# Developing a Global Road Safety Model

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## Introduction - Background

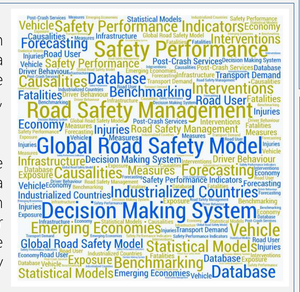
- Road accidents constitute a **major social problem** in modern societies, with road traffic injuries being estimated as the eighth leading cause death globally.
- Particularly in **low and middle income countries**, road traffic injuries are twice those in high income countries and still increasing.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

### Main objective

- Develop a **global road safety model** based on global road safety data, which may serve as a road safety decision making tool for three types of policy analysis, i.e. intervention, benchmarking and forecasting analysis.

### Methodology

- A **conceptual framework** of five layers of the road safety system is suggested, and a **dedicated database** was developed with various road safety indicators for each layer (i.e. fatalities and injuries, performance indicators, road safety measures, economy and background).
- A **two-step modelling approach** was implemented the purposes of the research, including first the calculation of composite variables, and then their introduction in a generalized linear model correlating them with road safety outcomes.




### Research challenges

- 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.

| LAYERS | PILLARS | | | | |
|---|---|---|---|---|---|
| | 1. Road Safety Management | 2. Road Infrastructure | 3. Vehicle | 4. User | 5. Post-Crash Services |
| 1. Economy & Management | Economic Deve-lopments, Strategy & Targets, Regu-latory framework (compliance with UN regulations) | Existence of motorways, of non-quixed roads, of road tunnels, Existence of guidelines (for design, RSA etc.), Legislation on speeding | Number of regi-stered vehicles, Vehicle age, Technical inspec-tion 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 tolls, 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 Manage-ment, Improve-ment of signage, installation of road restraint systems, Lighting, Speed limits in urban areas/Traffic Calming | Renewal rate of vehicle fleet, Safety Measures for second-hand vehicles, Vehicle related roadside controls, Automated driving | Enforcement, campaigns, Road safety education, Training | e-call, First aid training, Existence & organization 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 infringe-ments, 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 |

## Conceptual Framework

Based on the 5 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

## Modelling Approach

- 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

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

*Where [Composite Variable]*

## Database

| Number | Variable | 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 | Percentage of popualition under 15 years old (2013) | World Bank Database |
| 6 | Percentage of popualition over 65 years old (2013) | World Bank Database |
| 7 | Percentage of urban population (2013) | World Bank Database |
| 8 | Existence of a road safety lead agency (2013) | WHO, 2015 |
| 9 | The lead agency is funded (2013) | WHO, 2015 |
| 10 | Existence of national road safety strategy (2013) | WHO, 2015 |
| 11 | The strategy is funded (2013) | WHO, 2015 |
| 12 | Existence of fatality reduction target (2013) | WHO, 2015 |
| 13 | Length of total road network (km) (2013 or latest availbale year) | IRF, 2015 |
| 14 | Percentage of motorways of total road network (2013 or latest available year) | IRF, 2015 |
| 15 | Percentage of paved roads of total road network (2013 or latest available year) | IRF, 2015 |
| 16 | Total number of vehicles in use (2013 or latest availble year) | IRF, 2015 |
| 17 | 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 | Number of vans and lorries in use (2013 or latest availble year) | IRF, 2015 |
| 20 | Number of powered two wheelers in use (2013 or latest availble year) | IRF, 2015 |
| 21 | 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 | Road Safety Audits on new roads (2013 or latest available year) | WHO, 2015 |
| 27 | Implementation of ADR | UNECE |
| 28 | Existence of national speed law (2013) | WHO, 2015 |
| 29 | Maximum speed limits on urban roads (2013) | WHO, 2015 |
| 30 | Maximum speed limits on rural roads (2013) | WHO, 2015 |
| 31 | Maximum speed limits on motorways (2013) | WHO, 2015 |
| 32 | Vehicle standards-seat belts (2013) | WHO, 2015 |
| 33 | Vehicle standards-seat belt anchorages (2013) | WHO, 2015 |
| 34 | Vehicle standards-frontal impact (2013) | WHO, 2015 |
| 35 | Vehicle standards-side impact (2013) | WHO, 2015 |
| 36 | Vehicle standards-Electronic Stability Control (2013) | WHO, 2015 |
| 37 | Vehicle standards-Pedestrian Protection (2013) | WHO, 2015 |
| 38 | Vehicle standards-child seats (2013) | WHO, 2015 |
| 39 | Existence of national drink-driving law (2013) | WHO, 2015 |
| 40 | BAC limits less than or equal to 0.05 g/dl (2013) | WHO, 2015 |
| 41 | BAC limits lower than or equal to 0.05g/dl for young/novice drivers (2013) | WHO, 2015 |
| 42 | BAC limits lower than or equal to 0.05g/dl for commercial drivers (2013) | WHO, 2015 |
| 43 | Existence of national seat-belt law (2013) | WHO, 2015 |
| 44 | The law applies to all occupants (2013) | WHO, 2015 |
| 45 | Existence of national child restraints law (2013) | WHO, 2015 |
| 46 | Existence of national helmet law (2013) | WHO, 2015 |
| 47 | Law requires helmet to be fastened (2013) | WHO, 2015 |
| 48 | Law requires specific helmet standards (2013) | WHO, 2015 |
| 49 | Existence of national law on mobile phone use while driving (2013) | WHO, 2015 |
| 50 | The law applies to hand-held phones (2013) | WHO, 2015 |
| 51 | The law applies to hands-free phones (2013) | WHO, 2015 |
| 52 | Demerit/Penalty Point System in place (2010) | WHO, 2013 |
| 53 | Training in emergency medicine for doctors (2013) | WHO, 2015 |
| 54 | Training in emergency medicine for nurses (2013) | WHO, 2015 |
| 55 | Effectiveness of seat-belt law enforcement (2013) | WHO, 2015 |
| 56 | Effectiveness of drink-driving law enforcement (2013) | WHO, 2015 |
| 57 | Effectiveness of speed law enforcement (2013) | WHO, 2015 |
| 58 | Effectiveness of helmet law enforcement (2013) | WHO, 2015 |
| 59 | Seat-Belt wearing rate-Front (2013 or latest available year) | WHO, 2015 |
| 60 | Seat-Belt wearing rate-Rear (2013 or latest available year) | WHO, 2015 |
| 61 | Helmet wearing rate-driver (2013 or latest available year) | WHO, 2015 |
| 62 | Estimated % seriously injured patients transported by ambulance (2013) | WHO, 2015 |
| 63 | 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 |

## Estimation of Composite Variables

- The **factor analyses** were implemented on each one of the layers of the road safety system, constrained to yield one factor per layer.
  - Economy and Management
  - Transport Demand and Exposure
  - Road Safety Measures
  - Performance Indicators
- For **fatalities and injuries indicators**, the fatality rate per population was selected as main dependent variable.

TABLE 1 Indicator loadings and coefficients on the estimated factor (composite variable) per layer

| | | Factor (composite variable) | |
|---|---|---|---|
| | | Loadings | Score coefficients |
| Economy and Management | EM2_lt15yo | -0,778 | -0,250 |
| | EM3_gt65yo | 0,714 | 0,229 |
| | EM4_UrbanPop | 0,709 | 0,228 |
| | EM7_NationalStrategy | 0,697 | 0,224 |
| | EM8_NationalStrategyFunded | 0,626 | 0,201 |
| | EM9_FatalityTargets | 0,692 | 0,222 |
| Transport Demand and Exposure | TE1_RoadNetworkDensity | 0,497 | 0,161 |
| | TE2_Motorways | 0,460 | 0,149 |
| | TE3_PavedRoads | 0,734 | 0,238 |
| | TE4_VehiclesPerPop | 0,839 | 0,272 |
| | TE5_PassCars | 0,825 | 0,267 |
| | TE7_PTW | 0-,681 | -0,221 |
| | TE10_PassengerFreight | 0-,360 | -0,117 |
| Road Safety Measures | ME2_ADR | 0,681 | 0,069 |
| | ME4_SpeedLimits_urban | 0,443 | 0,045 |
| | ME6_SpeedLimits_motorways | 0,634 | 0,064 |
| | ME7_VehStand_seatbelts | 0,877 | 0,088 |
| | ME8_VehStand_SeatbeltAnchorages | 0,906 | 0,091 |
| | ME9_VehStand_FrontImpact | 0,908 | 0,092 |
| | ME10_VehStand_SideImpact | 0,904 | 0,091 |
| | ME11_VehStand_ESC | 0,891 | 0,090 |
| | ME12_VehStand_PedProtection | 0,862 | 0,087 |
| | ME13_VehStand_ChildSeats | 0,896 | 0,090 |
| | ME15_BACLimits | 0,670 | 0,068 |
| | ME16_BACLimits_young | 0,670 | 0,068 |
| | ME17_BACLimits_commercial | 0,645 | 0,065 |
| | ME19_SeatBeltLaw_all | 0,570 | 0,057 |
| | ME20_ChildRestraintLaw | 0,628 | 0,063 |
| | ME22_HelmetFastened | 0,334 | 0,034 |
| | ME23_HelmetStand | 0,379 | 0,038 |
| | ME24_MobileLaw | 0,375 | 0,038 |
| | ME25_MobileLaw_handheld | 0,350 | 0,035 |
| | ME27_PenaltyPointSyst | 0,378 | 0,038 |
| | ME29_EmergTrain_nurses | 0,399 | 0,040 |
| Road Safety Performance Indicators | PI1_SeatBeltLaw_enf | 0,756 | 0,144 |
| | PI2_DrinkDrivingLaw_enf | 0,812 | 0,155 |
| | PI3_SpeedLaw_enf | 0,795 | 0,152 |
| | PI4_HelmetLaw_enf | 0,837 | 0,160 |
| | PI5_SeatBelt_rates_front | 0,811 | 0,155 |
| | PI6_SeatBelt_rates_rear | 0,766 | 0,146 |
| | PI7_Helmet_rates_driver | 0,784 | 0,150 |
| | PI8_SI_ambulance | 0,667 | 0,127 |
| | PI9_HospitalBeds | 0,607 | 0,116 |

## Generalized Linear Model Development

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

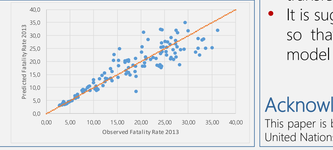
- The **dependent variable** is the logarithm of the fatality rate per population for 2013
- The main **explanatory variables** are the respective logarithm of fatality rate in 2010 and the respective logarithm of GDP per capita for 2013
- Four **composite** variables: the Economy & Management, the Transport Demand and Exposure, the Measures and the SPIs

TABLE 2 Parameter estimates and fit of the final generalized linear model

| Parameter | B | Std. 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 |
| 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 | 1379,00 | | | | | | |
| df | 6 | | | | | | |
| p-value | <0,001 | | | | | | |

## Statistical Model Assessment

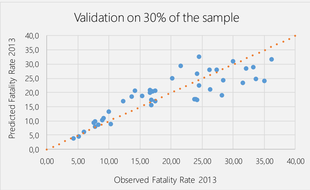
- The mean absolute prediction error is estimated at **2,7 fatalities per population**, whereas the mean percentage prediction error is estimated at **15%** of the observed value.

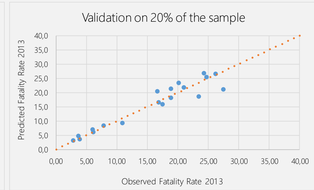



## Statistical Model Validation

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




## Conclusions –Discussion

- The model developed 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.

- Data and analysis methods have some **limitations** which should be kept in mind:
  - Fatality data are in some cases estimated numbers, and in all subject to **under-reporting**.
  - **Missing values** were addressed by imputation.
  - The available data for several indicators were **not detailed**.

- The **optimal use** of the model depends on a number of recommendations and rules:
  - The model provides overall forecasts of **short-term developments**, which might be extrapolated in the future.
  - The model includes many indicators which are correlated, thus testing **combinations of "similar" interventions** is recommended.
  - The model may not fully capture the effects on countries with very **particular characteristics**.
  - **Developing countries** are expected to be more sensitive in the testing of interventions than developed ones.

- The **lack of a global road safety database** with detailed and comparable data certainly compromises the efforts to develop a global road safety model.
- A **new wave of historical data** may allow to further validate and adjust the model, as well as to take more accurately into account the underlying trends by estimating future developments on the basis of longer historical trends.
- **Further changes in programs and measures** implemented in the various countries will allow to more accurately estimate their effects on outcomes, improving the transferability of estimates in other countries as well.
- It is suggested to **closely monitor global developments in data availability and accuracy**, so that the data are updated regularly and continuously, allowing to improve the model with more and more accurate data.

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