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Developing a Global Road Safety Model

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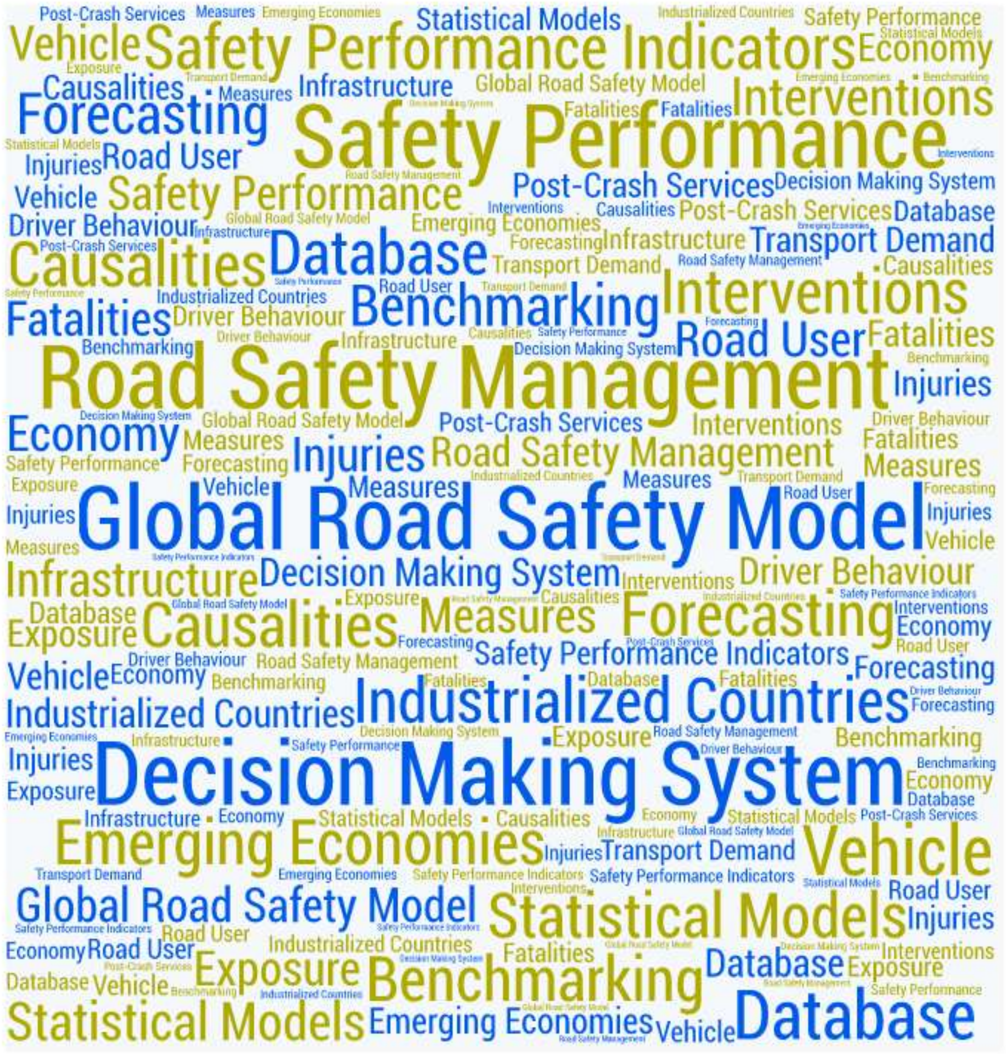
Background

- Road accidents constitute a major social problem in modern societies, with road traffic injuries being estimated as the eighth leading cause of death globally.
- Particularly in low and middle income countries, road traffic injuries rates are twice those in high income countries and still increasing.
- UN Decade of Action: need to strengthen global and national efforts for casualty reduction through evidence-based approaches.

Objective

- To develop a macroscopic **road safety model** to serve as 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.

- Based on work carried out in the framework of the **“Safe Future Inland Transport Systems (SafeFITS)”** project of the United Nations Economic Commission for Europe (UNECE), financed by the International Road Union (IRU).



Research challenges for a global model

- The relationships between indicators and road safety outcomes are complex and in some cases random.
- The problem is multi-dimensional, and transferability of known causalities in a global context is not recommended.
- Existing knowledge on road safety causalities is incomplete, and comes mostly from industrialized countries.
- There is lack of detailed historical data on several indicators and road safety outcomes at international level.

Conceptual Framework

Based on the five pillars of WHO Global Plan of Action (WHO, 2011) and an improved version of the SUNflower pyramid (2002):

SafeFITS layers

1. Economy and Management
2. Transport Demand and Exposure
3. Road Safety Measures
4. Road Safety Performance Indicators
5. Fatalities and Injuries

SafeFITS pillars

1. Road Safety Management
2. Road Infrastructure
3. Vehicle
4. User
5. Post-Crash Services

		PILLARS				
		1. Road Safety Management	2. Road Infrastructure	3. Vehicle	4. User	5. Post-Crash Services
LAYERS	1. Economy & Management	Economic Developments, Strategy & Targets, Regulatory framework (compliance with UN 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 & 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 & 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 & gender	
	3. Road Safety Measures	Assessment of measures, Data collection & 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 areasTraffic 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 & organisation of trauma centers
	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 & 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 samaritanians per population
	5. Fatalities & 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

Architecture of the database

- Data from the five layers and the five pillars
- **International databases** explored: WHO, UN, IRF, OECD, etc.
- Data for **130 countries** with population higher than 2,8 million inhabitants
- Data refer to **2013** or latest available year

Economy and Management

Demographic and Economic Characteristics

- **Population** (World Bank Database)
- **Area** (World Bank Database)
- **GNI per capita** in US dollars (World Bank Database)
- **Projected GDP per capita** for 2015-2030 in 2010 US dollars (ERS International Macroeconomic Data Set)

Road Safety Management Indicators (WHO)

- Existence of **RS lead agency**
- The **lead agency is funded**
- Existence of national **RS strategy**
- The **RS strategy is funded**
- Existence of **RS fatality targets**

Transport Demand and Exposure

<u>Roads</u>
- Road **network density** (IRF)
- Percentage of **motorways** (IRF)
- Percentage of **paved roads** (IRF, CIA)

<u>Vehicles</u> (IRF)
- Number of **vehicles in use** in total and by type of vehicle

<u>Traffic</u> (IRF)
- **Traffic Volume**
- Inland surface **passengers transport**
- Inland surface **freight transport**

Road Safety Measures (1/2)

<u>Roads</u> (WHO)

- Road safety **audits on new roads**
- Existence of **speed law**
- Max **speed limits on urban roads** (no speed limits; >50 km/h; ≤50 km/h)
- Max **speed limits on rural roads** (no speed limits; 100-120 km/h; 70-90 km/h; ≤70 km/h)
- Max **speed limits on motorways** (no speed limits; ≤100 km/h; 100-120 km/h; ≥120 km/h)

<u>Vehicles</u>

- Existence of **ADR law** (UNECE)
- **Vehicle standards** include seat-belts, electronic stability control, pedestrian protection (WHO)
- New cars subjected to **NCAP** (WHO)

<u>Post-crash care</u> (WHO)

- Training in emergency medicine for doctors
- Training in emergency training for nurses

Road Safety Measures (2/2)

Road User (WHO)

- Existence of **drink-driving law**
- Allowed **BAC limits** (3 separate variables for general population, young/novice drivers, commercial drivers)
- Existence of national **seat-belt law**
- The seat-belt law **applies to all occupants**
- Existence of national **child restraint law**
- Existence of national **helmet law**
- The law requires **helmet to be fastened**
- The helmet law defines specific **helmet standards**
- Existence of national law on **mobile phone use** while driving
- The law applies to **hand-held phones**
- The law applies to **hands-free phones**
- Existence of **penalty point system**

Road Safety Performance Indicators

Traffic law enforcement (WHO)
- 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

Road User (WHO)
- Seat-belt wearing rates in **front seats**
- Seat-belt wearing rates in **rear seats**
- **Helmet** wearing rates – driver

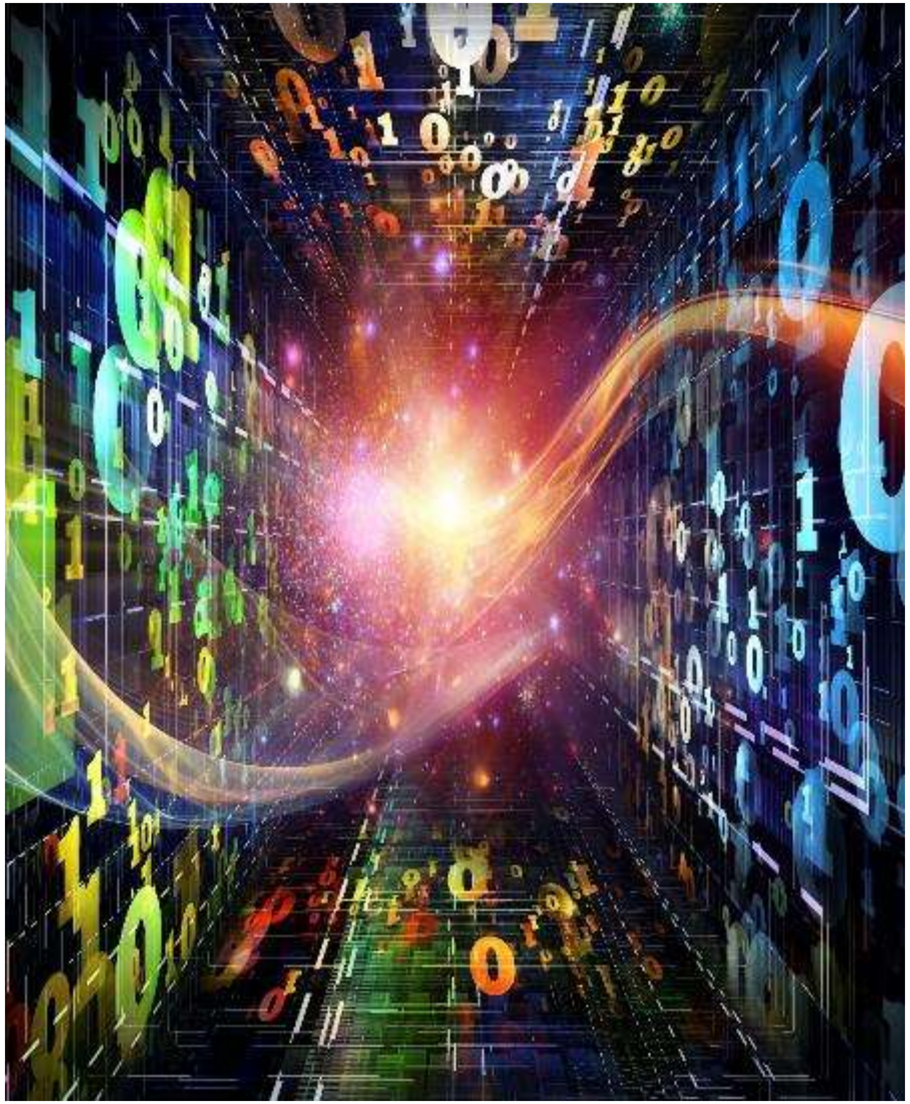
Post-crash care
- Estimated percentage of **seriously injured patients** transported by ambulance (WHO)
- Number of **hospital beds** per population (World Bank Database)

Fatalities and Injuries

- **Estimated number** of **road traffic fatalities** (WHO)
- Estimated road traffic fatality **rates per 100.000 population** (WHO)
- Distribution of road traffic fatalities **by road user type** (WHO)
- Distribution of road traffic fatalities **by gender** (WHO)
- Percentage of road traffic fatalities **attributed to alcohol** (WHO)

Database overview

- Wherever data for 2013 were not available, the **latest data available** were used.
- The missing values of each indicator of the countries were filled with **the mean value** of the indicator in their regions.
- The respective information of each variable is **properly represented** in the database for the statistical process.
- **Data for most variables were available for almost all countries.**
- **Low data availability** is observed for few variables regarding:
  - the restraint use rates
  - the percentage of fatalities attributed to alcohol
  - the distribution of fatalities by road user type
  - transport demand and exposure indicators



Model Development

- Data Analysis Methodology
- Estimation of Composite Variables
- Development of Statistical Model
  Correlating road safety outcomes with composite variables
- Model Validation

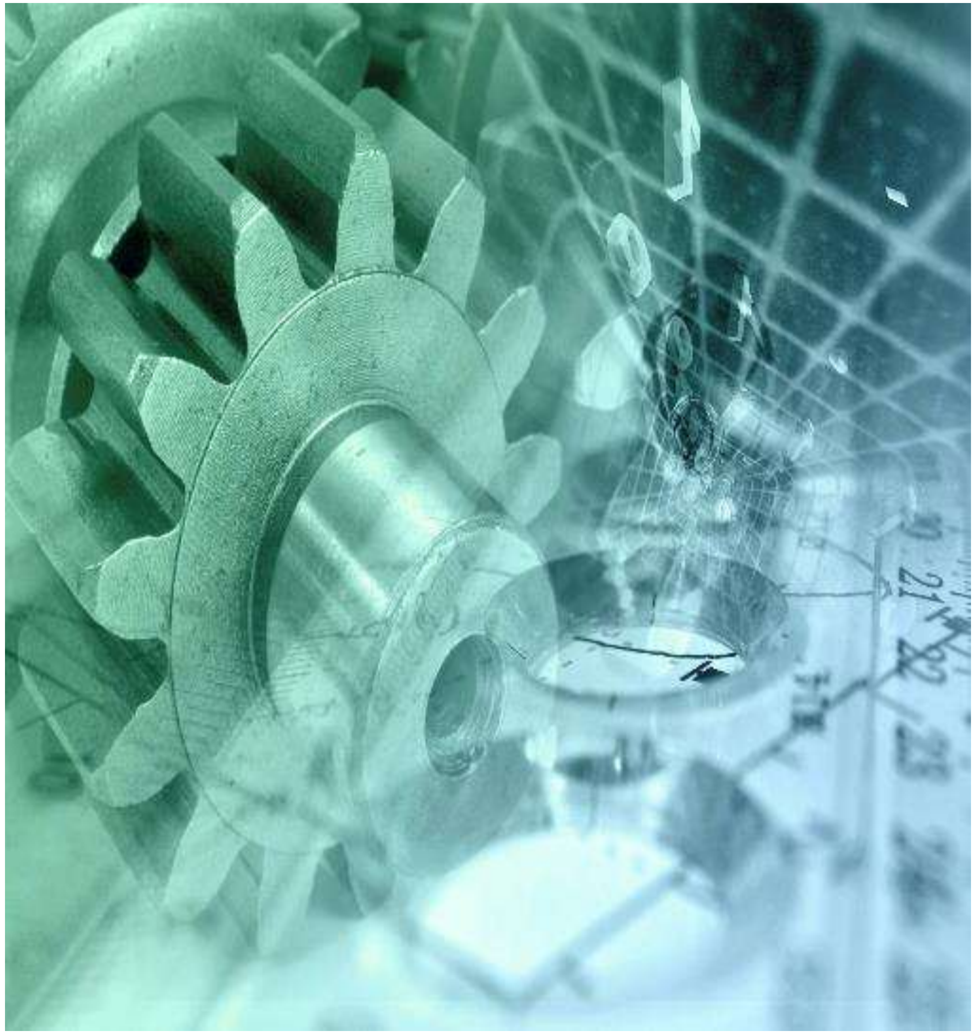
Data Analysis Methodology

- **Two-step approach** of statistical modeling:
  - Estimation of **composite variables** (factor analysis) in order to take into account as many indicators as possible of each layer
  - Correlating road safety outcomes with indicators through composite variables by developing a **regression model with explicit consideration of the time dimension**

- **Model specification**

$$Log(\text{Fatalities per Population})_{ti} = A_i + Log(\text{Fatalities per Population})_{(t-\tau)} + B_i * GDP_{ti} + K_i * [\text{Economy \& Management}] + L_i * [\text{Transport demand \& Exposure}]_{ti} + M_i * [\text{Road Safety Measures}]_{ti} + N_i * [RSPI]_{ti} + \varepsilon_i$$

Where [Composite Variable]



Calculation of composite variables – 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)

Indicator loadings and coefficients on the estimated factor (composite variable) on Economy and Management

	Component	
	Loadings	Score coefficients
EM1_Popdensity	,091	,029
EM2_lt15yo	-,778	-,250
EM3_gt65yo	,714	,229
EM4_UrbanPop	,709	,228
EM5_LeadAgency	,284	,091
EM6_LeadAgencyFunded	,226	,073
EM7_NationalStrategy	,697	,224
EM8_NationalStrategyFunded	,626	,201
EM9_FatalityTargets	,692	,222

Calculation of composite variables – 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)

Indicator loadings and coefficients on the estimated factor (composite variable) on Transport Demand and Exposure

	Component	
	Loadings	Score coefficients
TE1_RoadNetworkDensity	,497	,161
TE2_Motorways	,460	,149
TE3_PavedRoads	,734	,238
TE4_VehiclesPerPop	,839	,272
TE5_PassCars	,825	,267
TE6_VansLorries	-,132	-,043
TE7_PTW	-,681	-,221
TE8_Vehkm_Total	,269	,087
TE9_RailRoad	,136	,044
TE10_PassengerFreight	-,360	-,117

Calculation of composite variables - 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(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)

Indicator loadings and coefficients on the estimated factor (composite variable) on Measures

	Component	
	Loadings	Score coefficients
ME1_RSA	,245	,025
ME2_ADR	**,681**	**,069**
ME3_SpeedLaw	,229	,023
ME4_SpeedLimits_urban	**,443**	**,045**
ME5_SpeedLimits_rural	,200	,020
ME6_SpeedLimits_motorways	**,634**	**,064**
ME7_VehStand_seatbelts	**,877**	**,088**
ME8_VehStand_SeatbeltAnchorages	**,906**	**,091**
ME9_VehStand_FrontImpact	**,908**	**,092**
ME10_VehStand_SideImpact	**,904**	**,091**
ME11_VehStand_ESC	**,891**	**,090**
ME12_VehStand_PedProtection	**,862**	**,087**
ME13_VehStand_ChildSeats	**,896**	**,090**
ME14_DrinkDrivingLaw	,126	,013
ME15_BAClimits	**,670**	**,068**
ME16_BAClimits_young	**,670**	**,068**
ME17_BAClimits_commercial	**,645**	**,065**
ME18_SeatBeltLaw	,297	,030
ME19_SeatBeltLaw_all	**,570**	**,057**
ME20_ChildRestraintLaw	**,628**	**,063**
ME21_HelmetLaw	,236	,024
ME22_HelmetFastened	**,334**	**,034**
ME23_HelmetStand	**,379**	**,038**
ME24_MobileLaw	**,375**	**,038**
ME25_MobileLaw_handheld	**,350**	**,035**
ME26_MobileLaw_handsfree	-,295	-,030
ME27_PenaltyPointSyst	**,378**	**,038**
ME28_EmergTrain_doctors	,178	,018
ME29_EmergTrain_nurses	**,399**	**,040**

Calculation of composite variables - SPIs

[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)

Indicator loadings and coefficients on the estimated factor (composite variable) on **SPIs**

	Component	
	Loadings	Score coefficients
PI1_SeatBeltLaw_enf	,756	,144
PI2_DrinkDrivingLaw_enf	,812	,155
PI3_SpeedLaw_enf	,795	,152
PI4_HelmetLaw_enf	,837	,160
PI5_SeatBelt_rates_front	,811	,155
PI6_SeatBelt_rates_rear	,766	,146
PI7_Helmet_rates_driver	,784	,150
PI8_SI_ambulance	,667	,127
PI9_HospitalBeds	,607	,116

Final Statistical Model

The **optimal performing model** for the purposes of the analysis

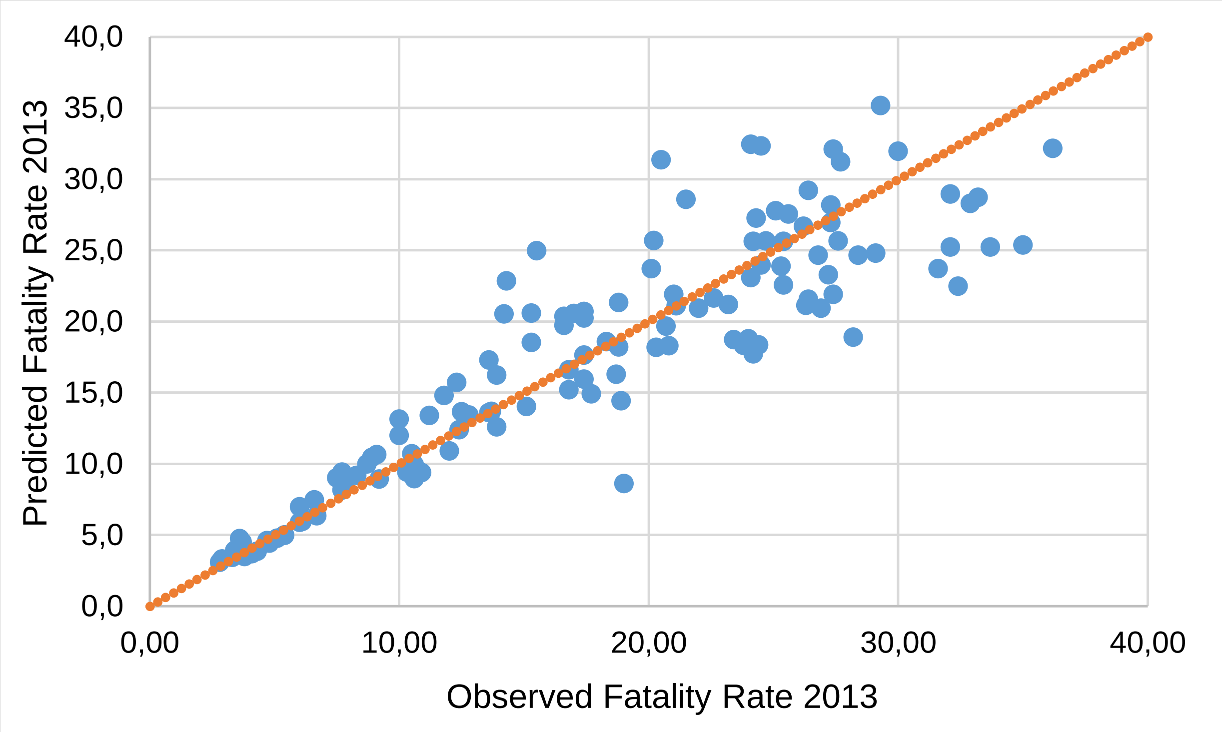
- **Dependent variable** is the logarithm of the fatality rate per population for 2013
- The main **explanatory variables** are the respective logarithm of fatality rate in 2010 and the respective logarithm of GDP per capita for 2013
- Four **composite** variables: the economy & management, the transport demand and exposure, the measures, and the SPIs

Parameter	B	Std. Error	95% Confidence Interval		Hypothesis Test		
			Lower	Upper	Wald Chi-Square	df	p-value
(Intercept)	1,694	,2737	1,157	2,230	38,291	1	<,001
Comp_ME	-,135	,0646	-,261	-,008	4,358	1	,037
Comp_TE	-,007	,0028	-,013	-,002	7,230	1	,007
Comp_PI	-,007	,0030	-,013	-,001	5,652	1	,017
Comp_EM	,007	,0051	-,003	,017	2,009	1	,156
LNFestim_2010	,769	,0462	,678	,859	276,322	1	<,001
LNGNI_2013	-,091	,0314	-,153	-,030	8,402	1	,004
(Scale)	,038						
Likelihood Ratio	1379,00						
df	6						
p-value	<,001						

Model Assessment

In order to **assess** the model, a comparison of the observed and the predicted values was carried out:

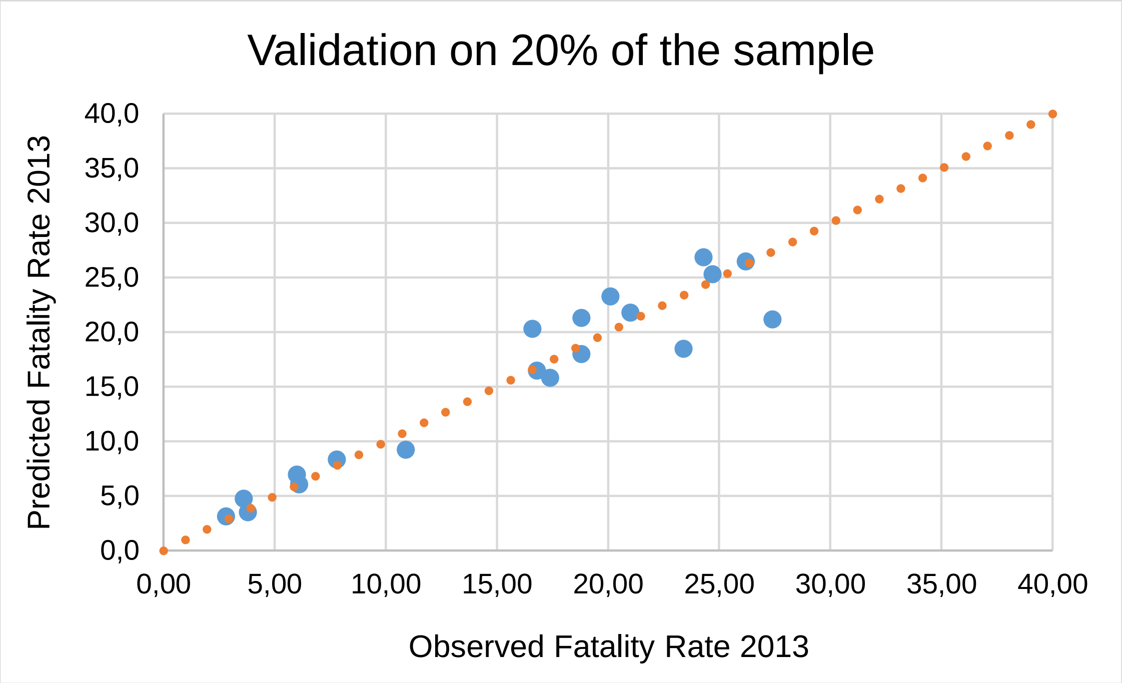
- The mean absolute prediction error is estimated at **2.7 fatalities per population**, whereas the mean percentage prediction error is estimated at **15%** of the observed value.
- The model is of **very satisfactory performance** as regards the good performing countries (low fatality rate) and of **quite satisfactory performance** as regards the medium performing countries.

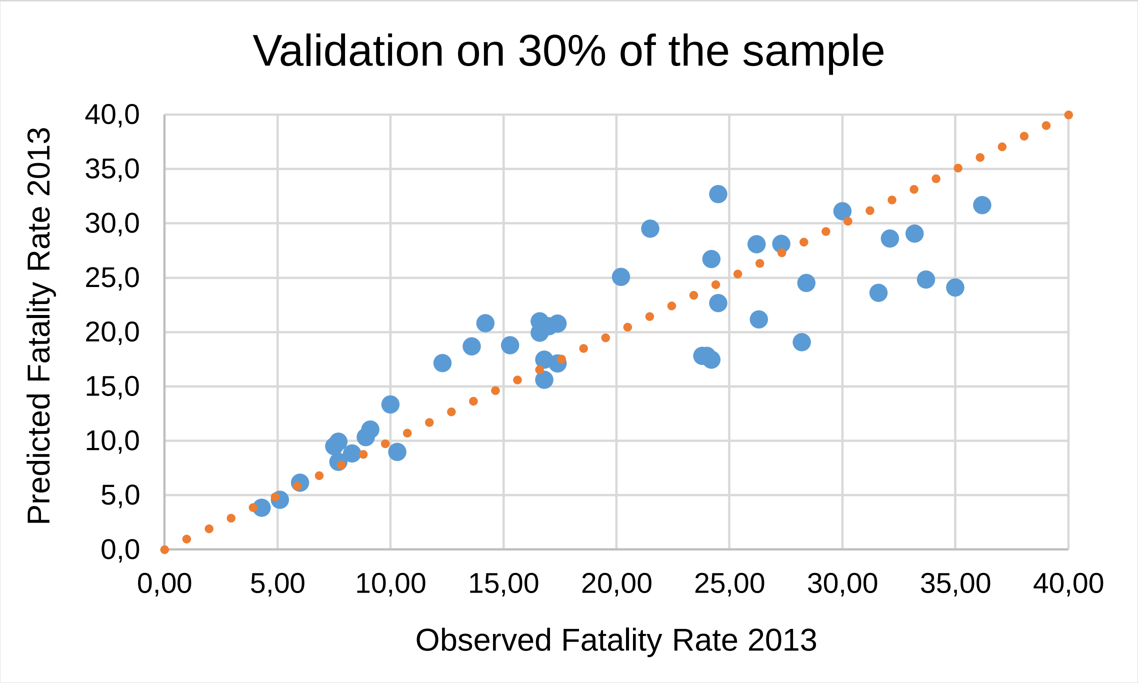


Model Validation

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

- **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
- **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

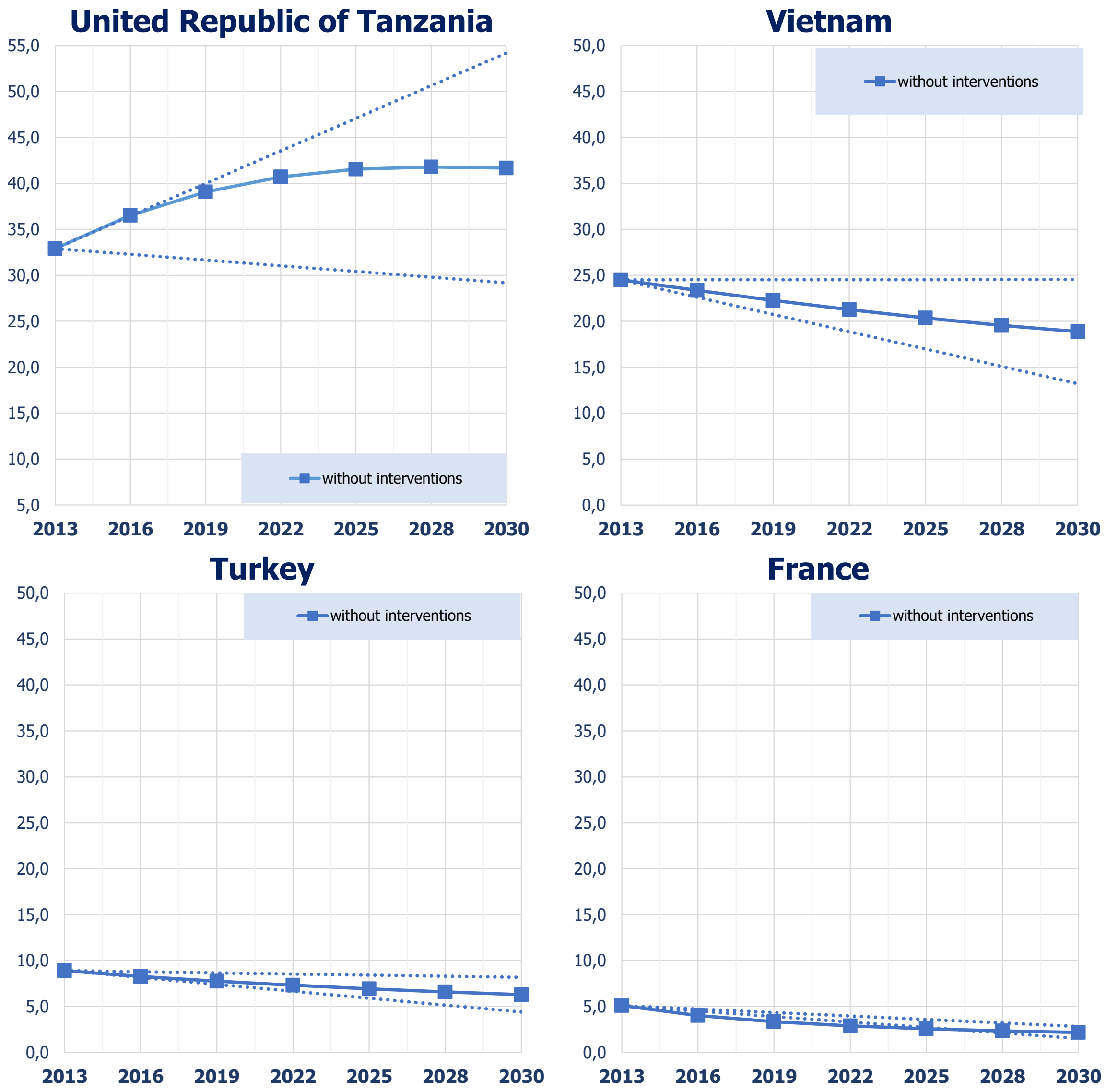




Model Application

Examples of model application for **forecasting fatalities 2013-2030:**

- one **low performance** country
- two **middle performance** countries
- one **high performance** country



Model limitations and future improvements

- The model was developed on the basis of **the most recent and good quality data available internationally**, and by means of rigorous statistical methods. However, data and analysis methods always have some limitations.

- Data are primarily **directed at vehicle occupants** and thus, effects on road safety outcomes of VRUs may not be captured.

- The effects of interventions may 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 etc.)

- The factor analysis procedure **does not assume or indicate that a causal relationship exists**.

- The **calibration with new data** will be the ultimate way to fully assess the performance of the model.

Benefits for the Policy Makers

- **The first global road safety model to be used for policy support**
  - Global assessments (i.e. monitoring the global progress towards the UN road safety targets)
  - Individual country assessments of various policy scenarios

- A framework which **enhances the understanding of road safety causalities**, as well as of the related difficulties.

- Full exploitation of the currently available global data, and use of rigorous analysis techniques, to **serve key purposes in road safety policy analysis**: benchmarking, forecasting.

- An important step for **monitoring, evidence-base and systems approach** to be integrated in decision-making.

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