question, the following has to be noted:

- The presence of correlation within the variables in the model should be kept in mind. The effects reflected in the parameters estimates do not express the unique contribution of each variable / indicator, but its contribution given (i.e. conditional on) the effects of the other variables / indicators (direct vs indirect effects).
- The prediction accuracy is not affected by the presence of correlated variables; on the contrary, an increased number of variables is known to improve model predictions (although as mentioned above the parameter estimates may be affected). Given that the primary purpose of SafeFITS is to provide reliable predictions on the basis of policy scenarios, and not to estimate the unique effect of each indicator, the presence of correlations is considered acceptable.
- In the application of the model, the consideration of changes / interventions in groups of variables that are intuitively correlated will allow us to minimize the effects of multicollinearity (i.e. the cumulative effect of several correlated variables is more likely to reflect a true effect).

Based on the above, the final SafeFITS statistical model is fully defined as follows:

Box 7.5
Final SafeFITS global model specification[6]

log(**Fatalities per Population**$_{2013}$**)** = **1.694 +0.769** * log(**Fatalities per Population** $_{2010}$**)** - **0.091** * log(**GDP**$_{2013}$**)** +
+ **0.007** * **[**-0.250 (EM2_<15yo) + 0.229 (EM3_>65yo) + 0.228 * (EM4_UrbanPop(%)) + 0.224 (EM7_NationalStrategy) +
+ 0.201(EM8_NationalStrategyFunded) +0.222(EM9_FatalityTargets)**] - 0.007** * [0.161(TE1_RoadNetworkDensity) +
+0.149(TE2_Motorways(%)) + 0.238(TE3_PavedRoads(%)) + 0.272(TE4_VehiclesPerPop) +
+ 0.267(TE5_PassCars(%)) - 0.221(TE7_PTW(%)) - 0.117(TE10_Passenger/Freight)] - **0.135** * [0.069(ME2_ADR) +
+ 0.045(ME4_SpeedLimits_urban) + 0.064 * (ME6_SpeedLimits_motorways) + 0.088(ME7_VehStand_seatbelts) + 0.091 *
* (ME8_VehStand_SeatbeltAnchorages) + 0.092(ME9_VehStand_FrontImpact) + 0.091 * (ME10_VehStand_SideImpact) +
+ 0.090(ME11_VehStand_ESC) + 0.087 * (ME12_VehStand_PedProtection) + 0.090(ME13_VehStand_ChildSeats) + 0.068 *
* (ME15_BAClimits) + 0.068(ME16_BAClimits_young) + 0.065(ME17_BAClimits_commercial) +
+ 0.057(ME19_SeatBeltLaw_all) + 0.063(ME20_ChildRestraintLaw) + 0.034 * (ME22_HelmetFastened) +
+ 0.038(ME23_HelmetStand) + 0.038(ME24_MobileLaw) + 0.035 * (ME25_MobileLaw_handheld) +
+ 0.038(ME27_PenaltyPointSyst) + 0.040 * (ME29_EmergTrain_nurses)**] - 0.007** * [0.144(PI1_SeatBeltLaw_enf) + 0.155 *
* (PI2_DrinkDrivingLaw_enf) + 0.152(PI3_SpeedLaw_enf) + 0.160(PI4_HelmetLaw_enf) + 0.155(PI5_SeatBelt_rates_front) +
+ 0.146(PI6_SeatBelt_rates_rear) + 0.150(PI7_Helmet_rates_driver) + 0.127(PI8_SI_ambulance(%)) +
+ 0.116(PI9_HospitalBeds)**]**.

[6] Logarithmic function of the statistical model refers to natural logarithm.

Table 7.6
Final SafeFITS global model specification

Parameter	B	Standard error	95% confidence interval		Hypothesis test		
			Lower	Upper	Wald chi square	df	p-value
(Intercept)	1.694	0.2737	1.157	2.230	38.291	1	<0.001
Comp_ME	*-0.135*	*0.0646*	*-0.261*	*-0.008*	*4.358*	*1*	*0.037*
ME2_ADR	0.069						
ME4_SpeedLimits_urban	0.045						
ME6_SpeedLimits_motor ways	0.064						
ME7_VehStand_seatbelts	0.088						
ME8_VehStand_Seatbelt Anchorages	0.091						
ME9_VehStand_Front Impact	0.092						
ME10_VehStand_Side Impact	0.091						
ME11_VehStand_ESC	0.090						
ME12_VehStand_Ped Protection	0.087						
ME13_VehStand_Child Seats	0.090						
ME15_BAClimits	0.068						
ME16_BAClimits_young	0.068						
ME17_BAClimits_commer	0.065						
ME19_SeatBeltLaw_all	0.057						
ME20_ChildRestraintLaw	0.063						
ME22_HelmetFastened	0.034						
ME23_HelmetStand	0.038						
ME24_MobileLaw	0,038						
ME25_MobileLaw_hand held	0.035						
ME27_PenaltyPointSyst	0.038						
ME29_EmergTrain_nurses	0.040						
Comp_TE	*-0.007*	*0.0028*	*-0.013*	*-0.002*	*7.230*	*1*	*0.007*
TE1_RoadNetworkDensity	0.161						
TE2_Motorways(%)	0.149						
TE3_PavedRoads(%)	0.238						
TE4_VehiclesPerPop	0.272						
TE5_PassCars(%)	0.267						
TE7_PTW(%)	0.221						
TE10_Passenger/Freight	0.117						

Parameter	B	Standard error	95% confidence interval		Hypothesis test		
			Lower	Upper	Wald chi square	df	p-value
Comp_PI	*-0.007*	*0.0030*	*-0.013*	*-0.001*	*5.652*	*1*	*0.017*
PI1_SeatBeltLaw_enf	0.144						
PI2_DrinkDrivingLaw_enf	0.155						
PI3_SpeedLaw_enf	0.152						
PI4_HelmetLaw_enf	0.160						
PI5_SeatBelt_rates_front	0.155						
PI6_SeatBelt_rates_rear	0.146						
PI7_Helmet_rates_driver	0.150						
PI8_SI_ambulance(%)	0,127						
PI9_HospitalBeds	0,116						
Comp_EM	*0.007*	*0.0051*	*-0.003*	*0.017*	*2.009*	*1*	*0.156*
EM2_<15yo	-0.250						
EM3_>65yo	0.229						
EM4_UrbanPop(%)	0.228						
EM7_NationalStrategy	0.224						
EM8_NationalStrategyFunded	0.201						
EM9_FatalityTargets	0.222						
LNFestim_2010	0.769	0.0462	0.678	0.859	276.322	1	<0.001
LNGNI_2013	-0.091	0.0314	-0.153	-0.030	8.402	1	0.004
(Scale)	*0.038*						
Likelihood Ratio	*1379.0*						
df	*6*						
p-value	*<0.001*						

7.5 Model validation

In order to validate the model, a cross-validation was carried out with two subsets of the sample:

- 80% of the sample was used to develop (fit) the model, and then the model was implemented to predict the fatality rate for 2013 of the 20% of the sample not used to fit the model.
- 70% of the sample was used to develop (fit) the model, and then the model was implemented to predict the fatality rate for 2013 of the 30% of the sample not used to fit the model.

In both cases, the samples were split at random.[7]

Figure 7.5 shows the results of the model cross-validation. Again, a model perfectly predicting the outcomes would result in all the points lying on the diagonal. The deviation from the graph diagonal reflects the prediction error. In the first case (20% of the sample used for validation), the predictions are quite satisfactory, with the exception of two outliers. The mean absolute prediction error is 1.7 fatalities per population and the mean percentage prediction error is 12%.

In the second case (30% of the sample used for validation), no striking outliers exist, but overall there appears to be an underestimation of the fatality rate by the predicted values for countries with more than 20 fatalities per population. This is partly due to the fact that the model performance naturally drops when a significantly smaller sample is used for its development. The mean absolute prediction error is 3.6 fatalities per population and the mean percentage prediction error is 19% (but would drop at 3.5 and 17% respectively if the three largest errors were ignored).

[7] On the basis of a binomial (Bernoulli) distribution, random binary variables were used to select the requested share of the sample.

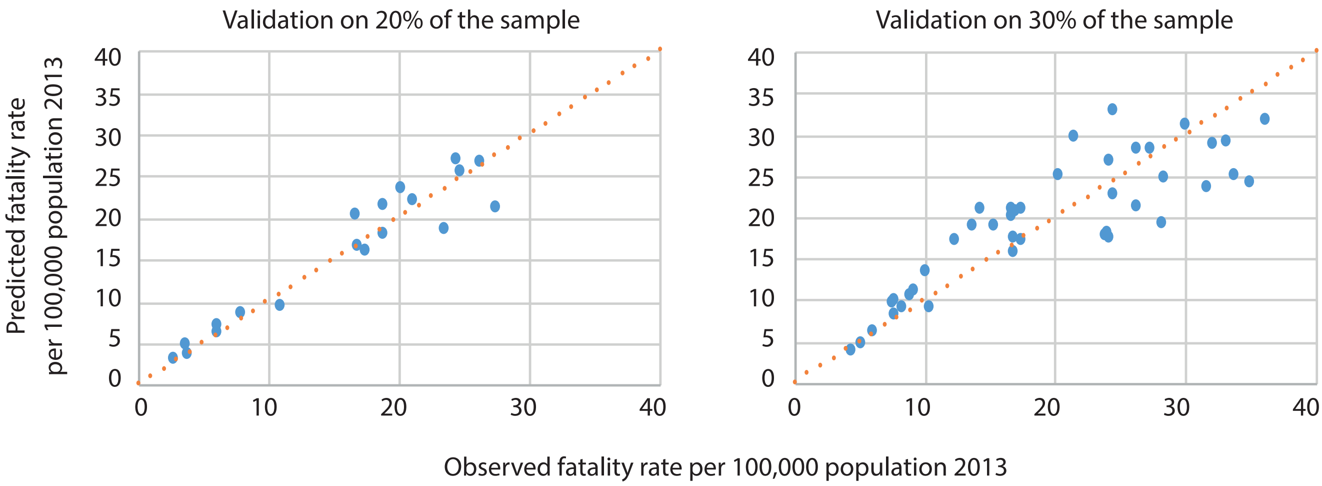


Figure 7.5
Cross-validation of the final model - 20% of the sample kept for validation (left panel), 30% of the sample kept for validation (right panel)

Overall, these results are considered satisfactory. In both cases, the errors are more considerable for the countries that have initially high fatality rates (poor performing countries, mostly African and Latin-American countries).

Therefore, it seems meaningful to attempt to develop models for different groups of countries. These are discussed in the next section.

7.6 Customization for groups of countries

The groups of countries presented in section 7.3 were considered for the fitting of separate models. There is a twofold interest in this type of modelling: first, it may allow for meaningful policy scenarios for the industrialized/good performing countries. These countries have already very high scores in most of the composite variables examined, and some of the composite variables may be non-significant. Second, emerging economies / poor performing countries may turn out to be affected differently by the composite variables than the effects found in the global model, and therefore the accuracy of their predictions may improve.

The model specification shown in section 7.4.1 was tested for the following groups of countries:

- On the first classification, based on geopolitical criteria as follows:
  - Region 1: African and Asia-Pacific countries
  - Region 2: Eastern European and Latin American and Caribbean countries
  - Region 3: Western European and developed countries
- On the second classification, based on economic and road safety performance criteria:
  - Region 1: Low performance countries
  - Region 2: Middle performance countries
  - Region 3: High performance countries

The modelling showed that none of the regional models is of satisfactory performance; which is not very surprising, given that the grouping results in much smaller samples for the regional models, which significantly compromise the model quality.

Both classifications resulted models with only a couple of variables statistically significant, and GDP was the main indicator. Even in these models, it is unlikely that better forecasts could be obtained with a smaller number of variables, compared to the global model (box 5.3).

The other regions resulted in models with no variables that were statistically significant. This is also not very surprising, as there is little variation in fatalities and other indicators between these countries, and therefore the variation is difficult to capture with the existing indicators.

On the basis of the above, the global model of box 5.3 appears to be the best model for testing policy scenarios within SafeFITS.

7.7 Customization for countries with particular characteristics

Particular emphasis was placed on developing countries with particular characteristics that would warrant separate treatment. These include:

- Countries with very low GDP per capita (several African countries) and a very high number of fatalities. These were treated separately as their fatalities are expected to keep increasing in the coming years where they will be exhibiting rapid development. Therefore, one might expect different model coefficients (e.g. effect of GDP, effect of measures) than the ones applicable in other countries.
- Countries with a very high share of motorcycles in their vehicle fleet (several Asian countries) and related motorcycle fatalities. In these countries, motorcycle-related measures (e.g. helmet law) might have a different and higher model coefficient than the one applicable in other countries, as these measures would have a higher effect on total fatalities.

None of the models tested for these particular cases resulted in better performance than the global model (box 5.3), and in most cases no different coefficients for the variables of interest was obtained. The reasons are the same as those outlined in section 7.6 above for the basic regional modelling attempts.

Additional information in the literature to correct the model coefficients for these particular cases was sought. The analysis of detailed causalities on GDP and helmet law effects carried out within SafeFITS project was reviewed, as well as specific key publications (e.g. Kopits and Cropper, 2005; Koornstra, 2007). But no additional information was found in the literature for these particular cases.

7.8 Model application

In order to evaluate the usefulness of the model for countries with different economic and road safety background, the statistical model was applied for one low performance country, the United Republic of Tanzania, two middle performance countries, Viet Nam and Turkey, and one high performance country, France.

The projections of their road safety performance up to 2030 are presented below, based only on the projected changes of GDP, without any intervention taking place, alongside with the respective confidence intervals (dotted lines).

Economic growth is expected to improve the road safety performance of countries that have already recorded progress during the previous years, while for low performance countries, the economic growth is expected to lead to an increase in motorization and thus, deterioration of road safety. Thus, the impact of road safety indicators included in the SafeFITS model will be higher for these countries in contrast with the developed countries with high road safety performance.

United Republic of Tanzania

The United Republic of Tanzania is among the least developed countries in the world, with the GDP per capita being equal to US $784 in 2013. The country recorded an 18% increase in traffic fatalities per 100,000 population between 2010 and 2013. If no road safety interventions take place in the coming years, it is forecasted that the country's economic growth will negatively affect its road safety performance. The fatality rate is forecasted to be 41.7 in 2030 compared with 32.9 in 2013, an increase of 26.7%.

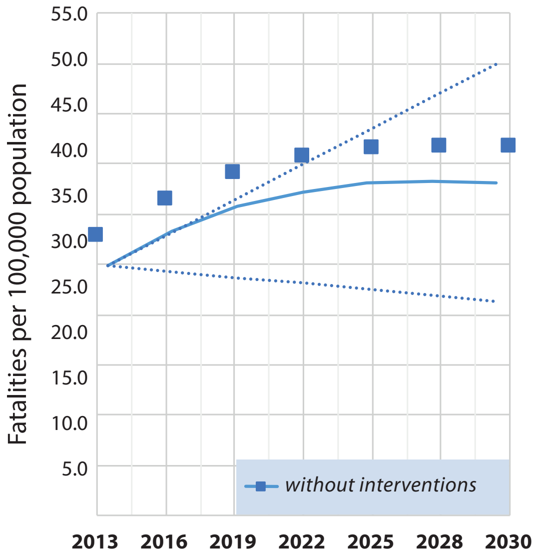


Figure 7.6
Forecasted fatalities per 100,000 population in the United Republic of Tanzania, 2013-2030

Viet Nam

Viet Nam is a developing country whose GDP per capita was US $1,478 in 2013. Viet Nam experienced a slight decrease in road fatalities, by 0.8%, between 2010 and 2013. According to the statistical model, the economic growth of the country will positively affect its road safety performance, and a 27.2% decrease in the fatality rate is forecasted for 2030, as shown in figure 7.7.

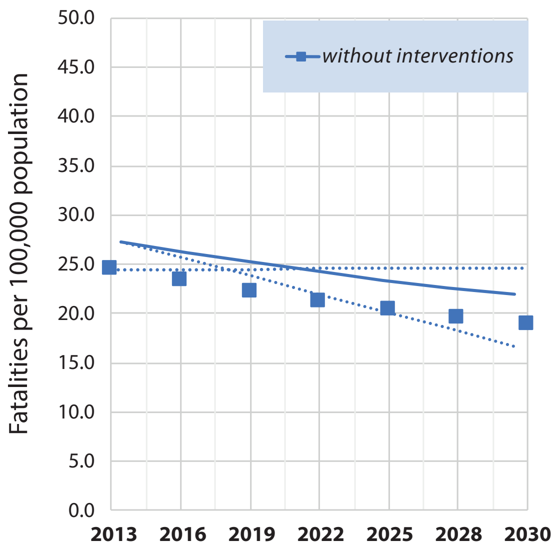


Figure 7.7
Forecasted fatalities per 100,000 population in Viet Nam, 2013-2030

Turkey

Turkey is a middle performance country, with a GDP per capita of US $10,936 in 2013. Its fatality rate decreased by 26% between 2010 and 2013. The country's fatality rate is forecasted to be 6.3 in 2030 compared with 8.9 in 2013, a decrease of 29.4%.

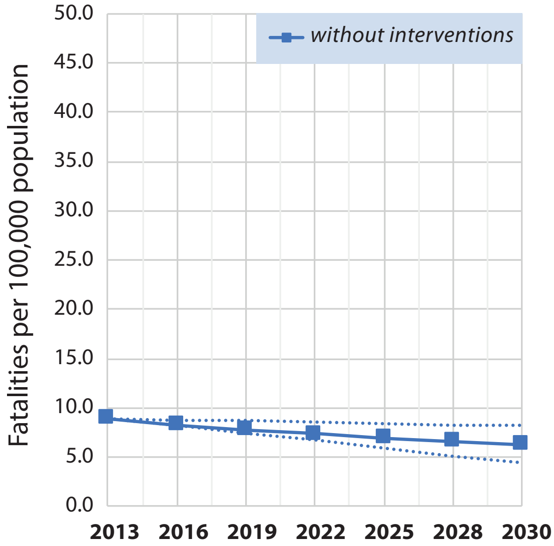


Figure 7.8
Forecasted fatalities per 100,000 population in Turkey, 2013-2030

France

France is a developed country with high economic and road safety performance. The GDP per capita was US $41,314 in 2013, while the traffic fatality rate fell by 17% between 2010 and 2013. The fatality rate is forecasted to be almost halved by 2030 compared with 2013.

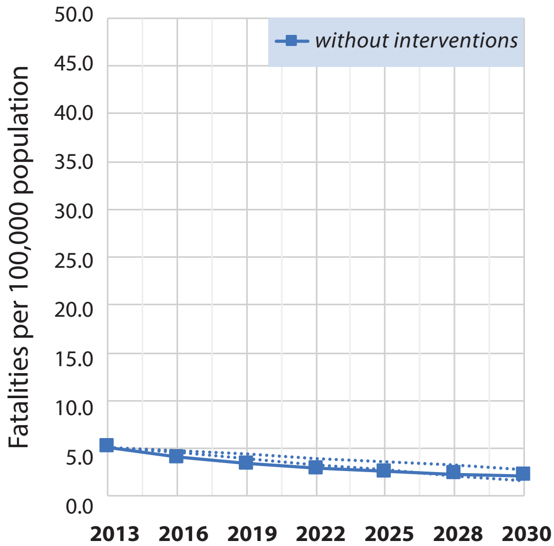


Figure 7.9
Forecasted fatalities per 100,000 population in France, 2013-2030

7.9 Identification of policy scenarios

On the basis of the results of the models development and validation, the policy scenarios to be considered in SafeFITS should take the following into account:

i. Economic developments (GDP) are the core indicator for forecasting future road safety developments, with or without further intervention. Ignoring the expected GDP developments when applying the model would lead to potentially serious prediction errors.

ii. From a theoretical viewpoint, although the model comprises numerous indicators, through the use of composite variables, a moderate extent of testing combinations of these indicators would be recommended. The model is based on a rather short period of historical data (2010-2013), and its predictions are extrapolated in the future on a step-by-step basis (i.e. 3 year steps); obviously, this results in some uncertainty in the predictions. In order to keep this uncertainty at a minimum level, it is recommended not to test extreme values combinations or combinations of too many indicators in the policy scenarios. It is likely that the model may be overly sensitive to abrupt simultaneous changes in many indicators yielding unreliable estimates.

iii. On the other hand, the basic priority of the analysis was to include as many indicators as possible in the composite variables. It is well known that several road safety indicators are correlated, and including them all together in a model may affect (i.e. underestimate) their effects. It is strongly suggested, when changing the value of one indicator, to consider and change at the same time other indicators that are obviously related to the initial indicator of interest. For example, when considering the effect of alcohol enforcement, it would be recommended to considering the effects of other types of enforcement as well, as it is expected that the intensification of enforcement will be implemented in all enforcement areas. Moreover, when testing the effect of increase in front seat-belt wearing rates, it would be reasonable to introduce an increase in the rear seat wearing rates as well, as they both concern an increase in road user behaviour and safety culture. A change in vehicle standards would normally concern several vehicle standards and not just one or two etc.

Overall, the following approach is recommended for the identification of policy scenarios:

- Start always by the base scenario, which is the current (reference) situation for year 2013 and carefully examine the values of the indicators for the base scenario.
- Obtain a forecast under the base scenario, based on the GDP projections available for the period of interest. This allows to obtain a picture of the forecasted road safety performance in a scenario with no new interventions, before testing interventions.
- Introduce the interventions serially, and not in parallel: test a single intervention for an indicator of interest and examine the model results. If necessary / desired, add a second intervention and compare the results.
- For each intervention introduced, consider and add the related interventions that would be expected to take place e.g. changes in several vehicle standards, improvement in several areas of enforcement, introduction of a group of measures, demographic changes affecting several indicators in the database etc.
- In total, the consideration of policy scenarios with more than 8 interventions is not recommended.

8. MODEL DEMONSTRATION

The overall model implementation of SafeFITS includes the following three distinct steps:

- Benchmarking
- Forecasting under a base case scenario
- Testing interventions (policy scenarios).

The following sections describe each of these steps, while indicative screens of the SafeFITS tool (these will be referred to as “wire-frames”) are included, aiming to present the overall user experience of implementing the SafeFITS model.

8.1 Things to know when using the SafeFITS model

The SafeFITS model was developed on the basis of the most recent and good quality data available internationally, and by means of rigorous statistical methods, also taking into account the basic features and required functionalities of the model. However, as always, data and analytical methods have limitations, which should be kept in mind:

- The fatality data used for the model development are in some cases estimated numbers, and in all subject to under-reporting (the degree of which is mostly unknown, and likely to vary between countries).
- Missing values were addressed by imputation, in order to be able to develop the model. These missing values were replaced by the regional known mean value. Users should take into account that indicators related to exposure (e.g. percentage of motorways of total road network) and road safety performance (e.g. protective systems use rates) had the most missing values, which concerned to a greater extent the developing countries (mostly African and Asian). Thus, the outcome in these countries may be more sensitive to indicator change in the testing of such interventions.
- The available data for several indicators were as detailed as necessary. In most cases, a binary variable (yes/no) was available, which may not always reflect the true value of the variable. For example, a measure may be partially implemented, a national strategy may exist but there is no information on whether it is implemented and monitored. The best approximation available was used.

The optimal use of the model depends on a number of recommendations and rules in order to minimize errors and inaccuracies in the model outcomes.

- The model is based on the extrapolation of short-term developments in the future – an approach that has several advantages but also some obvious limitations. Confidence intervals for the predictions are calculated to reflect the uncertainty in this extrapolation, on the basis of the mean prediction error of the model. The prediction error is considered to increase as the prediction horizon extends.
- The model includes many indicators which are obviously correlated (by definition, part of the correlation is taken into account by grouping them into composite variables). Composite variables, however, may also be correlated with one another (e.g. measures with performance indicators), since a correlation may exist between indicators included in separate composite variables. Therefore, the effects of interventions do not reflect the unique contribution of each separate intervention. It is strongly recommended to test combinations of "similar" interventions (e.g. several vehicle standards, several types of enforcement or safety equipment use rates) and always consider "what else would be likely to change, together with a given change?". The cumulative effect of "similar" indicators either within the same composite variable or from separate composite variables is more likely to accurately reflect true (and not conditional) effects.
- The model may not fully capture the effects on countries with very particular characteristics such as very low GDP, or a very high share of motorcycle or cyclist fatalities. Although every effort was made to customize the model for different geographical or geopolitical groups, as well as for such particularities, the available data in the international databases and the available information in the literature were not sufficient to allow for such customization.
- The outcomes in developing countries are expected to be more sensitive to indicator change in the testing of interventions than in developed ones. Several industrialized countries already have very high values on all indicators, and their GDP is expected to keep increasing. For these countries, a further slightly decreasing trend is forecasted by the model, but in order to forecast substantial further reductions, other types of interventions will be required, for which no data are currently available. Therefore, the current forecasts for these countries may be quite conservative.

For a comprehensive discussion of data and modelling limitations in the light of future improvements of the model, see also section 9.2.

8.2 SafeFITS tool – Introduction

The introduction page presents some basic information concerning the SafeFITS project and the particular characteristics of the SafeFITS application. It includes a welcome page that presents some general information concerning road safety, which is what users will first see when entering the website. Additionally, the user can choose to read guidelines concerning the use of SafeFITS.

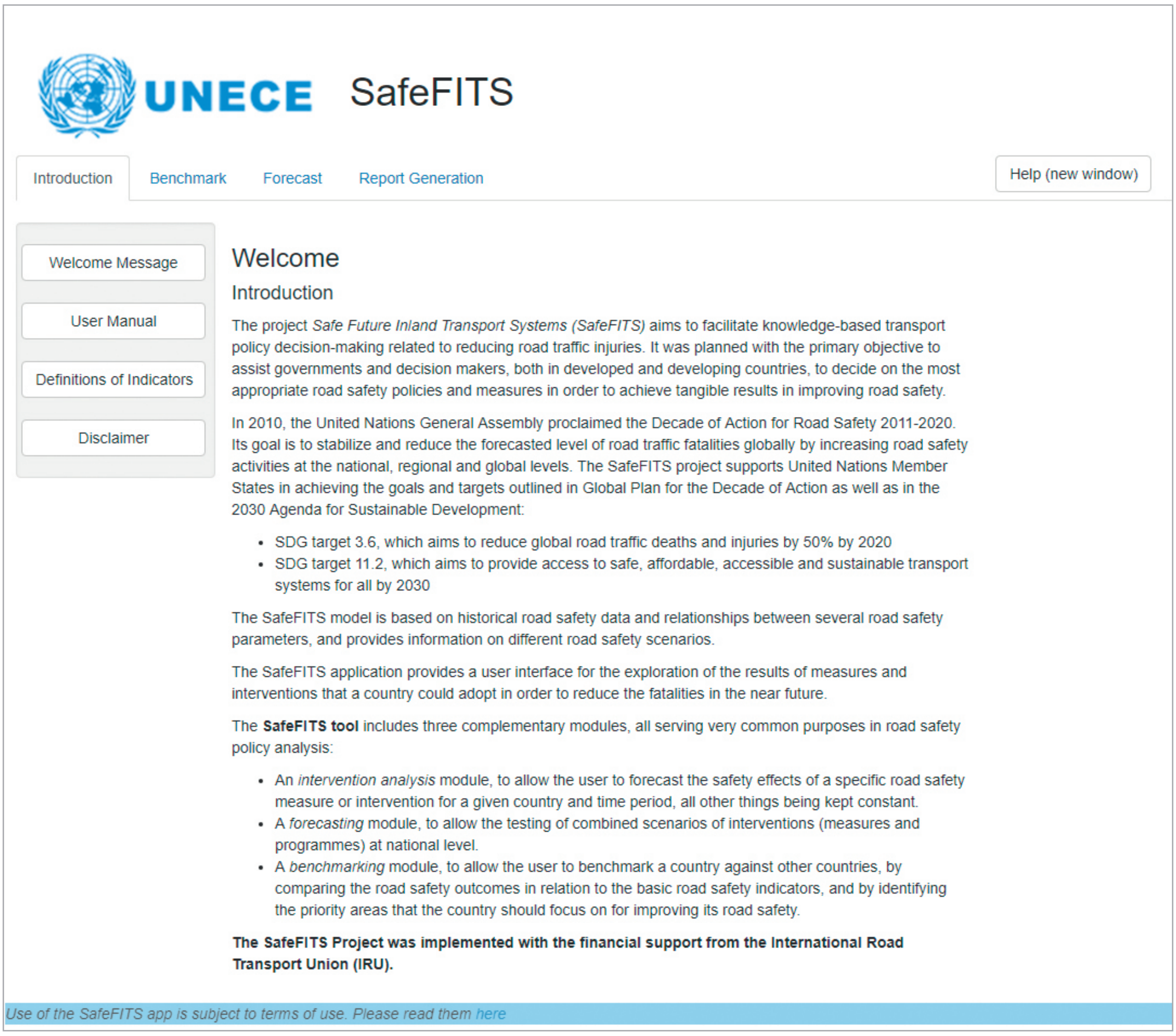


Figure 8.1
Screenshot of the SafeFITS Introduction page

8.3 SafeFITS tool – Benchmark

The objective of this step is to provide the user with an overall picture of the road safety performance and general information concerning the selected country for the base year 2013. The performance of that country will be presented for each of the road safety related indicators, which are divided in categories. Benchmarking is presented at both global and country cluster level.

User input

The user has the option to select a country to analyse, as presented in the figure 8.2. The user also has the opportunity to select the category of the indicators and the benchmark type (i.e. global or country cluster).

Model implementation

This step presents the basic parameters as well as the respective results, based on the SafeFITS database contents. The outputs are based only on the database and no statistical modelling implementation is taking place.

Outputs

Based on the SafeFITS database, the outputs of this step concern:

- Values of all indicators for the requested country and year
- Benchmarking results, including:
  - A figure regarding the overall ranking of the selected country for each indicator of the selected category of indicators.
  - A figure regarding the country cluster ranking of the selected country for each indicator of the selected category of indicators.

These outputs of the basic scenario are indicatively presented in the figure 8.2.

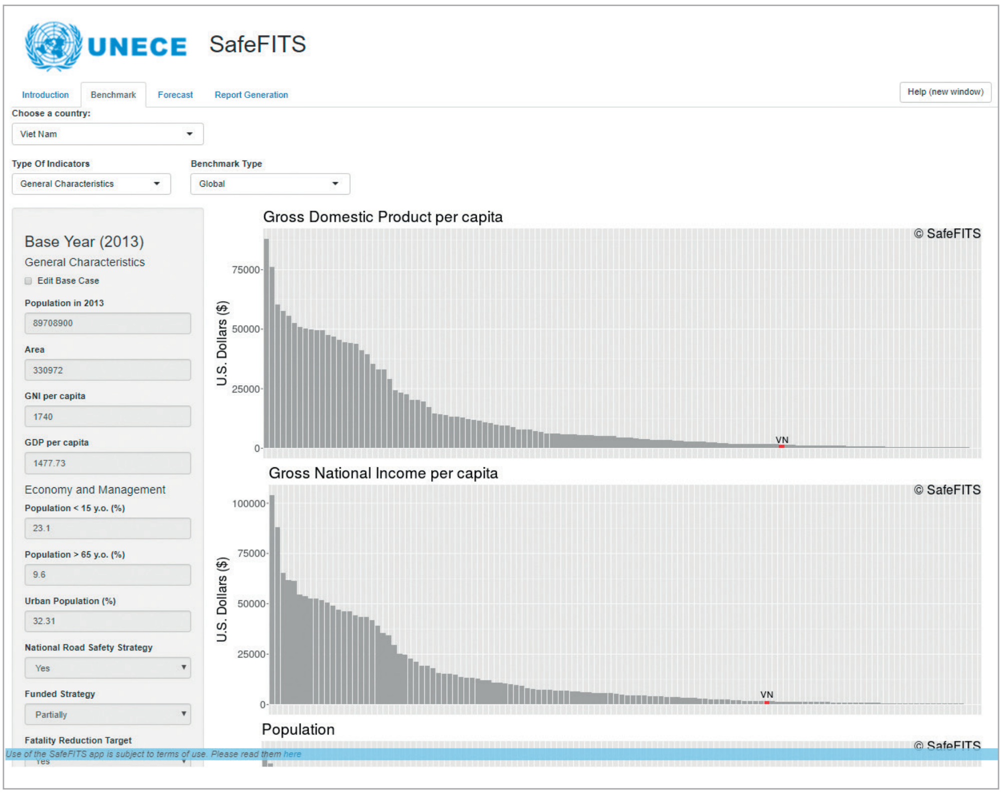


Figure 8.2
Screenshot of the SafeFITS Benchmark page

8.4 SafeFITS tool – Forecast

The objective of the second step is to forecast the road safety performance of a country in the base case that no new interventions will take place. This step is very important to give the user an idea of what road safety developments are expected if no additional action is taken ("base case" scenario), and this may serve as a reference to assess the impact of road safety actions to be tested.

User input

The user selects the intervention year, and two different options are available concerning the benchmark type (global or country cluster), as presented in the figure 8.3.

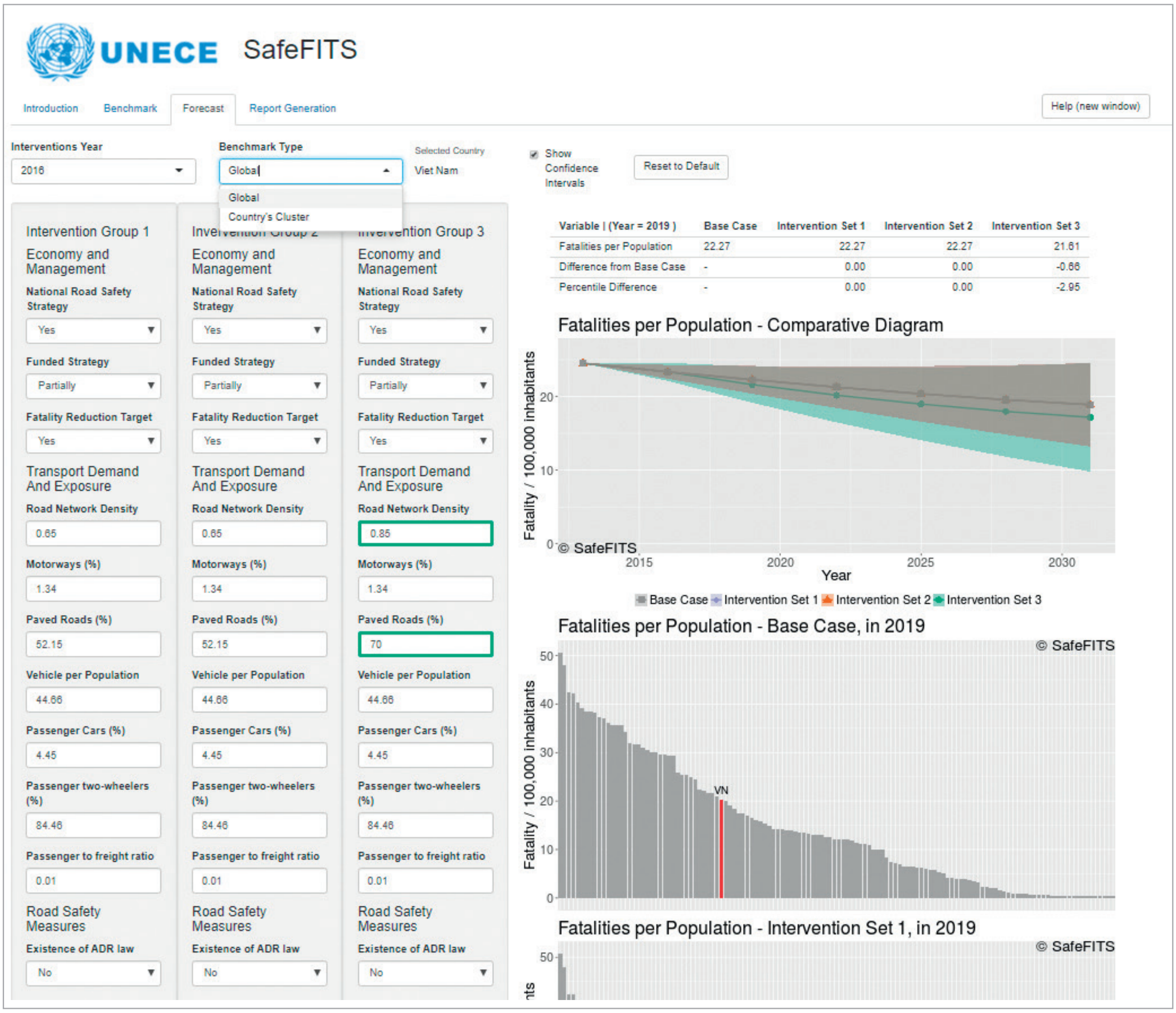


Figure 8.3
Screenshot of the SafeFITS Forecast page

Model implementation

Based on the projected values of the GNI and the demographic indicators, the SafeFITS model is implemented regarding the selected country, in order to forecast the road safety outcome for the intervention year.

Outputs

By selecting e.g. "Viet Nam" and intervention year "2022", the following outputs appear, as presented in the figure 8.4.

Road safety results

- Fatalities per population in the intervention year
- Change of fatalities per population in the intervention year compared with 2013
- General ranking of the country in the intervention year
- Country cluster rank in the intervention year.

Forecasting

In this section, a new figure appears, which presents the trend for the variable fatalities per population through the years (2013-2031), on which the forecast for the intervention year (2022) is also identifiable. Confidence intervals have been also calculated, based on the mean predicted error for the year 2016 and are gradually doubled up to 2031, as shown in the figure 8.3.

Benchmarking

A new figure appears within the framework of the benchmarking analysis. According to the benchmark type selected, the new figure may refer to the following:

- The overall ranking of the selected country in the intervention year
- The country cluster ranking of the selected country in the intervention year.

8.5 SafeFITS tool – Testing interventions

The objective of this step is to forecast the road safety performance of a country based on specific interventions that the user selects. The development of GNI and demographic indicators is also taken into account. Within this framework, the user may select up to three groups of interventions (scenarios) from the list of available indicators.

User input

The user selects the intervention year (e.g. 2022).Three different columns regarding each one of the possible groups of interventions (scenarios) appear, as presented in the figure 8.4.

Model implementation

Based on the different scenarios and their respective interventions, the SafeFITS statistical model is implemented regarding the selected country, testing separately each group of interventions at a time.

For the different group of interventions, the SafeFITS model is implemented three times, providing the respective results and figures: one time for the first group of interventions, one time for the second group of interventions and one time for the third group of interventions.

Outputs

In the figure 8.4, the respective wireframes are presented regarding each group of interventions. The example concerns the testing of the following three groups of interventions, for Viet Nam (intervention year 2022):

- First group of interventions: introduction of vehicle standards for seat belts, pedestrian protection and child seats.
- Second group of interventions: increase of seat-belt law enforcement from 6 to 8 (on a scale from 0 to 10), increase of seat-belt use rates in front seats from 47% to 60% and in rear seats from 10% to 20%.
- Third group of interventions: increase of road density from 0.65 to 0.85 km/km2 of total area and increase of percentage of paved roads from 52.15% to 70.00% of total road network.

A key component in this step is that in the forecasting figure the trend for each group of interventions is presented by a new line in order to give the user an overall and comparable picture of the cumulative effect of each intervention.

In each case, the results regarding fatality rate, fatality rate change, general and country cluster benchmarking for the intervention year are presented as shown in the previous steps. As far as benchmarking is concerned, the fatality rates for the remaining countries are the projected values from the "base case" scenario.

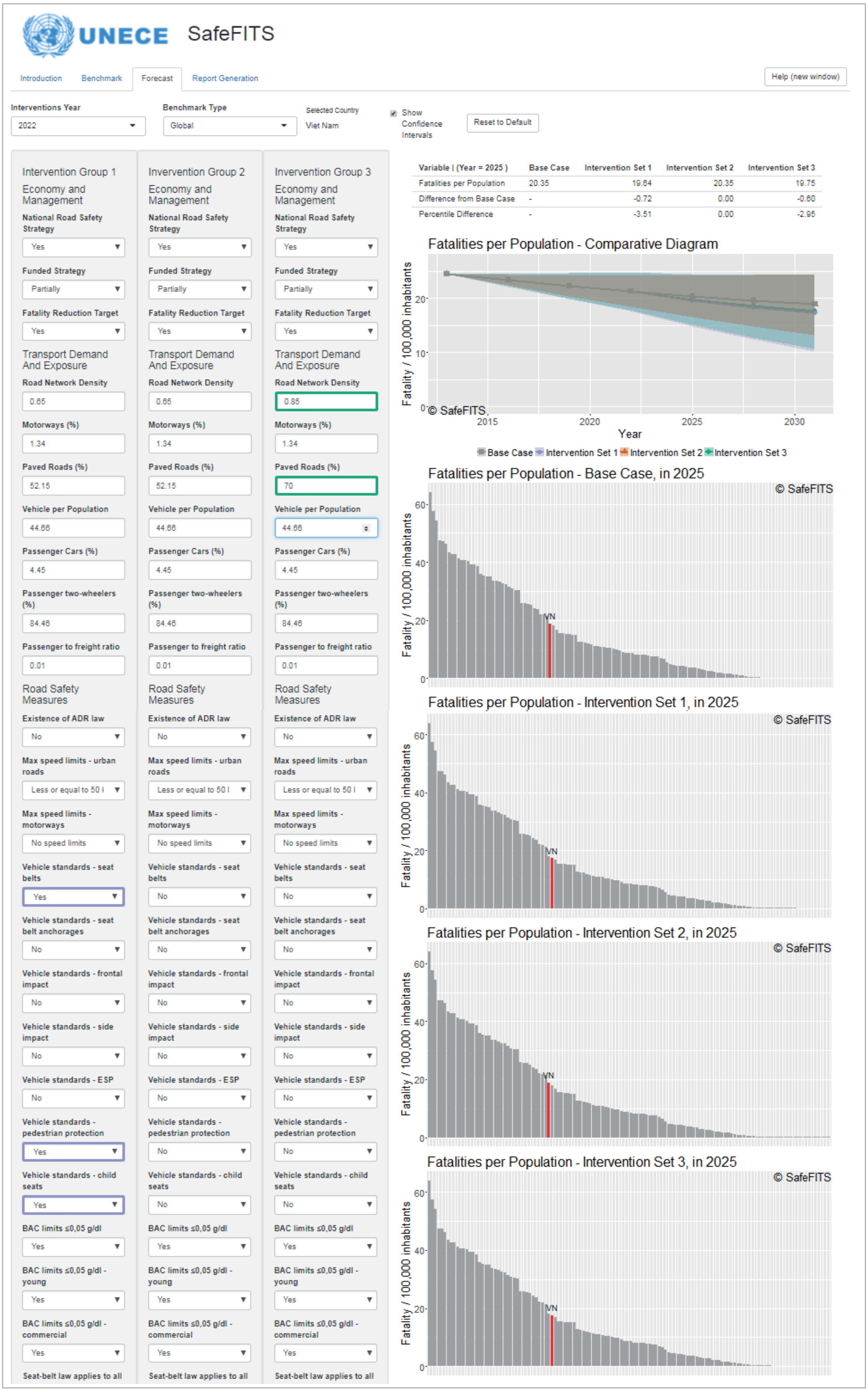


Figure 8.4
Full screenshot of the SafeFITS Forecast page

8.6 Report generation

The final step of the SafeFITS application for a user is the optional development of reports that can be downloaded for follow-up/offline use. Users can choose which parts of the analysis they want to have exported, as well as the file format in which the report will be generated (PDF, html, MS Word), as shown in the figure 8.5.

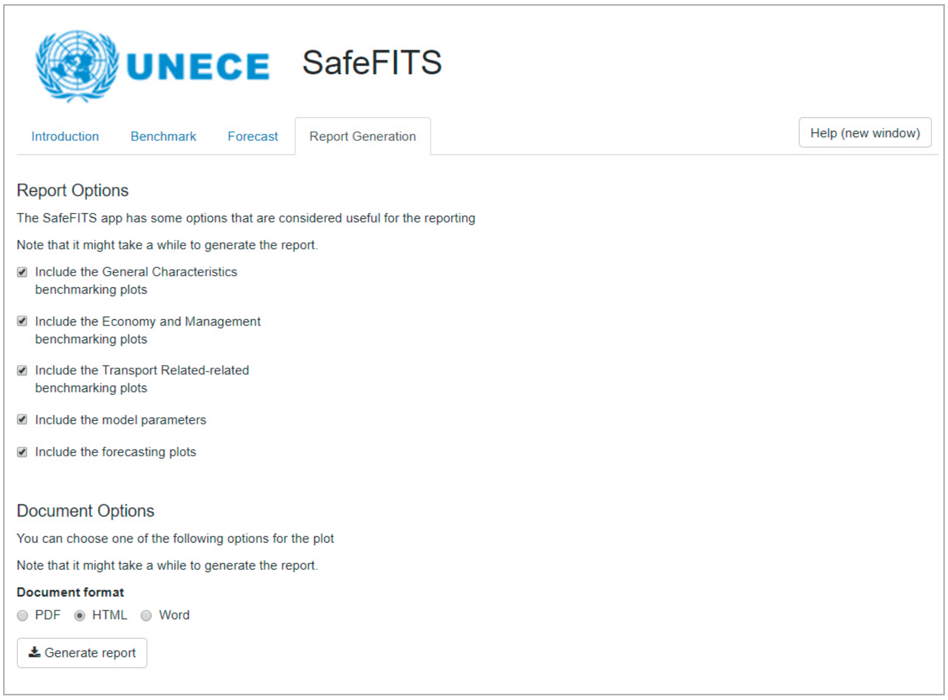


Figure 8.5
Screenshot of the SafeFITS Report Generation page

9. CONCLUSIONS AND NEXT STEPS

9.1 Summary

This report presents the results of the project Safe Future Inland Transport Systems (SafeFITS), which aims to develop a robust road safety decision-making tool to support the most appropriate road safety policies and measures to achieve tangible results.

Within the first two phases of the project:

- A suitable methodological framework for the SafeFITS tool was designed, combining the five road safety pillars of the WHO Global Plan of Action (WHO, 2011) with five layers of road safety system.
- A broad literature review was carried out of the most relevant road safety studies and projects.
- A list of the statistical data that were considered necessary to describe and monitor road safety performance was presented, along with the identification of the available data sources.
- The SafeFITS conceptual framework was designed, which includes an outline of the model, architecture and a description of the data requirements.
- A list of the most relevant relations (causalities) between different road safety indicators / variables and effects was drawn up.

Building on the above results, in the last phase of the project the SafeFITS statistical model was developed on the basis of actual data, and the design and basic functionalities of the SafeFITS tool were defined.

SafeFITS includes the following two background components:

- A database with data on indicators from all layers of the road safety management system.
- A set of statistical models fitted on the database indicators to produce the SafeFITS outputs.

The modules of SafeFITS can be summarized as follows:

- Intervention analysis: allows the user to examine the effects of single interventions at national or country cluster level.
- Forecasting analysis: allows the user to define own scenarios of measures (or combinations of measures) in a country and obtain medium/long term road safety forecasts for each scenario.
- Benchmarking analysis: allows the user to benchmark a country against a group of countries (e.g. all countries, countries of similar economic or road safety performance).

The database consists of numerous indicators for 130 countries globally, which were collected from various data sources. The WHO reports on the global road safety status were the primary source of data, but were complemented with data from other international organizations (e.g. United Nations, OECD, IRF). The data were carefully checked and processed to address missing values, and collect the latest available year in each case.

The statistical model took into account several challenges and particularities of road safety analyses. The task of road safety forecasting on the basis of policy scenarios, i.e. combining an explanatory approach on road safety with the time dimension at global level, was a challenge on its own, as there is no similar example in the literature. A dedicated methodology had to be developed, different statistical techniques were combined and adjusted and several alternative hypotheses were tested in order to meet the objectives of the analysis while dealing with data and methodological limitations.

The proposed approach is based on the calculation of composite variables and their introduction in a regression model (two-step approach), and the development of a model on the basis of short-term differences, accumulated to obtain medium- and long-term forecasts. Both these scientific choices have their limitations, but they were the optimal solutions for dealing with the complexity of the model to be developed on the basis of the available data.

The final model is robust, with satisfactory performance and acceptable prediction errors. The cross-validation undertaken is considered successful and can be implemented in the SafeFITS tool. However, care should be taken that the limitations of the model are taken into account, and several recommendations are made for optimal use of the model (e.g. combinations of policy scenarios). The development of models for different regions was less successful and was not retained, largely due to the small sample size resulting from the subgroups of countries, compromising the statistical analyses.

The present report also includes an indicative demonstration of the model implementation within a future SafeFITS tool, by means of wire-frames presentation. The model may provide forecasting and benchmarking estimates:

- For a “base case” scenario, solely on the basis of GNI projections (either official projections, or user-defined). This scenario serves as a reference case for assessing the effects of interventions.
- Policy scenarios with up to a maximum of eight interventions, in addition to GNI developments. This allows one to assess the cumulative impact of these interventions on the forecasted road safety outcomes, and the country’s position globally or within its country cluster.

Overall, the model can be used for global assessments (i.e. monitoring the global progress towards the road safety targets), as well as for individual country assessments of various policy scenarios. However, the successful application of the model, especially for individual countries, strongly depends on the optimal use recommendations (see section 8.1), taking into account the data limitations and the assumptions and possibilities of the modelling techniques used. The following section presents a complete discussion of these limitations, as well as the priorities for future improvements.

9.2 Model limitations and future improvements

The lack of a global road safety database with detailed and comparable data compromises the efforts to develop a global road safety model. On the one hand, lack of data (especially for transport demand, exposure and performance indicators) and lack of detail in the data values (especially for the partial implementation of measures) limit the potential of the SafeFITS model. These data are most crucial for the intervention and forecasting analyses, which are also the priority tools for most road safety stakeholders.

Previous studies have indicated that there may be more data on exposure and RSPI at national level than those reported in international statistics, and their collection, harmonization and use will be a major challenge with considerable added value for improving the SafeFITS model to better support road safety decision-making.

Issues that need to be addressed in the future for improving the SafeFITS model include the presence of estimated figures in the data and underreporting of fatalities.

Especially as regards the fatalities estimates and the degree of underreporting, known differences exist and have been reported between the WHO published figures (often "estimates", albeit by a dedicated methodology) and national figures (often inaccurate owing to deficiencies in the data collection and reporting systems, especially in low-income countries).

The WHO fatality data for a large group of countries (referred to as "group 4": countries without eligible death registration data in the WHO methodology documentation) are themselves estimated by means of statistical models, with GDP, vehicle fleet and some road safety measures as predictors.

The use of these fatality data in the SafeFITS model may have statistical implications that need to be further investigated. A separate model for this group of countries might be considered.

The majority of the available data is primarily directed at vehicle occupants, yet vulnerable road users (VRUs) – pedestrians, motorcyclists, cyclists) – represent around half of traffic fatalities globally (and an even larger share in some countries). While general interventions on road infrastructure, speed limits, etc. have some relevance, there is rarely strong information describing VRU exposure or dedicated infrastructure and traffic control features (e.g. no data globally available on the existence of 30 km/h zones). With the data currently available, the SafeFITS model may be more capable of estimating changes in totals of (motorized vehicle) users, rather than VRUs, and further evaluation and calibration of the model is needed of this point.

The modelling techniques used were considered optimal for the purposes of the project and the data available, but also have some limitations.

Unlike the common approach to modelling the effect of a single measure at a time and for a targeted group of fatalities, the modelling procedure aimed to explain fatality rates on the basis of a large number of variables. The approach was to include several indicators to model fatality rate in a comprehensive manner to meet the project objectives. One consequence of this is that, any single measure or indicator is shown to have a relatively small effect on the total fatality rate, and for the less informed user raises an unclear impression of the system.

For example, the effect of some vehicle technologies and systems, or the effect of establishing a lead agency for road safety, appears to be small, but only because these are examined in conjunction with numerous other correlated factors. Dedicated analyses in the literature have reported much higher effects when looking at these measures in isolation. Although every effort was made to point out this particularity, and guide the users towards testing appropriate combinations of interventions, rather than single interventions, further ways to present the results will be explored, e.g. by examining the impact on more specific target groups, in order to reflect more accurately the true effect of individual interventions.

At the current stage, there are two possibilities for improving the selection of scenarios to be tested: (a) by better defining the groups/combinations of interventions that would warrant to be considered jointly, and a priori making this information known to the SafeFITS model user and (b) by allowing a selection of interventions based on the total score of the composite variable, rather than on individual indicators (e.g. testing an increase of 15% on a country score on the composite variable "measures", which may be achieved by different combinations of changes in indicators). The latter option may be advantageous in the sense that policy makers may then identify and decide which combination of interventions would be needed to achieve this increase in the total score of the composite variable.

In the future steps, priority will be given to examining the possibility of additional formulation of the model for individual road user groups and also the transferability to non-typical countries with skewed road user type distributions (e.g. large share of motorcyclists).

Another implication of the primary objective to include a large number of variables comes from the resulting use of factor analysis to calculate composite variables. The factor analysis procedure assumes that the combination of indicators within each factor is the most explanatory; but it does not assume or indicate that a causal relationship exists. The model does not therefore make any assumptions about the effects of safety measures, and if there is no contribution of an indicator to the explanatory capability of a factor, then the coefficient of the indicator takes a small value.

Interactions between variables were not directly tested in the current model (although the composite variables allow a form of interaction between indicators to be tested) but will be also pursued in the future.

Following a thorough investigation of published results on known causalities, as well as the available data, it was decided to base the functional form of the model on straightforward statistical analysis, being the only option allowing all the available data for all countries to be exploited. The choice to model a change in mortality as a function of the instantaneous value of some variables may be counter-intuitive but the results are encouraging and largely confirm the feasibility of this approach. Once larger time series for all indicators are available, further refinement of the model will be possible, resulting in an even more robust model.

Overall, despite the successful cross-validation, the calibration with new data will be the ultimate way to fully assess the performance of the model and to implement significant improvements.

Since the WHO reports were the primary source of data for the SafeFITS project, the latest WHO report can be used for updating the database and further refining the model, as well as for improving its predictions.

In addition, the availability of comparable data for more years can be useful for improving the statistical modelling, and thus the robustness of the SafeFITS model. Most importantly, a new wave of historical data may enable the time dimension within the model to be better taken into account, by estimating future developments on the basis of longer historical trends for fatalities and key economy, exposure and RSPI.

It may also allow for the exploration of different mathematical formulations of the model, e.g. the role of GDP, for which different formulations have been suggested in the literature, or other variables for which a nonlinear relationship has been indicated (e.g. exposure, “safety in numbers” effects for cyclists, pedestrians etc.).

Further changes in programmes and measures implemented in the various countries will allow for more accurate estimates of their effects on outcomes, improving the transferability of estimates in other countries as well. Finally, expected WHO fatality figures for different age groups will bring new possibilities for more disaggregate models.

An additional component of road safety concerns road user attitudes, perceptions and motivations, directly related to road safety culture. Currently, there are few international data available, but it would be very interesting if more data on these aspects became available and could be exploited.

It is therefore suggested to closely monitor global developments in data availability and accuracy, so that the SafeFITS database can be updated regularly and continuously.

9.3. Next steps

In the next steps, the implementation of the model and the related user interfaces development will take place. The operational phase should start with a pilot phase during which the model will be tested by selected users and be revised accordingly at the end of the first year.

Focused case studies during the pilot operation, in Albania and Georgia, also taking into account the national and more detailed data, might provide valuable insight into the current data limitations and further data requirements, as well as user feedback on the model functionalities, the improvement of the policy scenarios to be examined, the interface and presentation of the outputs. Subsequently, the full operation phase may start and the SafeFITS model may be opened to the audience selected.

The SafeFITS tool will be further enhanced by continuously taking into account users' feedback through the application platform. Data, functionalities and outputs will be extensively and continuously re-evaluated according to the users' input.

In the future, biennial revisions of all SafeFITS components (knowledge base, database and statistical models) should also take place in order to incorporate any new developments in the field and further improve the present model, in particular by addressing the limitations and the specific areas for improvement already identified.

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11. APPENDICES

Appendix A. Identified detailed causalities per priority indicator

Appendix B. Overview of the SafeFITS database

Appendix C. Groups of countries

Appendices

Appendix A. Identified detailed causalities per priority indicator

Table A.1
Identified relations regarding indicator I01 ("GDP per capita")

SafeFITS MODEL PRIORITY INDICATOR					IDENTIFIED DETAILED CAUSALITY					REFERENCE / SOURCE OF DETAILED CAUSALITY				DATA USED					COMMENTS
no.	Description	Layer	Pillar	Variable Type	Equation / Relation	Type of study	Level of significance / R²	Type of statistical model	Explanatory variables of statistical model	Title	Issue Date	Author	Publisher	Origin	Adminis-trative level	Road types	Road user types	Time period	
I01	GDP per capita	Economy & Management	Road safety management	arithmetic value	for low GDP per capita (< ~3.000$): => increase of GDP => increase in fatality rates for high GDP per capita (> ~3.000$): => increase of GDP => decrease in fatality rates	Individual effects	5%	not applicable	not applicable	Economic development and traffic accident mortality in the industrialized world, 1962-1990	2000	van Beeck E., Borsboom G., Mackenbach J.	International Journal of Epidemiology, 29 (2000), 503-509.	21 OECD countries	national	all	all	1962-1990	
I01	GDP per capita	Economy & Management	Road safety management	arithmetic value	Association of GDP per capita changes to fatalities per capita changes (Table 3.2.1.1)	Statistical Model	adjusted R^2 = 0.8695	Log-linear regression	- GDP per capita - Geographic region	Traffic fatalities and economic growth.	2005	Kopits E., Cropper M.	Accident Analysis and Prevention 37 (2005), 169-178.	88 countries	national	all	all	1963-1999	
I01	GDP per capita	Economy & Management	Road safety management	arithmetic value	Association of GDP per capita changes to annual fatalities per capita changes (Table 3.2.1.2)	Statistical Model	n/a	Mixed linear regression	- Change in GDP per capita - Geographic region	Effect of GDP changes on road traffic fatalities	2014	Yannis G., Papadimitriou E., Folla K.	Safety Science 63 (2014) 42-49	27 European countries	national	all	all	1975-2011	

Table A.2
Identified relations regarding indicator I02 ("Country has a national road safety strategic plan")

SafeFITS MODEL PRIORITY INDICATOR					IDENTIFIED DETAILED CAUSALITY					REFERENCE / SOURCE OF DETAILED CAUSALITY				DATA USED					COMMENTS
no.	Description	Layer	Pillar	Variable Type	Equation / Relation	Type of study	Level of significance / R²	Type of statistical model	Explanatory variables of statistical model	Title	Issue Date	Author	Publisher	Origin	Adminis-trative level	Road types	Road user types	Time period	
I02	Country has a national road safety strategic plan	Economy & Management	Road safety management	yes / no	yes => -5% in fatalities per year	Individual effects	5%	not applicable	not applicable	Updates of Road Safety Status in Malaysia	2005	Umar R.	IATSS Research, Vol.29 (2005) No.1, 106-108	Malaysia	national	all	all	1972-2000	
I02	Country has a national road safety strategic plan	Economy & Management	Road safety management	yes / no	no direct statistical relationship	Statistical Model	n/a	not applicable	not applicable	DaCoTA Deliverable 1.5 Vol.II.: Analysis of Road Safety Managementin the European countries	2012	Papadimitriou E. et al.	Research Project DaCoTA	30 European countries	national	all	all	2001-2010	

Table A.3
Identified relations regarding indicator I03 ("Country has time-based, quantified national road safety targets")

SafeFITS MODEL PRIORITY INDICATOR					IDENTIFIED DETAILED CAUSALITY					REFERENCE / SOURCE OF DETAILED CAUSALITY				DATA USED					COMMENTS
no.	Description	Layer	Pillar	Variable Type	Equation / Relation	Type of study	Level of significance / R²	Type of statistical model	Explanatory variables of statistical model	Title	Issue Date	Author	Publisher	Origin	Adminis-trative level	Road types	Road user types	Time period	
I03	Country has time-based, quantified national road safety targets	Economy & Management	Road safety management	yes / no	inconclusive	Individual effects	n/a	not applicable	not applicable	Aktion „Minus 10 Prozent" in Österreich	1987	Risser R., Michalik C.	Forshnungsberichte der Bundesanstalt für Strassenwesen, Bereich Unfallforshung, Heft 159	Austria	national	all	all	1980's	
I03	Country has time-based, quantified national road safety targets	Economy & Management	Road safety management	yes / no	yes => -10% in injury accidents the 1st year, gradually no effect	Individual effects	n/a	not applicable	not applicable	The target –10% programme	1989	Lebrun D.	PTRC Summer Annual Meeting (proceedings of seminar H), 163-169	France	national	all	all	1980's	
I03	Country has time-based, quantified national road safety targets	Economy & Management	Road safety management	yes / no	yes => 2% increase in injury accidents and 3% increase in fatal accidents	Individual effects	not significant	not applicable	not applicable	The TAG-1 model for France	2000	Jaeger L., Lassarre S.	Structural Road Accident Models. The International DRAG Family, 157-184. Oxford, Pergamon Press (Elsevier Science)	France	national	all	all	1980's	
I03	Country has time-based, quantified national road safety targets	Economy & Management	Road safety management	yes / no	yes => -8.2 in injury accidents (one year)	Individual effects	n/a	not applicable	not applicable	Erhöhung der Verkehrssicherheit nach Plan. Realistischer Ansatz oder perspektivlose Träumerei?	1990	Schlabbach, K.	Zeitschrift für Verkehrssicherheit, 36, 146-155.	Germany (city of Darmstadt)	local	all	all	1980's	
I03	Country has time-based, quantified national road safety targets	Economy & Management	Road safety management	yes / no	yes => -0.77% in fatalities per year	Individual effects	5%	not applicable	not applicable	Quantified road safety targets. An assessment of evaluation methodology	2001	Elvik R.	Report 539. Institute of Transport Economics, Oslo	14 OECD countries	national	all	all	1970-1998	
I03	Country has time-based, quantified national road safety targets	Economy & Management	Road safety management	yes / no	yes => -0.92% in fatalities per year	Individual effects	1%	not applicable	not applicable	Association between setting quantified road safety targets and road fatality reduction.	2006	Wong S.C., Sze N.N., Yip H.F., Loo B.P.Y., Hung W.T., Lo H.K.	Accident Analysis and Prevention 38 (2006), 997-1005.	9 OECD countries	national	all	all	1981-1999	
I03	Country has time-based, quantified national road safety targets	Economy & Management	Road safety management	yes / no	no direct statistical relationship	Statistical Model	n/a	not applicable	not applicable	DaCoTA Deliverable 1.5 Vol.II.: Analysis of Road Safety Managementin the European countries	2012	Papadimitriou E. et al.	Research Project DaCoTA	30 European countries	national	all	all	2001-2010	

Table A.4
Identified relations regarding indicator I04 ("Country has a clearly empowered agency leading road safety")

SafeFITS MODEL PRIORITY INDICATOR					IDENTIFIED DETAILED CAUSALITY					REFERENCE / SOURCE OF DETAILED CAUSALITY				DATA USED					COMMENTS
no.	Description	Layer	Pillar	Variable Type	Equation / Relation	Type of study	Level of significance / R²	Type of statistical model	Explanatory variables of statistical model	Title	Issue Date	Author	Publisher	Origin	Adminis-trative level	Road types	Road user types	Time period	
I04	Country has a clearly empowered agency leading road safety	Economy & Management	Road safety management	yes / no	no direct statistical relationship	Statistical Model	n/a	not applicable	not applicable	DaCoTA Deliverable 1.5 Vol.II.: Analysis of Road Safety Managementin the European countries	2012	Papadimitriou E. et al.	Research Project DaCoTA	30 European countries	national	all	all	2001-2010	

Table A.5
Identified relations regarding indicator I05 ("Country has a defined allocation of expenditure for dedicated road safety programmes")

SafeFITS MODEL PRIORITY INDICATOR					IDENTIFIED DETAILED CAUSALITY					REFERENCE / SOURCE OF DETAILED CAUSALITY				DATA USED					COMMENTS
no.	Description	Layer	Pillar	Variable Type	Equation / Relation	Type of study	Level of significance / R^2	Type of statistical model	Explanatory variables of statistical model	Title	Issue Date	Author	Publisher	Origin	Adminis-trative level	Road types	Road user types	Time period	
I05	Country has a defined allocation of expenditure for dedicated road safety programmes	Economy & Management	Road safety management	yes / no	no direct statistical relationship	Statistical Model	n/a	not applicable	not applicable	DaCoTA Deliverable 1.5 Vol.II.: Analysis of Road Safety Managementin the European countries	2012	Papadimitriou E. et al.	Research Project DaCoTA	30 European countries	national	all	all	2001-2010	

Table A.6
Identified relations regarding indicator I06 ("Share of trips / traffic per mode")

SafeFITS MODEL PRIORITY INDICATOR					IDENTIFIED DETAILED CAUSALITY					REFERENCE / SOURCE OF DETAILED CAUSALITY				DATA USED					COMMENTS
no.	Description	Layer	Pillar	Variable Type	Equation / Relation	Type of study	Level of significance / R^2	Type of statistical model	Explanatory variables of statistical model	Title	Issue Date	Author	Publisher	Origin	Adminis-trative level	Road types	Road user types	Time period	
I06	Percentage of traffic per mode	Transport demand & Exposure	Road safety management	yes / no (existence of public transport)	no => +18% in injury accidents	Individual effects	95% confidence intervals: -1% to +41%	not applicable	not applicable	Changes in the road accident pattern as a result of a strike at the municipal public transport undertaking in The Hague.	1982	Boot M., Wassenberg P., van Zwam H.	SWOV Institute for Road Safety Research. Proceedings of Seminar on Short-term and Area-wide Evaluation of Road Safety Measures, Amsterdam, April 19–21, 1982	The Netherlands (Hague)	local	urban roads	all	unknown	
I06	Percentage of traffic per mode	Transport demand & Exposure	Road safety management	percentage change	-14% in public transport => +4% in number of injuries	Individual effects	95% confidence intervals: +3% to +6%	not applicable	not applicable	Road Casualties and Public Transport Fares in London.	1986	Allsop R. & Turner E.	Accident Analysis and Prevention Vol. 18 No.2, pp. 147-156	UK (London)	local	urban roads	all	1978-1983	
I06	Percentage of traffic per mode	Transport demand & Exposure	Road safety management	percentage	Fatalities estimated according to model (direct model equation not avaialble)	Statistical Model	n/a	Risk-analysis (Case Fatality Ratios)	- probability of a crash per mode - probability of fatality in the event of a crash per mode - percentage of traffic per mode - transport growth	A Risk-Based Method for Modeling Traffic Fatalities.	2007	Bhalla K., Ezzati M., Mahal A., Salomon J., Reich M. (2007).	Risk Analysis, Vol. 27, No. 1 (2007), pp. 125-136	mostly low- and middle-income countries	national	all	all	unknown	
I06	Percentage of traffic per mode	Transport demand & Exposure	Road safety management	annual public transit trips per capita	Annual fatalities per capita estimated according to graph of Figure 3.2.6.1	Statistical Model	R^2 = 0.6391	Graphical Curve Fit	- annual transit trips per capita	Safer Than You Think! Revising the Transit Safety Narrative.	2015	Litman T.	Victoria Transport Policy Institute (VTPI)	35 North American Cities	local	urban roads	all	unknown	

Table A.7
Identified relations regarding indicator I07 ("Country has a target to eliminate high-risk roads")

SafeFITS MODEL PRIORITY INDICATOR					IDENTIFIED DETAILED CAUSALITY					REFERENCE / SOURCE OF DETAILED CAUSALITY				DATA USED					COMMENTS
no.	Description	Layer	Pillar	Variable Type	Equation / Relation	Type of study	Level of significance / R^2	Type of statistical model	Explanatory variables of statistical model	Title	Issue Date	Author	Publisher	Origin	Adminis-trative level	Road types	Road user types	Time period	
I07	Country has a target to eliminate high-risk roads	Economy & Management	Road Infrastructure	yes / no	no quantitative relation identified in literature														

Table A.8
Identified relations regarding indicator I08 ("Number of passenger cars per 1,000 inhabitants")

SafeFITS MODEL PRIORITY INDICATOR					IDENTIFIED DETAILED CAUSALITY					REFERENCE / SOURCE OF DETAILED CAUSALITY				DATA USED					COMMENTS
no.	Description	Layer	Pillar	Variable Type	Equation / Relation	Type of study	Level of significance / R^2	Type of statistical model	Explanatory variables of statistical model	Title	Issue Date	Author	Publisher	Origin	Adminis-trative level	Road types	Road user types	Time period	
I08	Number of passenger cars per 1000 inhabitants	Economy & Management	Vehicle	arithmetic value	association of motorization rate to fatalities (Table 3.2.8.1)	Statistical Model	R^2 = 0.747 to 0.940	Lognormal regression	- Number of registered vehicles - % of PTWs - Population (different model per country or countries group)	An exploration of road safety parameters in Greece and Turkey	2007	Yannis G., Laiou A., Vardaki S., Kanellaidis G.	Journal of Transport and Shipping, Issue 4 (December 2007), 125-134	Greece, Turkey and 20 European Countries	national	all	all	1985-2004	
I08	Number of passenger cars per 1000 inhabitants	Economy & Management	Vehicle	arithmetic value	association of motorization rate to fatalities per capita (Figure 3.2.8.1)	Statistical Model	varying per country	Piece-wise linear regression	- Number of vehicles per 1,000 population (different model per country)	When may road fatalities start to decrease?	2011	Yannis G., Antoniou C., Papadimitriou E., Katsohis D.	Journal of Safety Research, Vol. 42, Issue 1, February 2011, 17-25	8 European Countries	national	all	all	1960-2005	

Table A.9
Identified relations regarding indicator I09 ("Share of powered two-wheelers in the vehicle fleet")

SafeFITS MODEL PRIORITY INDICATOR					IDENTIFIED DETAILED CAUSALITY					REFERENCE / SOURCE OF DETAILED CAUSALITY				DATA USED					COMMENTS
no.	Description	Layer	Pillar	Variable Type	Equation / Relation	Type of study	Level of significance / R^2	Type of statistical model	Explanatory variables of statistical model	Title	Issue Date	Author	Publisher	Origin	Adminis-trative level	Road types	Road user types	Time period	
I09	Share of powered two-wheelers in the vehicle fleet	Economy & Management	Vehicle	percentage	Increase of PTW share from 23.4% to 63.2% resulted in increase of PTW fatalities by 5.5 times.	Individual effects	not tested	not applicable	not applicable	Motorcycle ownership and injury in China	2004	Zhang J., Norton R., Tang K.C., Lo S.K., Jiatong Z., Wenkui G.	Injury Control & Safety Promotion, 11 (2004), 159 - 163	China	national	all	PTWs	1987-2001	Possible influence of other factors has not been statistically controlled.
I09	Share of powered two-wheelers in the vehicle fleet	Economy & Management	Vehicle	percentage	association of share of PTWs in the vehicle fleet to fatalities (Table 3.2.9.1)	Statistical Model	R^2 = 0.747 to 0.940	Lognormal regression	- Number of registered vehicles - % of PTWs - Population (different model per country or countries group)	An exploration of road safety parameters in Greece and Turkey	2007	Yannis G., Laiou A., Vardaki S., Kanellaidis G.	Journal of Transport and Shipping, Issue 4 (December 2007), 125-134	Greece, Turkey and 20 European Countries	national	all	all	1985-2004	

Table A.10
Identified relations regarding indicator I10 ("Country has a comprehensive helmet use law")

SafeFITS MODEL PRIORITY INDICATOR					IDENTIFIED DETAILED CAUSALITY					REFERENCE / SOURCE OF DETAILED CAUSALITY				DATA USED					COMMENTS
no.	Description	Layer	Pillar	Variable Type	Equation / Relation	Type of study	Level of significance / R^2	Type of statistical model	Explanatory variables of statistical model	Title	Issue Date	Author	Publisher	Origin	Adminis-trative level	Road types	Road user types	Time period	
I10	Country has a comprehensive helmet use law	Economy & Management	User	yes / no	yes => -10% in PTW fatalities per 10,000 registered PTWs	Individual effects	not significant	not applicable	not applicable	The reinstated comprehensive motorcycle helmet law in Texas. Insurance Institute for Highway Safety	1992	Mounce N., Brackett Q., Hinshaw W., Lund A., Wells J.	Insurance Institute for Highway Safety. Arlington VA	USA (Texas)	local	all	PTWs	1985-1990	Possible influence of other factors has not been statistically controlled.
I10	Country has a comprehensive helmet use law	Economy & Management	User	yes / no	yes => - 11% in PTW serious injuries & fatalities per 10,000 registered PTWs	Individual effects	5%	not applicable	not applicable	The reinstated comprehensive motorcycle helmet law in Texas. Insurance Institute for Highway Safety	1992	Mounce N., Brackett Q., Hinshaw W., Lund A., Wells J.	Insurance Institute for Highway Safety. Arlington VA	USA (Texas)	local	all	PTWs	1985-1990	Possible influence of other factors has not been statistically controlled.
I10	Country has a comprehensive helmet use law	Economy & Management	User	yes / no	no => +21.3% in PTW fatalities per 10,000 registered PTWs	Individual effects	5%	not applicable	not applicable	Florida's motorcycle helmet law repeal and fatality rates	2004	Muller A.	American Journal of Public Health, 94 (2004), 556 – 558	USA (Florida)	local	all	PTWs	1994-2001	Possible influence of other factors has not been statistically controlled.
I10	Country has a comprehensive helmet use law	Economy & Management	User	yes / no	no => +20.8% in PTW fatalities per 10,000 registered PTWs	Individual effects	not tested	not applicable	not applicable	Florida Motorcycle Helmet Use: Observational Survey and Trend Analysis	2004	Turner P., Hagelin C., Chu X., Greenman M., Read J., West M.	Center for Urban Transportation Research - University of South Florida	USA (Florida)	local	all	PTWs	1999-2001	Possible influence of other factors has not been statistically controlled.
I10	Country has a comprehensive helmet use law	Economy & Management	User	yes / no	no => +13.8% in PTW fatalities per 100 million PTW Vehicle Miles Travelled	Individual effects	not tested	not applicable	not applicable	Florida Motorcycle Helmet Use: Observational Survey and Trend Analysis	2004	Turner P., Hagelin C., Chu X., Greenman M., Read J., West M.	Center for Urban Transportation Research - University of South Florida	USA (Florida)	local	all	PTWs	1999-2001	
I10	Country has a comprehensive helmet use law	Economy & Management	User	yes / no	no => +9.1% in PTW fatalities (controlled for no. of registered PTWs and for nationwide trends)	Individual effects	1%	not applicable	not applicable	Evaluation of the repeal of the all-rider motorcycle helmet law in Florida	2005	Ulmer R., Northrup V.S.	National Highway Traffic Safety Administration (NHTSA), Washington DC	USA (Florida)	local	all	PTWs	1998-2002	
I10	Country has a comprehensive helmet use law	Economy & Management	User	yes / no	no => +21% in PTW fatalities	Individual effects	not tested	not applicable	not applicable	Evaluation of motorcycle helmet law repeal in Arkansas and Texas	2000	Preusser D.F., Hedlund J.H., Ulmer R.G.	National Highway Traffic Safety Administration (NHTSA), Washington DC	USA (Arkansas)	local	all	PTWs	1996-1998	Possible influence of other factors has not been statistically controlled.
I10	Country has a comprehensive helmet use law	Economy & Management	User	yes / no	no => +31% in PTW fatalities	Individual effects	not tested	not applicable	not applicable	Evaluation of motorcycle helmet law repeal in Arkansas and Texas	2000	Preusser D.F., Hedlund J.H., Ulmer R.G.	National Highway Traffic Safety Administration (NHTSA), Washington DC	USA (Texas)	local	all	PTWs	1996-1998	Possible influence of other factors has not been statistically controlled.
I10	Country has a comprehensive helmet use law	Economy & Management	User	yes / no	no => +37.5% in PTW fatalities per 10,000 registered PTWs	Individual effects	not tested	not applicable	not applicable	Evaluation of the Repeal of Motorcycle Helmet Laws in Kentucky and Louisiana	2003	Ulmer R.G. & Preusser D.F.	National Highway Traffic Safety Administration (NHTSA), Washington DC	USA (Kentucky)	local	all	PTWs	1996-2000	Possible influence of other factors has not been statistically controlled.
I10	Country has a comprehensive helmet use law	Economy & Management	User	yes / no	no => +75% in PTW fatalities per 10,000 registered PTWs	Individual effects	not tested	not applicable	not applicable	Evaluation of the Repeal of Motorcycle Helmet Laws in Kentucky and Louisiana	2003	Ulmer R.G. & Preusser D.F.	National Highway Traffic Safety Administration (NHTSA), Washington DC	USA (Louisiana)	local	all	PTWs	1996-2000	Possible influence of other factors has not been statistically controlled.
I10	Country has a comprehensive helmet use law	Economy & Management	User	yes / no	yes => -25% in PTW fatalities per 10,000 registered PTWs	Individual effects	5%	not applicable	not applicable	Impact of a helmet law on two wheel motor vehicle crash mortality in a southern European urban area	2000	Ferrando J., Plasencia A., Oros M., Borrell C., Kraus J.	Injury Prevention 6 (3), 184-188	Spain (Barcelona)	local	urban roads	PTWs	1990-1995	1. Possible influence of other factors has not been statistically controlled. 2. Restricted to urban areas only.
I10	Country has a comprehensive helmet use law	Economy & Management	User	yes / no	yes => - 31.7% in PTW traumatic brain injury (TBI) admissions per 10,000 registered PTWs	Individual effects	0.1%	not applicable	not applicable	Effect of Italy's motorcycle helmet law on traumatic brain injuries	2003	Servadei F., Begliomini C., Gardini E., Giustini M., Taggi F., Kraus J.	Injury Prevention 9 (2003), 257–260	Italy (Romagna region)	local	all	PTWs	1999-2001	1. Effects refer to number of PTW-related traumatic brain injury (TBI) admissions (not fatalities).
I10	Country has a comprehensive helmet use law	Economy & Management	User	yes / no	yes => - 33% in PTW head injuries	Individual effects	0.1%	not applicable	not applicable	The Effect of the Taiwan Motorcycle Helmet Use Law on Head Injuries	2000	Chiu W.T., Kuo C.Y., Hung C.C., Chen M.	American Journal of Public Health, 90 (2000), 793 – 796	Taiwan	national	all	PTWs	1996-1998	1. Effects refer to number of motorcycle-related head injuries (not fatalities). 2. Possible influence of other factors has not been statistically controlled.
I10	Country has a comprehensive helmet use law	Economy & Management	User	yes / no	yes => - 14% in PTW fatalities	Individual effects	1%	not applicable	not applicable	Effect of the mandatory helmet law in Taiwan	1999	Tsai M.-C., Hemenway D.	Injury Prevention 5 (1999), 290-291	Taiwan	national	all	PTWs	1996-1997	Possible influence of other factors has not been statistically controlled.
I10	Country has a comprehensive helmet use law	Economy & Management	User	yes / no	yes => -20.8% in fatalities among injured PTWs	Individual effects	not significant	not applicable	not applicable	Effect of the helmet act for motorcyclists in Thailand	2003	Ichikawa M., Chadbunchachai W., Marui E.	Accident Analysis and Prevention 35 (2003), 183-189	Thailand	local	all	PTWs	1994-1997	1. Analysis restricted on injured PTWs only. 2. Possible influence of other factors has not been statistically controlled.
I10	Country has a comprehensive helmet use law	Economy & Management	User	yes / no	yes => -26% in PTW fatalities	Meta-analysis	95% confidence intervals: -33% to -19%	not applicable	not applicable	The Handbook of Road Safety Measures (2nd Edition)	2009	Elvik R., Hoye A., Vaa T. & Sorensen M.	Emerald Group Publishing Ltd	USA	national	all	PTWs	1967-1992	1. Changes in exposure, climate and demographic parameters have not been statistically controlled in original studies. 2. Time period refers to publication dates of original studies.
I10	Country has a comprehensive helmet use law	Economy & Management	User	yes / no	yes => -27% in PTW injuries	Meta-analysis	95% confidence intervals: -28% to -25%	not applicable	not applicable	The Handbook of Road Safety Measures (2nd Edition)	2009	Elvik R., Hoye A., Vaa T. & Sorensen M.	Emerald Group Publishing Ltd	USA	national	all	PTWs	1967-1992	1. Changes in exposure, climate and demographic parameters have not been statistically controlled in original studies. 2. Time period refers to publication dates of original studies.
I10	Country has a comprehensive helmet use law	Economy & Management	User	yes / no	no => +30% in PTW fatalities	Meta-analysis	95% confidence intervals: +25% to +35%	not applicable	not applicable	The Handbook of Road Safety Measures (2nd Edition)	2009	Elvik R., Hoye A., Vaa T. & Sorensen M.	Emerald Group Publishing Ltd	USA	national	all	PTWs	1967-1992	1. Changes in exposure, climate and demographic parameters have not been statistically controlled in original studies. 2. Time period refers to publication dates of original studies.
I10	Country has a comprehensive helmet use law	Economy & Management	User	yes / no	no => +8% in PTW injuries	Meta-analysis	95% confidence intervals: +6% to +10%	not applicable	not applicable	The Handbook of Road Safety Measures (2nd Edition)	2009	Elvik R., Hoye A., Vaa T. & Sorensen M.	Emerald Group Publishing Ltd	USA	national	all	PTWs	1967-1992	1. Changes in exposure, climate and demographic parameters have not been statistically controlled in original studies. 2. Time period refers to publication dates of original studies.

SafeFITS MODEL PRIORITY INDICATOR					IDENTIFIED DETAILED CAUSALITY					REFERENCE / SOURCE OF DETAILED CAUSALITY				DATA USED					COMMENTS
no.	Description	Layer	Pillar	Variable Type	Equation / Relation	Type of study	Level of significance / R^2	Type of statistical model	Explanatory variables of statistical model	Title	Issue Date	Author	Publisher	Origin	Adminis-trative level	Road types	Road user types	Time period	
I10	Country has a comprehensive helmet use law	Economy & Management	User	yes / no	yes => -3.63% in PTW fatalities per 10,000 registered PTWs (all other parameters equal) Further results according to model (Table 3.2.10.2)	Statistical Model	90% confidence intervals: -21% to +14% R^2 = 0.554	Random-effects generalized least squares regression	- Helmet law (yes/no) - Population density - Average annual precipitation - Alcohol consumption per capita -Max. speed limit -% of urban roads - Average PTWs engine displacement - Average age of decedents - Median age	Helmet use laws and motorcycle rider death rates	2001	Branas C. & Knudson M.	Accident Analysis and Prevention 33 (2001), 641-648	USA (all states)	national	all	PTWs	1994-1996	Limited amount of fatalities data
I10	Country has a comprehensive helmet use law	Economy & Management	User	yes / no	PTW fatalities per 10,000 registered PTWs estimated according to model (Table 3.2.10.3)	Statistical Model	χ^2 = 1.04	Quasi-maximum likelihood generalized linear regression	- Helmet law (yes/no) - Annual heating degree days - Average annual precipitation	Generalized linear regression analysis of association of universal helmet laws with motorcyclist fatality rates	2006	Morris C.	Accident Analysis and Prevention 38 (2006), 142-147	USA (all states)	national	all	PTWs	1993-2002	Only influence of climate parameters has been statistically controlled.
I10	Country has a comprehensive helmet use law	Economy & Management	User	universal / partial / no	PTW fatalities per 10,000 registered PTWs estimated according to model (Table 3.2.10.4)	Statistical Model	adjusted R^2 = 0.6796	Fixed effects regression	- Helmet law (universal / partial / none) - Min. legal drinking age - BAC limit - Max. speed limit - Income per capita - % of population aged 25+ with 16+ yearsof education - Alcohol consumption per capita - Population density - Annual daily mean temperature - Average annual precipitation	Motorcyclist fatality rates and mandatory helmet-use laws	2008	Houston D. & Richardson L.	Accident Analysis and Prevention 40 (2008), 200-208	USA (all states)	national	all	PTWs	1975-2004	
I10	Country has a comprehensive helmet use law	Economy & Management	User	universal / partial / no	PTW fatalities per 100,000 population estimated according to model (Table 3.2.10.4)	Statistical Model	adjusted R^2 = 0.7485	Fixed effects regression	- Helmet law (universal / partial / none) - Min. legal drinking age - BAC limit - Max. speed limit - No. of registered PTWs per 1,000 population - Income per capita - % of population aged 25+ with 16+ yearsof education - Alcohol consumption per capita - Population density - Annual daily mean temperature - Average annual precipitation	Motorcyclist fatality rates and mandatory helmet-use laws	2008	Houston D. & Richardson L.	Accident Analysis and Prevention 40 (2008), 200-208	USA (all states)	national	all	PTWs	1975-2004	
I10	Country has a comprehensive helmet use law	Economy & Management	User	universal / partial / no	PTW fatalities per 10 billion Vehicle Miles Travelled estimated according to model (Table 3.2.10.4)	Statistical Model	adjusted R^2 = 0.8265	Fixed effects regression	- Helmet law (universal / partial / none) - Min. legal drinking age - BAC limit - Max. speed limit - No. of registered PTWs per 1,000 population - Income per capita - % of population aged 25+ with 16+ yearsof education - Alcohol consumption per capita - Population density - Annual daily mean temperature - Average annual precipitation	Motorcyclist fatality rates and mandatory helmet-use laws	2008	Houston D. & Richardson L.	Accident Analysis and Prevention 40 (2008), 200-208	USA (all states)	national	all	PTWs	1975-2004	VMT refer to all vehicles, not only PTWs.

Table A.11
Identified relations regarding indicator I11 ("Country has systematic policies and practices in place for Road Safety Audits of new road projects")

SafeFITS MODEL PRIORITY INDICATOR					IDENTIFIED DETAILED CAUSALITY					REFERENCE / SOURCE OF DETAILED CAUSALITY				DATA USED					COMMENTS
no.	Description	Layer	Pillar	Variable Type	Equation / Relation	Type of study	Level of significance / R^2	Type of statistical model	Explanatory variables of statistical model	Title	Issue Date	Author	Publisher	Origin	Adminis-trative level	Road types	Road user types	Time period	
I11	Country has systematic policies and practices in place for Road Safety Audits of new road projects	Road Safety Measures	Road Infrastr ucture	yes / no	audited vs non-audited projects: -60% reduction in accidents in audited vs -10% in non-audited	Individual effects	n/a	not applicable	not applicable	Study of Surrey County Council in Great Britain (unknown exact title)	1994	unknown	unknown	UK (Surrey County)	local	audited roads only	all	unknown	Refers only to specific road sections that were audited (not the nationwide implementation of RSAs)
I11	Country has systematic policies and practices in place for Road Safety Audits of new road projects	Road Safety Measures	Road Infrastr ucture	yes / no	audited projects: 20% - 40% reduction in accidents	Individual effects	n/a	not applicable	not applicable	FHWA Road Safety Audit Guidelines. Publivation No. FHWA-SA-06-06	2006		Federal Highway Administration (FHWA)	USA (state of New York)	local	audited roads only	all	unknown	1. Refers only to specific road sections that were audited (not the nationwide implementation of RSAs) 2. Refers to Road Safety Inspections of existing traffic schemes.
I11	Country has systematic policies and practices in place for Road Safety Audits of new road projects	Road Safety Measures	Road Infrastr ucture	yes / no	audited projects: 12.5% - 23.4% reduction in accidents	Individual effects	n/a	not applicable	not applicable	FHWA Road Safety Audit Guidelines. Publivation No. FHWA-SA-06-06	2006		Federal Highway Administration (FHWA)	USA (South Carolina)	local	audited roads only	all	unknown	Refers only to specific road sections that were audited (not the nationwide implementation of RSAs)

Table A.12
Identified relations regarding indicator I12 ("Number of enforcement controls (speed, alcohol, seat belt, helmet etc.) per 1,000 population")

SafeFITS MODEL PRIORITY INDICATOR					IDENTIFIED DETAILED CAUSALITY					REFERENCE / SOURCE OF DETAILED CAUSALITY				DATA USED					COMMENTS
no.	Description	Layer	Pillar	Variable Type	Equation / Relation	Type of study	Level of significance / R^2	Type of statistical model	Explanatory variables of statistical model	Title	Issue Date	Author	Publisher	Origin	Adminis-trative level	Road types	Road user types	Time period	
I12	Number of enforcement controls (speed, alcohol, seat belt, helmet etc.) per 1,000 population	Road Safety Measures	User	arithmetic value	39,036hours of enforcement / year - average 198controls per 1,000 population per year => - 14.9% in fatal crashes (network wide)	Individual effects	1%	not applicable	not applicable	The crash reduction effectiveness of a network-wide traffic police deployment system	2001	Newstead S.V, Cameron M.H., Leggett L.M.W.	Accident Analysis and Prevention, 33 (2001), 393-406	Australia (Queensland)	local	all	all	1986-1997	1. Effects refer to number of fatal accidents (not fatalities). 2. Rough assumptions made to convert the results to a comparable form.
I12	Number of enforcement controls (speed, alcohol, seat belt, helmet etc.) per 1,000 population	Road Safety Measures	User	arithmetic value	inconclusive	Individual effects	n/a	not applicable	not applicable	The evaluation of effects on driver behaviour and accidents of concentrated general enforcement on interurban roads in Israel.	2001	Hakkert A.S., Gitelman V., Cohen A., Doveh E., Umansky T.	Accident Analysis and Prevention 33 (2001), 43–63	Israel	national	rural roads	all	1995-1998	
I12	Number of enforcement controls (speed, alcohol, seat belt, helmet etc.) per 1,000 population	Road Safety Measures	User	percentage change	up to 3 times increase in enforcement => no significant effect	Meta-analysis	n/a	not applicable	not applicable	The effects of speed enforcement on individual road user behavior and accidents	1991	Østvik E., Elvik R.	In: Koornstra, M.J., Christensen, J. (Eds.) Enforcement and Rewarding: Strategies and Effects. SWOV, pp. 56–59.	9 studies (England, Sweden, Denmark, Texas & Finland)	national	enforced sections only	all	1964-1988	1. Effects refer to number of injury accidents. 2. Time period refers to publication dates of original studies.
I12	Number of enforcement controls (speed, alcohol, seat belt, helmet etc.) per 1,000 population	Road Safety Measures	User	percentage change	3 to 5 times increase in enforcement => -10% to -20% in accidents	Meta-analysis	n/a	not applicable	not applicable	The effects of speed enforcement on individual road user behavior and accidents	1991	Østvik E., Elvik R.	In: Koornstra, M.J., Christensen, J. (Eds.) Enforcement and Rewarding: Strategies and Effects. SWOV, pp. 56–59.	9 studies (England, Sweden, Denmark, Texas & Finland)	national	enforced sections only	all	1964-1988	1. Effects refer to number of injury accidents. 2. Time period refers to publication dates of original studies.
I12	Number of enforcement controls (speed, alcohol, seat belt, helmet etc.) per 1,000 population	Road Safety Measures	User	percentage change	more than 5 times increase in enforcement => -20% to -30% in accidents	Meta-analysis	n/a	not applicable	not applicable	The effects of speed enforcement on individual road user behavior and accidents	1991	Østvik E., Elvik R.	In: Koornstra, M.J., Christensen, J. (Eds.) Enforcement and Rewarding: Strategies and Effects. SWOV, pp. 56–59.	9 studies (England, Sweden, Denmark, Texas & Finland)	national	enforced sections only	all	1964-1988	1. Effects refer to number of injury accidents. 2. Time period refers to publication dates of original studies.
I12	Number of enforcement controls (speed, alcohol, seat belt, helmet etc.) per 1,000 population	Road Safety Measures	User	percentage change	Relation of Figure 3.2.12.1	Meta-analysis	not tested	not applicable	not applicable	Cost-benefit analysis of police enforcement	2001	Elvik R.	Escape Research Project, Working paper 1	UK, USA, Sweden and Austria	national	all	all	1966-1998	1. Effects refer to number of injury accidents. 2. Time period refers to publication dates of original studies.
I12	Number of enforcement controls (speed, alcohol, seat belt, helmet etc.) per 1,000 population	Road Safety Measures	User	arithmetic value	No. of injury accidents estimated according to model (Table 3.2.12.1)	Statistical Model	n/a	Negative binomial regression	- No. of alcohol controls - No. of speed violations - % of national road network (different model per county)	Multilevel modeling for the regional effect of enforcement on road accidents	2007	Yannis G., Papadimitriou E., Antoniou C.	Accident Analysis and Prevention, 39 (2007), 818-825	Greece (Athens & Thessaloniki metropolitan areas excluded)	local	rural roads	all	1998-2002	1. Effects refer to number of injury accidents. 2. Modelling approach focuses on regional differences.

Table A.13
Identified relations regarding indicator I13 ("Roadside police alcohol tests per 1,000 population")

SafeFITS MODEL PRIORITY INDICATOR					IDENTIFIED DETAILED CAUSALITY					REFERENCE / SOURCE OF DETAILED CAUSALITY				DATA USED					COMMENTS
no.	Description	Layer	Pillar	Variable Type	Equation / Relation	Type of study	Level of significance / R^2	Type of statistical model	Explanatory variables of statistical model	Title	Issue Date	Author	Publisher	Origin	Adminis-trative level	Road types	Road user types	Time period	
I13	Roadside police alcohol tests per 1,000 population	Road Safety Measures	User	arithmetic value	estimated 16.3 controls per 1,000 population per year => -35% in drunk-driving fatal & non-fatal injury accidents	Individual effects	n/a	not applicable	not applicable	The 2006 National Labor Day Impaired Driving Enforcement Crackdown: Drunk Driving. Over the Limit. Under Arrest. Report No. DOT HS 811 039.	2008	Solomon M., Hedlund J., Haire E., Chaffe R. & Cosgrove L.	National Highway Traffic Safety Administration (NHTSA), Washington D.C.	USA (Anoka county, Minnesota)	local	all	drunk drivers	2004-2007	1. Effects refer to number of injury accidents. 2. Rough assumptions made to convert the results to a comparable form.
I13	Roadside police alcohol tests per 1,000 population	Road Safety Measures	User	percentage change	58 times increase in DUI checkpoints => - 20.4% in fatal drunk-driving accidents	Individual effects	statistically significant - specific level not mentioned	not applicable	not applicable	Checkpoint Tennessee: Tennessee's Statewide Sobriety Checkpoint Program	1999	Lacey J., Jones R., Smith R.	National Highway Traffic Safety Administration (NHTSA), Washington D.C.	USA (Tenessee)	local	all	drunk drivers	1988-1996	
I13	Roadside police alcohol tests per 1,000 population	Road Safety Measures	User	percentage change	3 times increase in alcohol enforcement => -1.15% in total casualties	Individual effects	95% confidence intervals: -1.07% to -1.24%	not applicable	not applicable	Cost-benefit analysis of safety measures for vulnerable and inexperienced road users. TØI report 435.	1999	Elvik, R.	Institute of Transport Economics, Oslo.	Norway	national	all	all	unknown	
I13	Roadside police alcohol tests per 1,000 population	Road Safety Measures	User	percentage change	4 times increase in alcohol enforcement => reduction of drunk-driving fatalities from 30% of total fatalities to 20%	Individual effects	n/a	not applicable	not applicable	Worldwide Trends in Alcohol and Drug Impaired Driving	2007	Sweedler B.	Proceedings of ICADTS-T2007 Conference, August 26-30, 2007, Seattle, Washington.	UK	national	all	drunk drivers	1982-1998	
I13	Roadside police alcohol tests per 1,000 population	Road Safety Measures	User	yes / no	yes => -19 to -24% in fatal accidents in 'high alcohol hours'	Individual effects	n/a	not applicable	not applicable	Analysis of reductions in Victorian road casualties, 1989 to 1992	1994	Cameron M., Newstead S., Vulcan P.	Proceedings 17th ARRB Conference, Part 5, Australian Road Research Board, pp. 165–182	Australia (Melbourne)	local	urban - enforced sections only	drunk drivers	1989-1992	Effect refers to accidents in "high alcohol hours". An average of about 38% of serious casualty crashes in these hours involve a driver with a BAC over 0.05%.
I13	Roadside police alcohol tests per 1,000 population	Road Safety Measures	User	method	CBT & zero BAC for young drivers => -22.1% in night-time serious injury & fatal accidents	Individual effects	90% confidence intervals: -34.3% to -7.7%	not applicable	not applicable	Cost savings from a sustained compulsory breath testing and media campaign in New Zealand	2004	Miller T., Blewden M., Zhang J.- F.	Accident Analysis and Prevention 36 (2004), 783-794	New Zealand	national	all	drunk drivers	1987-1995	

SafeFITS MODEL PRIORITY INDICATOR					IDENTIFIED DETAILED CAUSALITY					REFERENCE / SOURCE OF DETAILED CAUSALITY				DATA USED					COMMENTS
no.	Description	Layer	Pillar	Variable Type	Equation / Relation	Type of study	Level of significance / R²	Type of statistical model	Explanatory variables of statistical model	Title	Issue Date	Author	Publisher	Origin	Adminis-trative level	Road types	Road user types	Time period	
I13	Roadside police alcohol tests per 1,000 population	Road Safety Measures	User	method	CBT & media campaign => -13.9% in night-time serious injury & fatal accidents	Individual effects	90% confidence intervals: -26.1% to -0.1%	not applicable	not applicable	Cost savings from a sustained compulsory breath testing and media campaign in New Zealand	2004	Miller T., Blewden M., Zhang J.- F.	Accident Analysis and Prevention 36 (2004), 783-794	New Zealand	national	all	drunk drivers	1994-1996	The estimate refers to further accident reduction after first implementing a "CBT & zero BAC for young drivers" approach.
I13	Roadside police alcohol tests per 1,000 population	Road Safety Measures	User	method	Booze buses => -27.4% in night-time serious injury & fatal accidents	Individual effects	90% confidence intervals: -40.8% to -11.0%	not applicable	not applicable	Cost savings from a sustained compulsory breath testing and media campaign in New Zealand	2004	Miller T., Blewden M., Zhang J.- F.	Accident Analysis and Prevention 36 (2004), 783-794	New Zealand (nortern North Island)	local	all	drunk drivers	1996-1997	The estimate refers to further accident reduction after first implementing a "CBT & zero BAC for young drivers" and then a "CBT & media campaign" approach.
I13	Roadside police alcohol tests per 1,000 population	Road Safety Measures	User	percentage change	3 times increase in alcohol enforcement => -9% in total fatalities	Meta-analysis	95% confidence intervals: -11% to -6%	not applicable	not applicable	Cost effective EU Transport Safety Measures	2003		European Transport Safety Council (ETSC)	11 European countries	national	enforced sections only	all	unknown	
I13	Roadside police alcohol tests per 1,000 population	Road Safety Measures	User	yes / no	yes (RBT) => -22% in drunk-driving fatalities	Meta-analysis	Interquartile range (IQR): -35% to -14%	not applicable	not applicable	Effectiveness of Sobriety Checkpoints for Reducing Alcohol-Involved Crashes	2002	Elder R., Shults R., Sleet D., Nichols J., Zaza S., & Thompson R.	Traffic Injury Prevention, 3 (2002), 266-274	Australia (4studies) & France (1 study)	local	enforced sections only	drunk drivers	1981-1997	Time period refers to publication dates of original studies.
I13	Roadside police alcohol tests per 1,000 population	Road Safety Measures	User	yes / no	yes (RBT) => -16% in drunk-driving fatal & non-fatal injury accidents	Meta-analysis	Interquartile range (IQR): -20% to -11%	not applicable	not applicable	Effectiveness of Sobriety Checkpoints for Reducing Alcohol-Involved Crashes	2002	Elder R., Shults R., Sleet D., Nichols J., Zaza S., & Thompson R.	Traffic Injury Prevention, 3 (2002), 266-274	Australia (9 studies) & France (1 study)	local	enforced sections only	drunk drivers	1981-1997	Time period refers to publication dates of original studies.
I13	Roadside police alcohol tests per 1,000 population	Road Safety Measures	User	yes / no	yes (SBT) => -23% in drunk-driving fatalities	Meta-analysis	n/a	not applicable	not applicable	Effectiveness of Sobriety Checkpoints for Reducing Alcohol-Involved Crashes	2002	Elder R., Shults R., Sleet D., Nichols J., Zaza S., & Thompson R.	Traffic Injury Prevention, 3 (2002), 266-274	USA & Canada	local	urban - enforced sections only	drunk drivers	1985-1999	Time period refers to publication dates of original studies.
I13	Roadside police alcohol tests per 1,000 population	Road Safety Measures	User	yes / no	yes (SBT) => -20% in drunk-driving fatal & non-fatal injury accidents	Meta-analysis	Interquartile range (IQR): -23% to -9%	not applicable	not applicable	Effectiveness of Sobriety Checkpoints for Reducing Alcohol-Involved Crashes	2002	Elder R., Shults R., Sleet D., Nichols J., Zaza S., & Thompson R.	Traffic Injury Prevention, 3 (2002), 266-274	USA & Canada	local	urban - enforced sections only	drunk drivers	1985-1999	Time period refers to publication dates of original studies.
I13	Roadside police alcohol tests per 1,000 population	Road Safety Measures	User	yes / no	yes => -9% in total accidents in affected road sections	Meta-analysis	95% confidence intervals: -12% to -7%	not applicable	not applicable	The Handbook of Road Safety Measures (2nd Edition)	2009	Elvik R., Hoye A., Vaa T. & Sorensen M.	Emerald Group Publishing Ltd	40 studies from high-income countries	national	enforced sections only	all	1981-2005	Time period refers to publication dates of original studies.
I13	Roadside police alcohol tests per 1,000 population	Road Safety Measures	User	yes / no	yes => -13% in total accidents in affected road sections	Meta-analysis	95% confidence intervals: -14% to -12%	not applicable	not applicable	The Handbook of Road Safety Measures (2nd Edition)	2009	Elvik R., Hoye A., Vaa T. & Sorensen M.	Emerald Group Publishing Ltd	Australia (19 studies)	national	enforced sections only	all	1981-2005	Time period refers to publication dates of original studies.
I13	Roadside police alcohol tests per 1,000 population	Road Safety Measures	User	arithmetic value	No. of single-vehicle night-time accidents estimated according to model (Table 3.2.13.3)	Statistical Model	n/a	Log-linear regression	- RBT - introduction - RBT - program - RBT - ongoing enforcement - Seasonal Term - Day of week - Type of day (school holiday etc.) - Road usage - GDP - Alcohol consumption - Exp. disposable income - Unemployment - Rainfall - Time - BAC legislation	The Long-Term Effects of Random Breath Testing in four Australian States: A Time Series Analysis.Report No. CR 162.	1997	Henstridge J., Homel R., Mackay PJ.	Dpt of Transport & Regional Development, Federal Office of Road Safety. Canberra, Australia	Australia (New South Wales)	local	all	drunk drivers	1976-1992	Effect refers to number of single-vehicle night-time accidents
I13	Roadside police alcohol tests per 1,000 population	Road Safety Measures	User	arithmetic value	No. of single-vehicle night-time accidents estimated according to model (Table 3.2.13.4)	Statistical Model	n/a	Log-linear regression	- RBT - Seasonal Term - Day of week - Type of day (school holiday etc.) - Road usage - Exp. disposable income - Unemployment - Maximum - Rainfall - Time	The Long-Term Effects of Random Breath Testing in four Australian States: A Time Series Analysis.Report No. CR 162.	1997	Henstridge J., Homel R., Mackay PJ.	Dpt of Transport & Regional Development, Federal Office of Road Safety. Canberra, Australia	Australia (Western Australia)	local	all	drunk drivers	1980-1992	Effect refers to number of single-vehicle night-time accidents
I13	Roadside police alcohol tests per 1,000 population	Road Safety Measures	User	arithmetic value	No. of injury accidents estimated according to model (Table 3.2.12.1)	Statistical Model	n/a	Negative binomial regression	- No. of alcohol controls - No. of speed violations - % of national road network (different model per county)	Multilevel modeling for the regional effect of enforcement on road accidents	2007	Yannis G., Papadimitriou E., Antoniou C.	Accident Analysis and Prevention, 39 (2007), 818-825	Greece (Athens & Thessaloniki metropolitan areas excluded)	local	rural roads	all	1998-2002	1. Effects refer to number of injury accidents. 2. Modelling approach focuses on regional differences.
I13	Roadside police alcohol tests per 1,000 population	Road Safety Measures	User	arithmetic value	No. of injury accidents estimated according to model (Table 3.2.13.5)	Statistical Model	n/a	Hybrid extra-Poisson multilevel regression	- No.of alcohol controls - Regional effect	Impact of enforcement on traffic accidents and fatalities: A multivariate multilevel analysis	2008	Yannis G., Papadimitriou E., Antoniou C.	Safety Science, Vol. 46 (2008), 738-750	Greece (Athens & Thessaloniki metropolitan areas excluded)	local	rural roads	all	1998-2002	
I13	Roadside police alcohol tests per 1,000 population	Road Safety Measures	User	arithmetic value	No. of fatalities estimated according to model (Table 3.2.13.5)	Statistical Model	n/a	Hybrid extra-Poisson multilevel regression	- No.of alcohol controls - Regional effect	Impact of enforcement on traffic accidents and fatalities: A multivariate multilevel analysis	2008	Yannis G., Papadimitriou E., Antoniou C.	Safety Science, Vol. 46 (2008), 738-750	Greece (Athens & Thessaloniki metropolitan areas excluded)	local	rural roads	all	1998-2002	

Table A.14
Identified relations regarding indicator I14 ("Roadside police speed checks per 1,000 population")

SafeFITS MODEL PRIORITY INDICATOR					IDENTIFIED DETAILED CAUSALITY					REFERENCE / SOURCE OF DETAILED CAUSALITY				DATA USED					COMMENTS
no.	Description	Layer	Pillar	Variable Type	Equation / Relation	Type of study	Level of significance / R²	Type of statistical model	Explanatory variables of statistical model	Title	Issue Date	Author	Publisher	Origin	Adminis-trative level	Road types	Road user types	Time period	
I14	Roadside police speed checks per 1,000 population	Road Safety Measures	User	arithmetic value	3,300 police speed checks per 1,000 population annually => -4.2% in injury accidents in affected road sections per year	Individual effects	n/a	not applicable	not applicable	The effects of speed enforcement with mobile radar on speed and accidents: an evaluation study on rural roads in the Dutch province Friesland	2005	Goldenbeld C., van Schagen I.	Accident Analysis and Prevention 37 (6), 1135-1144	the Netherlands (Friesland province)	local	rural - enforced sections only	all	1990-2002	
I14	Roadside police speed checks per 1,000 population	Road Safety Measures	User	arithmetic value	3,300 police speed checks per 1,000 population annually => -4.2% in fatalities & injuries in affected road sections per year	Individual effects	n/a	not applicable	not applicable	The effects of speed enforcement with mobile radar on speed and accidents: an evaluation study on rural roads in the Dutch province Friesland	2005	Goldenbeld C., van Schagen I.	Accident Analysis and Prevention 37 (6), 1135-1144	the Netherlands (Friesland province)	local	rural - enforced sections only	all	1990-2002	
I14	Roadside police speed checks per 1,000 population	Road Safety Measures	User	arithmetic value	99.4 police speed checks per 1,000 population annually => -10.2% in speed related accidents (injury & PDO) in affected road sections per year	Individual effects	n/a	not applicable	not applicable	Experimental evaluation of municipal speed enforcement programs	1995	Stuster J.	National Highway Traffic Safety Administration (NHTSA), Washington DC	USA (California: Modesto, San Bernardino & Salinas cities)	local	urban- enforced sections only	all	1990-2002	Effect refers to all **speed-related** accidents (injury and PDO), i.e. 'unsafe speed', 'following-too-closely' or 'right-of-way violation' as the primary collision factor
I14	Roadside police speed checks per 1,000 population	Road Safety Measures	User	percentage change	3 times increase in speed enforcement => -3.94% in total casualties	Individual effects	95% confidence intervals: -1.58% to -6.32%	not applicable	not applicable	Cost-benefit analysis of safety measures for vulnerable and inexperienced road users. TØI report 435.	1999	Elvik, R.	Institute of Transport Economics, Oslo.	Norway	national	all	all	unknown	
I14	Roadside police speed checks per 1,000 population	Road Safety Measures	User	method	stationary visible enforcement => -17% in total accidents in affected road sections	Meta-analysis	95% confidence intervals: -31% to -2%	not applicable	not applicable	The Handbook of Road Safety Measures (2nd Edition)	2009	Elvik R., Hoye A., Vaa T. & Sorensen M.	Emerald Group Publishing Ltd	Australia, Sweden, Finland	national	enforced sections only	all	1966-2002	Time period refers to publication dates of original studies.
I14	Roadside police speed checks per 1,000 population	Road Safety Measures	User	method	one patrolling unit => not significant effect	Meta-analysis	95% confidence intervals: -5% to +4%	not applicable	not applicable	The Handbook of Road Safety Measures (2nd Edition)	2009	Elvik R., Hoye A., Vaa T. & Sorensen M.	Emerald Group Publishing Ltd	USA	national	enforced sections only	all	1961-2002	Time period refers to publication dates of original studies.
I14	Roadside police speed checks per 1,000 population	Road Safety Measures	User	method	composite enforcement => not significant effect	Meta-analysis	95% confidence intervals: -11% to +9%	not applicable	not applicable	The Handbook of Road Safety Measures (2nd Edition)	2009	Elvik R., Hoye A., Vaa T. & Sorensen M.	Emerald Group Publishing Ltd	high-income countries	national	enforced sections only	all	1966-2002	Time period refers to publication dates of original studies.
I14	Roadside police speed checks per 1,000 population	Road Safety Measures	User	arithmetic value	No. of injury accidents estimated according to model (Table 3.2.12.1)	Statistical Model	n/a	Negative binomial regression	- No. of alcohol controls - No. of speed violations - % of national road network (different model per county)	Multilevel modeling for the regional effect of enforcement on road accidents	2007	Yannis G., Papadimitriou E., Antoniou C.	Accident Analysis and Prevention, 39 (2007), 818-825	Greece (Athens & Thessaloniki metropolitan areas excluded)	local	rural roads	all	1998-2002	1. Effects refer to number of injury accidents. 2. Modelling approach focuses on regional differences.

Table A.15
Identified relations regarding indicator I15 ("Share of High Risk Sites treated")

SafeFITS MODEL PRIORITY INDICATOR					IDENTIFIED DETAILED CAUSALITY					REFERENCE / SOURCE OF DETAILED CAUSALITY				DATA USED					COMMENTS
no.	Description	Layer	Pillar	Variable Type	Equation / Relation	Type of study	Level of significance / R^2	Type of statistical model	Explanatory variables of statistical model	Title	Issue Date	Author	Publisher	Origin	Adminis-trative level	Road types	Road user types	Time period	
I15	Share of High Risk Sites treated	Road Safety Performance Indicators	Road Infrastructure	yes / no	yes => -26.4% in injury accidents	Individual effects	reported as significant	not applicable	not applicable	Evaluation of the 1992–1996 Transport Accident Commission funded accident black spot treatment program in Victoria. Report No. 182.	2001	Newstead S., Corben B.	Monash University Accident Research Centre, Melbourne, Australia.	Australia (Victoria)	local	treated sections / sites only	all	1987-1998	Effects refer to treated sites only.
I15	Share of High Risk Sites treated	Road Safety Performance Indicators	Road Infrastructure	yes / no	yes => -31.3% in injury accidents	Individual effects	reported as significant	not applicable	not applicable	Evaluation of the Effectiveness of the $240M Statewide Blackspot Program – Accident Blackspot Component, Project Number RSD-0130	2006	Scully J., Newstead S.,Corben B. & Candappa N.	Monash University Accident Research Centre, Melbourne, Australia.	Australia (Victoria)	local	treated sections / sites only	all	2000-2005	Effects refer to treated sites only.
I15	Share of High Risk Sites treated	Road Safety Performance Indicators	Road Infrastructure	yes / no	yes => -27.0% in injury accidents	Individual effects	reported as significant	not applicable	not applicable	Evaluation of the Effectiveness of the $240M Statewide Blackspot Program – Accident Blackspot Component, Project Number RSD-0130	2006	Scully J., Newstead S.,Corben B. & Candappa N.	Monash University Accident Research Centre, Melbourne, Australia.	Australia (Victoria)	local	urban -treated sections / sites only	all	2000-2005	Effects refer to treated sites only.
I15	Share of High Risk Sites treated	Road Safety Performance Indicators	Road Infrastructure	yes / no	yes => -41.8% in injury accidents	Individual effects	reported as significant	not applicable	not applicable	Evaluation of the Effectiveness of the $240M Statewide Blackspot Program – Accident Blackspot Component, Project Number RSD-0130	2006	Scully J., Newstead S.,Corben B. & Candappa N.	Monash University Accident Research Centre, Melbourne, Australia.	Australia (Victoria)	local	rural -treated sections / sites only	all	2000-2005	Effects refer to treated sites only.
I15	Share of High Risk Sites treated	Road Safety Performance Indicators	Road Infrastructure	yes / no	yes => -14.6% in all reported accidents (injury & PDO)	Individual effects	< 0.1%	not applicable	not applicable	Effectiveness of the Black Spot Programs in Western Australia	2006	Meuleners L., Hendrie D., Lee A. H. & Legge M.	Accident Analysis and Prevention, 40 (2008), 1211-1216.	Australia (Western Australia)	local	treated sections / sites only	all	2000-2002	Effects refer to treated sites only.
I15	Share of High Risk Sites treated	Road Safety Performance Indicators	Road Infrastructure	yes / no	yes => -15.7% in all reported accidents (injury & PDO)	Individual effects	< 0.1%	not applicable	not applicable	Effectiveness of the Black Spot Programs in Western Australia	2006	Meuleners L., Hendrie D., Lee A. H. & Legge M.	Accident Analysis and Prevention, 40 (2008), 1211-1216.	Australia (Western Australia)	local	urban -treated sections / sites only	all	2000-2002	Effects refer to treated sites only.
I15	Share of High Risk Sites treated	Road Safety Performance Indicators	Road Infrastructure	yes / no	yes => -13.6% in all reported accidents (injury & PDO)	Individual effects	< 0.1%	not applicable	not applicable	Effectiveness of the Black Spot Programs in Western Australia	2006	Meuleners L., Hendrie D., Lee A. H. & Legge M.	Accident Analysis and Prevention, 40 (2008), 1211-1216.	Australia (Western Australia)	local	rural -treated sections / sites only	all	2000-2002	Effects refer to treated sites only.
I15	Share of High Risk Sites treated	Road Safety Performance Indicators	Road Infrastructure	yes / no	yes => -31.2% in injury accidents	Individual effects	1%	not applicable	not applicable	The black spot program 1996–2002 - An evaluation of the first three years. BTE Report 104	2001	Williams C., Amoako J., Simpson M.	Bureau of Transport Economics (BTE), Canberra	Australia	national	urban -treated sections / sites only	all	1988-1997	Effects refer to treated sites only.
I15	Share of High Risk Sites treated	Road Safety Performance Indicators	Road Infrastructure	yes / no	yes => -48.2% in injury accidents	Individual effects	1%	not applicable	not applicable	The black spot program 1996–2002 - An evaluation of the first three years. BTE Report 104	2001	Williams C., Amoako J., Simpson M.	Bureau of Transport Economics (BTE), Canberra	Australia	national	rural -treated sections / sites only	all	1988-1997	Effects refer to treated sites only.
I15	Share of High Risk Sites treated	Road Safety Performance Indicators	Road Infrastructure	yes / no	yes => -26% in injury accidents	Meta-analysis	95% confidence intervals: -27% to -25%	not applicable	not applicable	The Handbook of Road Safety Measures (2nd Edition)	2009	Elvik R., Hoye A., Vaa T. & Sorensen M.	Emerald Group Publishing Ltd	52 studies from high-income countries	local	treated sections / sites only	all	1697-2008	1. Time period refers to publication dates of original studies. 2. Effects refer to treated sites only.
I15	Share of High Risk Sites treated	Road Safety Performance Indicators	Road Infrastructure	yes / no	yes => -30% in injury accidents	Meta-analysis	95% confidence intervals: -31% to -28%	not applicable	not applicable	The Handbook of Road Safety Measures (2nd Edition)	2009	Elvik R., Hoye A., Vaa T. & Sorensen M.	Emerald Group Publishing Ltd	52 studies from high-income countries	local	urban -treated sections / sites only	all	1697-2008	1. Time period refers to publication dates of original studies. 2. Effects refer to treated sites only.
I15	Share of High Risk Sites treated	Road Safety Performance Indicators	Road Infrastructure	yes / no	yes => -43% in injury accidents	Meta-analysis	95% confidence intervals: -47% to -39%	not applicable	not applicable	The Handbook of Road Safety Measures (2nd Edition)	2009	Elvik R., Hoye A., Vaa T. & Sorensen M.	Emerald Group Publishing Ltd	52 studies from high-income countries	local	rural -treated sections / sites only	all	1697-2008	1. Time period refers to publication dates of original studies. 2. Effects refer to treated sites only.

Table A.16
Identified relations regarding indicator I16 ("Percentage of rural road network not satisfying design standards")

SafeFITS MODEL PRIORITY INDICATOR					IDENTIFIED DETAILED CAUSALITY					REFERENCE / SOURCE OF DETAILED CAUSALITY				DATA USED					COMMENTS
no	Description	Layer	Pillar	Variable Type	Equation / Relation	Type of study	Level of significance / R^2	Type of statistical model	Explanatory variables of statistical model	Title	Issue Date	Author	Publisher	Origin	Adminis-trative level	Road types	Road user types	Time period	
I16	Percentage of rural road network not satisfying design standards	Road Safety Performance Indicators	Road Infrastructure	yes / no	reconstruction according to standards => -20% in injury accidents	Meta-analysis	95% confidence intervals: -25% to -15%	not applicable	not applicable	The Handbook of Road Safety Measures (2nd Edition)	2009	Elvik R., Hoye A., Vaa T. & Sorensen M.	Emerald Group Publishing Ltd	Sweden, Denmark, UK, USA	national	rural roads	all	1976-1992	Time period refers to publication dates of original studies.

Table A.17
Identified relations regarding indicator I17 ("Daytime helmet wearing rates for motorcycles")

SafeFITS MODEL PRIORITY INDICATOR					IDENTIFIED DETAILED CAUSALITY					REFERENCE / SOURCE OF DETAILED CAUSALITY				DATA USED					COMMENTS
no.	Description	Layer	Pillar	Variable Type	Equation / Relation	Type of study	Level of significance / R^2	Type of statistical model	Explanatory variables of statistical model	Title	Issue Date	Author	Publisher	Origin	Adminis-trative level	Road types	Road user types	Time period	
I17	Daytime helmet wearing rates for motorcycles	Road Safety Performance Indicators	User	percentage change	increase from 44% to 98% in helmet use => -10% in PTW fatalities per 10,000 registered PTWs	Individual effects	not significant	not applicable	not applicable	The reinstated comprehensive motorcycle helmet law in Texas. Insurance Institute for Highway Safety	1992	Mounce N., Brackett Q., Hinshaw W., Lund A., Wells J.	Insurance Institute for Highway Safety. Arlington VA	USA (Texas)	local	all	PTWs	1985-1990	Possible influence of other factors has not been statistically controlled.
I17	Daytime helmet wearing rates for motorcycles	Road Safety Performance Indicators	User	percentage change	increase from 44% to 98% in helmet use => - 11% in PTW serious injuries & fatalities per 10,000 registered PTWs	Individual effects	5%	not applicable	not applicable	The reinstated comprehensive motorcycle helmet law in Texas. Insurance Institute for Highway Safety	1992	Mounce N., Brackett Q., Hinshaw W., Lund A., Wells J.	Insurance Institute for Highway Safety. Arlington VA	USA (Texas)	local	all	PTWs	1985-1990	Possible influence of other factors has not been statistically controlled.
I17	Daytime helmet wearing rates for motorcycles	Road Safety Performance Indicators	User	percentage change	decrease from 95% to 50% in helmet use => +20.8% in PTW fatalities per 10,000 registered PTWs	Individual effects	not tested	not applicable	not applicable	Florida Motorcycle Helmet Use: Observational Survey and Trend Analysis	2004	Turner P., Hagelin C., Chu X., Greenman M., Read J., West M.	Center for Urban Transportation Research - University of South Florida	USA (Florida)	local	all	PTWs	1999-2001	Possible influence of other factors has not been statistically controlled.
I17	Daytime helmet wearing rates for motorcycles	Road Safety Performance Indicators	User	percentage change	decrease from 95% to 50% in helmet use => +13.8% in PTW fatalities per 100 million PTW Vehicle Miles Travelled	Individual effects	not tested	not applicable	not applicable	Florida Motorcycle Helmet Use: Observational Survey and Trend Analysis	2004	Turner P., Hagelin C., Chu X., Greenman M., Read J., West M.	Center for Urban Transportation Research - University of South Florida	USA (Florida)	local	all	PTWs	1999-2001	
I17	Daytime helmet wearing rates for motorcycles	Road Safety Performance Indicators	User	percentage change	decrease from 95% to 50% in helmet use => +9.1% in PTW fatalities (controlled for no. of registered PTWs and for nationwide trends)	Individual effects	1%	not applicable	not applicable	Evaluation of the repeal of the all-rider motorcycle helmet law in Florida	2005	Ulmer R., Northrup V.S.	National Highway Traffic Safety Administration (NHTSA), Washington DC	USA (Florida)	local	all	PTWs	1998-2002	
I17	Daytime helmet wearing rates for motorcycles	Road Safety Performance Indicators	User	percentage change	decrease from 97% to 52% in helmet use => +21% in PTW fatalities	Individual effects	not tested	not applicable	not applicable	Evaluation of motorcycle helmet law repeal in Arkansas and Texas	2000	Preusser D.F., Hedlund J.H., Ulmer R.G.	National Highway Traffic Safety Administration (NHTSA), Washington DC	USA (Arkansas)	local	all	PTWs	1996-1998	Possible influence of other factors has not been statistically controlled.
I17	Daytime helmet wearing rates for motorcycles	Road Safety Performance Indicators	User	percentage change	decrease from 97% to 66% in helmet use => +31% in PTW fatalities	Individual effects	not tested	not applicable	not applicable	Evaluation of motorcycle helmet law repeal in Arkansas and Texas	2000	Preusser D.F., Hedlund J.H., Ulmer R.G.	National Highway Traffic Safety Administration (NHTSA), Washington DC	USA (Texas)	local	all	PTWs	1996-1998	Possible influence of other factors has not been statistically controlled.
I17	Daytime helmet wearing rates for motorcycles	Road Safety Performance Indicators	User	percentage change	decrease from 96% to 64% in helmet use => +37.5% in PTW fatalities per 10,000 registered PTWs	Individual effects	not tested	not applicable	not applicable	Evaluation of the Repeal of Motorcycle Helmet Laws in Kentucky and Louisiana	2003	Ulmer R.G. & Preusser D.F.	National Highway Traffic Safety Administration (NHTSA), Washington DC	USA (Kentucky)	local	all	PTWs	1996-2000	Possible influence of other factors has not been statistically controlled.
I17	Daytime helmet wearing rates for motorcycles	Road Safety Performance Indicators	User	percentage change	decrease from 100% to 52% in helmet use => +75% in PTW fatalities per 10,000 registered PTWs	Individual effects	not tested	not applicable	not applicable	Evaluation of the Repeal of Motorcycle Helmet Laws in Kentucky and Louisiana	2003	Ulmer R.G. & Preusser D.F.	National Highway Traffic Safety Administration (NHTSA), Washington DC	USA (Louisiana)	local	all	PTWs	1996-2000	Possible influence of other factors has not been statistically controlled.
I17	Daytime helmet wearing rates for motorcycles	Road Safety Performance Indicators	User	percentage change	increase from 19.5% to 97.5% in helmet use => - 31.7% in PTW traumatic brain injury (TBI) admissions per 10,000 registered PTWs	Individual effects	0.1%	not applicable	not applicable	Effect of Italy's motorcycle helmet law on traumatic brain injuries	2003	Servadei F., Begliomini C., Gardini E., Giustini M., Taggi F., Kraus J.	Injury Prevention 9 (2003), 257–260	Italy (Romagna region)	local	all	PTWs	1999-2001	1. Effects refer to number of PTW- related traumatic brain injury (TBI) admissions (not fatalities).
I17	Daytime helmet wearing rates for motorcycles	Road Safety Performance Indicators	User	percentage change	increase from 21% to 96% in helmet use => - 33% in PTW head injuries	Individual effects	0.1%	not applicable	not applicable	The Effect of the Taiwan Motorcycle Helmet Use Law on Head Injuries	2000	Chiu W.T., Kuo C.Y., Hung C.C., Chen M.	American Journal of Public Health, 90 (2000), 793 – 796	Taiwan	national	all	PTWs	1996-1998	1. Effects refer to number of motorcycle-related head injuries (not fatalities). 2. Possible influence of other factors has not been statistically controlled.
I17	Daytime helmet wearing rates for motorcycles	Road Safety Performance Indicators	User	percentage change	increase from 4.5% to 22.6% in helmet use => -20.8% in fatalities among injured PTWs	Individual effects	not significant	not applicable	not applicable	Effect of the helmet act for motorcyclists in Thailand	2003	Ichikawa M., Chadbunchachai W., Marui E.	Accident Analysis and Prevention 35 (2003), 183-189	Thailand	local	all	PTWs	1994-1997	1. Analysis restricted on injured PTWs only. 2. Possible influence of other factors has not been statistically controlled.

Table A.18
Identified relations regarding indicator I18 ("Seat belt wearing rates on front seats of cars")

SafeFITS MODEL PRIORITY INDICATOR					IDENTIFIED DETAILED CAUSALITY					REFERENCE / SOURCE OF DETAILED CAUSALITY				DATA USED					COMMENTS
no.	Description	Layer	Pillar	Variable Type	Equation / Relation	Type of study	Level of significance / R^2	Type of statistical model	Explanatory variables of statistical model	Title	Issue Date	Author	Publisher	Origin	Adminis-trative level	Road types	Road user types	Time period	
I18	Seat belt wearing rates on front seats of cars	Road Safety Performance Indicators	User	percentage change	increase from 64% to 77% in seat belt use => -9% in fatalities	Individual effects	not tested	not applicable	not applicable	Increasing seat belt use in North Carolina	1996	Williams A., Reinfurt D. & Wells J.	Journal of Safety Research, 27(1), 33-41	USA (North Carolina)	local	all	front seat car occupants	1992-1994	Possible influence of other factors has not been statistically controlled.
I18	Seat belt wearing rates on front seats of cars	Road Safety Performance Indicators	User	percentage change	increase from 83% to 93% in seat belt use => -13.4% in fatalities	Individual effects	not tested	not applicable	not applicable	Ninety five percent: An evaluation of law, policy, and programs to promote seat belt use in Washington state	2004	Salzberg P. & Moffat J.	Journal of Safety Research (2004), 35, 215-222	USA (Washington state)	local	all	front seat car occupants	2001-2003	Possible influence of other factors has not been statistically controlled.
I18	Seat belt wearing rates on front seats of cars	Road Safety Performance Indicators	User	percentage change	increase by 15 percentage points in seat belt use => -10.3% in fatalities	Individual effects	0.1%	not applicable	not applicable	How States Achieve High Seat Belt Use Rates. Report No. DOT HS 810 962	2008	Hedlund J., Gilbert H., Ledingham K. & Preusser D.	National Highway Traffic Safety Administration (NHTSA). Washington D.C.	USA (Michigan)	local	all	front seat car occupants	2000	Possible influence of other factors has not been statistically controlled.
I18	Seat belt wearing rates on front seats of cars	Road Safety Performance Indicators	User	percentage change	increase by 10.8 percentage points in seat belt use => -1.9% in fatalities	Individual effects	10%	not applicable	not applicable	How States Achieve High Seat Belt Use Rates. Report No. DOT HS 810 962	2008	Hedlund J., Gilbert H., Ledingham K. & Preusser D.	National Highway Traffic Safety Administration (NHTSA). Washington D.C.	USA (New Jersey)	local	all	front seat car occupants	2000	Possible influence of other factors has not been statistically controlled.
I18	Seat belt wearing rates on front seats of cars	Road Safety Performance Indicators	User	percentage change	increase by 17.4 percentage points in seat belt use => -4.7% in fatalities	Individual effects	5%	not applicable	not applicable	How States Achieve High Seat Belt Use Rates. Report No. DOT HS 810 962	2008	Hedlund J., Gilbert H., Ledingham K. & Preusser D.	National Highway Traffic Safety Administration (NHTSA). Washington D.C.	USA (Washington state)	local	all	front seat car occupants	2002	Possible influence of other factors has not been statistically controlled.
I18	Seat belt wearing rates on front seats of cars	Road Safety Performance Indicators	User	percentage change	increase by 18.9 percentage points in seat belt use => +1.2% in fatalities	Individual effects	10%	not applicable	not applicable	How States Achieve High Seat Belt Use Rates. Report No. DOT HS 810 962	2008	Hedlund J., Gilbert H., Ledingham K. & Preusser D.	National Highway Traffic Safety Administration (NHTSA). Washington D.C.	USA (Delaware)	local	all	front seat car occupants	2003	Possible influence of other factors has not been statistically controlled.
I18	Seat belt wearing rates on front seats of cars	Road Safety Performance Indicators	User	percentage change	higher by 14% percentage points seat belt use => -18.6% in fatalities	Individual effects	not tested	not applicable	not applicable	States with primary enforcement laws have lower fatality rates. Traffic Safety Facts Research Note, DOT HS 810 557.	2006	Liu C., Lindsey T., Chen C.-L. & Utter D.	National Highway Traffic Safety Administration (NHTSA). Washington D.C.	USA (all states)	national	all	front & rear seat car occupants	2000-2004	1. Cross-sectional approach 2. Seat belt wearing rates refer to all vehicle occupants and not only front seat occupants
I18	Seat belt wearing rates on front seats of cars	Road Safety Performance Indicators	User	percentage change	increase of <25% in seat belt use => -7% in fatalities	Meta-analysis	95% confidence intervals: -9% to -5%	not applicable	not applicable	The Handbook of Road Safety Measures (2nd Edition)	2009	Elvik R., Hoye A., Vaa T. & Sorensen M.	Emerald Group Publishing Ltd	25 studies from high-income countries	national	all	front seat car occupants	1970's-1990's	Time period refers to publication dates of original studies.
I18	Seat belt wearing rates on front seats of cars	Road Safety Performance Indicators	User	percentage change	increase of 25%-50% in seat belt use => -8% in fatalities	Meta-analysis	95% confidence intervals: -9% to -7%	not applicable	not applicable	The Handbook of Road Safety Measures (2nd Edition)	2009	Elvik R., Hoye A., Vaa T. & Sorensen M.	Emerald Group Publishing Ltd	25 studies from high-income countries	national	all	front seat car occupants	1970's-1990's	Time period refers to publication dates of original studies.
I18	Seat belt wearing rates on front seats of cars	Road Safety Performance Indicators	User	percentage change	increase of >50% in seat belt use => -21% in fatalities	Meta-analysis	95% confidence intervals: -22% to -20%	not applicable	not applicable	The Handbook of Road Safety Measures (2nd Edition)	2009	Elvik R., Hoye A., Vaa T. & Sorensen M.	Emerald Group Publishing Ltd	25 studies from high-income countries	national	all	front seat car occupants	1970's-1990's	Time period refers to publication dates of original studies.
I18	Seat belt wearing rates on front seats of cars	Road Safety Performance Indicators	User	percentage change	increase of <25% in seat belt use => +0.7% in all injuries	Meta-analysis	95% confidence intervals: +0.4% to +1%	not applicable	not applicable	The Handbook of Road Safety Measures (2nd Edition)	2009	Elvik R., Hoye A., Vaa T. & Sorensen M.	Emerald Group Publishing Ltd	25 studies from high-income countries	national	all	front seat car occupants	1970's-1990's	Time period refers to publication dates of original studies.
I18	Seat belt wearing rates on front seats of cars	Road Safety Performance Indicators	User	percentage change	increase of 25%-50% in seat belt use => -14% in all injuries	Meta-analysis	95% confidence intervals: -15% to -13%	not applicable	not applicable	The Handbook of Road Safety Measures (2nd Edition)	2009	Elvik R., Hoye A., Vaa T. & Sorensen M.	Emerald Group Publishing Ltd	25 studies from high-income countries	national	all	front seat car occupants	1970's-1990's	Time period refers to publication dates of original studies.
I18	Seat belt wearing rates on front seats of cars	Road Safety Performance Indicators	User	percentage change	increase of >50% in seat belt use => -16% in all injuries	Meta-analysis	95% confidence intervals: -16% to -15%	not applicable	not applicable	The Handbook of Road Safety Measures (2nd Edition)	2009	Elvik R., Hoye A., Vaa T. & Sorensen M.	Emerald Group Publishing Ltd	25 studies from high-income countries	national	all	front seat car occupants	1970's-1990's	Time period refers to publication dates of original studies.

Table A.19
Identified relations regarding indicator I19 ("Mean EMS response time")

SafeFITS MODEL PRIORITY INDICATOR					IDENTIFIED DETAILED CAUSALITY					REFERENCE / SOURCE OF DETAILED CAUSALITY				DATA USED					COMMENTS
no.	Description	Layer	Pillar	Variable Type	Equation / Relation	Type of study	Level of significance / R^2	Type of statistical model	Explanatory variables of statistical model	Title	Issue Date	Author	Publisher	Origin	Adminis-trative level	Road types	Road user types	Time period	
I19	Mean EMS response time	Road Safety Performance Indicators	Post-Crash Services	arithmetic value	pre-hospital time > 1h. => 3times more likely not to survive 6days at hospital	Individual effects	95% confidence intervals: 1.27 to 5.06	not applicable	not applicable	Impact of on-site care, prehospital time, and level of in-hospital care on survival in severely injured patients	1993	Sampalis J.S., Lavoie A., Williams J.I. et al.	Journal of Trauma, 34 (1993), 252-261	unknown	unknown	all	injured - admitted in hospital	1990	
I19	Mean EMS response time	Road Safety Performance Indicators	Post-Crash Services	general trend	unexpected survivors exhibited shorter EMS mean response time (3.5 ± 1.2 minutes) compared to unexpected deaths (5.9 ± 4.3 minutes)	Individual effects	5%	not applicable	not applicable	Does out-of-hospital EMS time affect trauma survival?	1995	Feero S., Hedges J., Simmons E. & Irwin L.	American Journal of Emergency Medicine, 13, 133–135	USA (city of Protland, Oregon)	local	urban roads	injured - admitted in hospital	1990	
I19	Mean EMS response time	Road Safety Performance Indicators	Post-Crash Services	general trend	1minute reduction in EMS response time => 1% reduction in accident consequences	Individual effects	n/a	not applicable	not applicable	Building on a Data Foundation: France's National ITS Policy in Focus.	1998	Bernard-Gely A.	Traffic Technology International, June/July, UK and International Press, Surrey	France	national	all	injured - admitted in hospital	unknown	

Appendix B. Overview of the SafeFITS database

Table B.1 - Overview of the SafeFITS database

No	Application indicator label	Definition	Source
1		Population in thousands (2013)	World Bank Database
2		Area (sq km) (2013 or latest available year)	World Bank Database
3		Projected Gross Domestic Product per capita in 2010 US $ (2015-2030)	ERS International Macroeconomic Dataset
4		Gross national income per capita in US $ (2013 or latest available year)	World Bank Database
5	EM2_lt15yo	Percentage of popualtion under 15 years old (2013)	World Bank Database
6	EM3_gt65yo	Percentage of popualtion over 65 years old (2013)	World Bank Database
7	EM4_UrbanPop	Percentage of urban population (2013)	World Bank Database
8	EM5_LeadAgency	Existence of a road safety lead agency (2013)	WHO, 2015
9	EM6_LeadAgencyFunded	The lead agency is funded (2013)	WHO, 2015
10	EM7_NationalStrategy	Existence of national road safety strategy (2013)	WHO, 2015
11	EM8_NationalStrategyFunded	The strategy is funded (2013)	WHO, 2015
12	EM9_FatalityTargets	Existence of fatality reduction target (2013)	WHO, 2015
13		Length of total road network (km) (2013 or latest availbale year)	IRF, 2015
14	TE2_Motorways	Percentage of motorways of total road network (2013 or latest available year)	IRF, 2015
15	TE3_PavedRoads	Percentage of paved roads of total road network (2013 or latest available year)	IRF, 2015
16	TE4_VehiclesPerPop	Total number of vehicles in use (2013 or latest availble year)	IRF, 2015
17	TE5_PassCars	Number of passenger cars in use (2013 or latest availble year)	IRF, 2015
18		Number of buses/motorcoaches in use (2013 or latest availble year)	IRF, 2015
19	TE6_VansLorries	Number of vans and lorries in use (2013 or latest availble year)	IRF, 2015
20	TE7_PTW	Number of powered two wheelers in use (2013 or latest availble year)	IRF, 2015
21	TE8_Vehkm_Total	Total number of vehicle kilometers in millions (2013 or latest available year)	IRF, 2015
22		Total number of passenger kilometers in millions (2013 or latest available year)	IRF, 2015
23		Number of road passenger kilometers in millions (2013 or latest available year)	IRF, 2015
24		Number of rail passenger kilometers in millions (2013 or latest available year)	IRF, 2015
25		Total number of tonnes-kilometers in millions (2013 or latest available year)	IRF, 2015
26	ME1_RSA	Road Safety Audits on new roads (2013 or latest available year)	WHO, 2015
27	ME2_ADR	Existence of ADR law (2013)	UNECE
28	ME3_SpeedLaw	Existence of national speed law (2013)	WHO, 2015
29	ME4_SpeedLimits_urban	Maximum speed limits on urban roads (2013)	WHO, 2015
30	ME5_SpeedLimits_rural	Maximum speed limits on rural roads (2013)	WHO, 2015
31	ME6_SpeedLimits_motorways	Maximum speed limits on motorways (2013)	WHO, 2015
32	ME7_VehStand_seatbelts	Vehicle standards-seat belts (2013)	WHO, 2015
33	ME8_VehStand_SeatbeltAnchorages	Vehicle standards-seat belt anchorages (2013)	WHO, 2015
34	ME9_VehStand_FrontImpact	Vehicle standards-frontal impact (2013)	WHO, 2015
35	ME10_VehStand_SideImpact	Vehicle standards-side impact (2013)	WHO, 2015
36	ME11_VehStand_ESC	Vehicle standards-Electronic Stability Control (2013)	WHO, 2015
37	ME12_VehStand_PedProtection	Vehicle standards-Pedestrian Protection (2013)	WHO, 2015
38	ME13_VehStand_ChildSeats	Vehicle standards-child seats (2013)	WHO, 2015
39	ME14_DrinkDrivingLaw	Existence of national drink-driving law (2013)	WHO, 2015
40	ME15_BAClimits	BAC limits less than or equal to 0.05 g/dl (2013)	WHO, 2015
41	ME16_BAClimits_young	BAC limits lower than or equal to 0.05g/dl for young/novice drivers (2013)	WHO, 2015
42	ME17_BAClimits_commercial	BAC limits lower than or equal to 0.05g/dl for commercial drivers (2013)	WHO, 2015
43	ME18_SeatBeltLaw	Existence of national seat-belt law (2013)	WHO, 2015
44	ME19_SeatBeltLaw_all	The law applies to all occupants (2013)	WHO, 2015
45	ME20_ChildRestraintLaw	Existence of national child restraints law (2013)	WHO, 2015
46	ME21_HelmetLaw	Existence of national helmet law (2013)	WHO, 2015
47	ME22_HelmetFastened	Law requires helmet to be fastened (2013)	WHO, 2015
48	ME23_HelmetStand	Law requires specific helmet standards (2013)	WHO, 2015
49	ME24_MobileLaw	Existence of national law on mobile phone use while driving (2013)	WHO, 2015
50	ME25_MobileLaw_handheld	The law applies to hand-held phones (2013)	WHO, 2015
51	ME26_MobileLaw_handsfree	The law applies to hands-free phones (2013)	WHO, 2015
52	ME27_PenaltyPointSyst	Demerit/Penalty Point System in place (2010)	WHO, 2013
53	ME28_EmergTrain_doctors	Training in emergency medicine for doctors (2013)	WHO, 2015
54	ME29_EmergTrain_nurses	Training in emergency medicine for nurses (2013)	WHO, 2015
55	PI1_SeatBeltLaw_enf	Effectiveness of seat-belt law enforcement (2013)	WHO, 2015
56	PI2_DrinkDrivingLaw_enf	Effectiveness of drink-driving law enforcement (2013)	WHO, 2015
57	PI3_SpeedLaw_enf	Effectiveness of speed law enforcement (2013)	WHO, 2015
58	PI4_HelmetLaw_enf	Effectiveness of helmet law enforcement (2013)	WHO, 2015
59	PI5_SeatBelt_rates_front	Seat-Belt wearing rate-Front (2013 or latest available year)	WHO, 2015
60	PI6_SeatBelt_rates_rear	Seat-Belt wearing rate-Rear (2013 or latest available year)	WHO, 2015
61	PI7_Helmet_rates_driver	Helmet wearing rate-driver (2013 or latest available year)	WHO, 2015
62	PI8_SI_ambulance	Estimated % seriously injured patients transported by ambulance (2013)	WHO, 2015
63	PI9_HospitalBeds	Number of hospital beds per 1,000 population (2012 or latest available year)	Wold Bank Database
64		Reported number of road traffic fatalities (2013 or latest available year)	IRF, 2015
65		Estimated number of road traffic fatalities (2013 or latest available year)	WHO, 2015
66		Distribution of fatalities by road user(%)-Drivers/passengers of 4-wheeled vehicles (2013 or latest available year)	WHO, 2015
67		Distribution of fatalities by road user(%)-Drivers/passengers of motorized 2- or 3-wheelers (2013 or latest available year)	WHO, 2015
68		Distribution of fatalities by road user(%)-Cyclists (2013 or latest available year)	WHO, 2015
69		Distribution of fatalities by road user(%)-Pedestrians (2013 or latest available year)	WHO, 2015
70		Distribution of fatalities by gender(%)-male (2013 or latest available year)	WHO, 2015
71		Distribution of fatalities by gender(%)-female (2013 or latest available year)	WHO, 2015
72		Attribution of road traffic deaths to alcohol (%) (2013)	WHO, 2015

Appendix C. Groups of countries

Table C.1 - Countries classification 1: United Nations Regional Groups

African Group	Asia-Pacific Group	Eastern European Group	Latin American and Carribean Group	Western European and Others Group
Algeria	Afghanistan	Albania	Argentina	Australia
Angola	Bangladesh	Armenia	Bolivia	Austria
Benin	Cambodia	Azerbaijan	Brazil	Belgium
Burkina Faso	China	Belarus	Chile	Canada
Cameroon	India	Bosnia and Herzegovina	Colombia	Denmark
Central African Republic	Indonesia	Bulgaria	Costa Rica	Finland
Chad	Iran (Islamic Republic of)	Croatia	Cuba	France
Congo	Iraq	Czechia	Dominican Republic	Germany
Côte d'Ivoire	Japan	Georgia	Ecuador	Greece
Democratic Republic of the Congo	Jordan	Hungary	El Salvador	Ireland
Egypt	Kazakhstan	Lithuania	Guatemala	Israel
Eritrea	Kuwait	Moldova, Republic of	Honduras	Italy
Ethiopia	Kyrgyzstan	Poland	Mexico	Netherlands
Ghana	Lao People's Democratic Republic	Romania	Nicaragua	New Zealand
Guinea	Lebanon	Russian Federation	Panama	Norway
Kenya	Malaysia	Serbia	Paraguay	Portugal
Liberia	Mongolia	Slovakia	Peru	Spain
Libya	Myanmar		Uruguay	Sweden
Madagascar	Nepal			Switzerland
Malawi	Oman			Turkey
Mali	Pakistan			United Kingdom of Great Britain and Northern Ireland
Mauritania	Papua New Guinea			United States of America
Morocco	Philippines			
Mozambique	Republic of Korea			
Niger	Saudi Arabia			
Nigeria	Singapore			
Rwanda	Tajikistan			
Senegal	Thailand			
Sierra Leone	Turkmenistan			
Somalia	United Arab Emirates			
South Africa	Uzbekistan			
Sri Lanka	Viet Nam			
Sudan	Yemen			
Togo				
Tunisia				
Uganda				
United Republic of Tanzania				
Zambia				
Zimbabwe				

Table C.2 - Countries classification 2: Economic and road safety performance

Region 1: Low performance	Region 2: Middle performance	Region 3: High performance
Afghanistan	Albania	Argentina
Angola	Algeria	Australia
Bangladesh	Armenia	Austria
Benin	Azerbaijan	Belgium
Burkina Faso	Belarus	Brazil
Cameroon	Bolivia	Bulgaria
Central African Republic	Bosnia and Herzegovina	Canada
Chad	Cambodia	Chile
Congo	China	Costa Rica
Côte d'Ivoire	Colombia	Croatia
Democratic Republic of the Congo	Cuba	Czechia
Eritrea	Dominican Republic	Denmark
Ethiopia	Ecuador	Finland
Ghana	Egypt	France
Guinea	El Salvador	Germany
Kenya	Georgia	Greece
Madagascar	Guatemala	Hungary
Malawi	Honduras	Ireland
Mali	India	Israel
Mauritania	Indonesia	Italy
Mozambique	Iran (Islamic Republic of)	Japan
Nepal	Iraq	Kuwait
Niger	Jordan	Lithuania
Nigeria	Kazakhstan	Malaysia
Pakistan	Kyrgyzstan	Mexico
Papua New Guinea	Lao People's Democratic Republic	Netherlands
Rwanda	Lebanon	New Zealand
Senegal	Liberia	Norway
Sierra Leone	Libya	Panama
Somalia	Moldova, Republic of	Poland
Sudan	Mongolia	Portugal
Tajikistan	Morocco	Republic of Korea
Togo	Myanmar	Romania
Uganda	Nicaragua	Singapore
United Republic of Tanzania	Oman	Slovakia
Uzbekistan	Paraguay	Spain
Yemen	Peru	Sweden
Zambia	Philippines	Switzerland
Zimbabwe	Russian Federation	United Arab Emirates
	Saudi Arabia	United Kingdom of Great Britain and Northern Ireland
	Serbia	United States of America
	South Africa	Uruguay
	Sri Lanka	
	Thailand	
	Tunisia	
	Turkey	
	Turkmenistan	
	Viet Nam	

Table C.3 - Countries classification 3: Economic and road safety performance

Region 1	Region 2	Region 3	Region 4	Region 5	Region 6
Angola	Afghanistan	Algeria	Albania	Argentina	Australia
Bangladesh	Burkina Faso	Cambodia	Armenia	Brazil	Austria
Benin	Chad	China	Azerbaijan	Bulgaria	Belgium
Burundi	Côte d'Ivoire	Egypt	Belarus	Chile	Canada
Cameroon	Ghana	India	Bolivia	Costa Rica	Denmark
Central African Republic	Kenya	Indonesia	Bosnia and Herzegovina	Croatia	Finland
Congo	Mauritania	Iran			
(Islamic Republic of)	Colombia	Czechia	France		
Democratic Republic of the Congo	Nepal	Iraq	Cuba	Greece	Germany
Eritrea	Nigeria	Jordan	Dominican Republic	Hungary	Ireland
Ethiopia	Pakistan	Kazakhstan	Ecuador	Lithuania	Israel
Guinea	Senegal	Kyrgyzstan	El Salvador	Malaysia	Italy
Madagascar	Tajikistan	Lao People's Democratic Republic	Georgia	Mexico	Japan
Malawi	Uganda	Lebanon	Guatemala	Panama	Kuwait
Mali	Uzbekistan	Liberia	Honduras	Poland	Netherlands
Mozambique	Yemen	Mongolia	Moldova, Republic of	Portugal	New Zealand
Niger	Zambia	Morocco	Nicaragua	Republic of Korea	Norway
Papua New Guinea	Zimbabwe	Myanmar	Paraguay	Romania	Singapore
Rwanda		Oman	Peru	Slovakia	Spain
Sierra Leone		Philippines	Russian Federation	Uruguay	Sweden
Somalia		Saudi Arabia	Serbia		Switzerland
Sudan		South Africa	Turkey		United Arab Emirates
United Republic of Tanzania		Sri Lanka			United Kingdom of Great Britain and Northern Ireland
		Thailand			United States of America
		Tunisia			
		Turkmenistan			
		Viet Nam			

SafeFITS

Safe Future Inland Transport Systems

This report presents the results of the project Safe Future Inland Transport Systems (SafeFITS), which aims to develop a robust road safety decision-making tool to support the most appropriate road safety policies and measures to achieve tangible results. SafeFITS tool includes the following two background components:

- Database with data on indicators from all layers of the road safety management system.
- Set of statistical models fitted on the database indicators to produce the SafeFITS outputs.

The SafeFITS tool is composed of three complementary modules:

- **Intervention analysis:** allows the user to examine the effects of single interventions at national or country cluster level.
- **Forecasting analysis:** allows the user to define own scenarios of measures (or combinations of measures) in a country and obtain medium/long term road safety forecasts for each scenario.
- **Benchmarking analysis:** allows the user to benchmark a country against a group of countries (e.g. all countries, countries of similar economic or road safety performance).

The present report includes an indicative demonstration of the model implementation within SafeFITS web-based tool, by means of wire-frames presentation. The model may provide forecasting and benchmarking estimates for 130 countries:

- Base case scenario, solely on the basis of GNI projections (either official projections, or user-defined). This scenario serves as a reference case for assessing the effects of interventions.
- Policy scenarios with up to a maximum of eight interventions, in addition to GNI developments. This allows one to assess the cumulative impact of these interventions on the forecasted road safety outcomes, and the country's position globally or within its country cluster.

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