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 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.
Objective

• To develop a macroscopic road safety decision making tool that will assist governments and decision makers, both in developed and developing countries, to decide on the most appropriate road safety policies and measures in order to achieve tangible results.

• 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).
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

<table>
<thead>
<tr>
<th>Layers</th>
<th>Pillars</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Economy &amp; Management</td>
<td>1. Road Safety Management</td>
</tr>
<tr>
<td>2. Transport demand &amp; exposure</td>
<td>2. Road Infrastructure</td>
</tr>
<tr>
<td>3. Road Safety Measures</td>
<td>3. Vehicle</td>
</tr>
<tr>
<td>4. Road Safety Performance Indicators</td>
<td>4. User</td>
</tr>
<tr>
<td>5. Fatalities &amp; Injuries</td>
<td>5. Post-Crash Services</td>
</tr>
</tbody>
</table>

**Pillars**

- **1. Road Safety Management**
  - Economic Development, Strategy & Targets, Regulatory framework (compliance with UN regulations)
  - Existence of motorways, non-modal roads, of road tunnels, existence of guidelines (for design, RSA etc.), Legislation on speeding

- **2. Road Infrastructure**
  - 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

- **3. Vehicle**
  - Treatment of high Risk Objs, Road Safety Audits, Road Safety Management, improvement of signage, Installation of road resident systems, Lighting, Speed limits in urban areas, Traffic calming

- **4. User**
  - Number of vehicles, Percentage of high risk users treated

- **5. Post-Crash Services**
  - Global NCAP score, Mean age of the vehicle fleet per vehicle type, Existence of safety equipment, e-safety

- **Emergency response time, Type of treatment in hospital, Number of readmissions per population, Total length of hospital stay**

- **Fatalities / Injuries per million passengers, fatal / injured per 10 billion passenger-km**

- **Roads / Microappable fatalities out of the total fatalities**

- **Deaths / 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

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

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

**Traffic** (IRF)
- Traffic Volume
- Inland surface passengers transport
- Inland surface freight transport
Road Safety Measures (1/2)

Roads (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)

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

Post-crash care (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)

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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
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**

\[
\text{Log(Fatalities per Population)}_{t_i} = A_i + \text{Log(Fatalities per Population)}_{(t-\tau)} + B_i \times \text{GDP}_{t_i} + K_i \times \text{[Economy & Management]}_{t_i} + L_i \times \text{[Transport demand & Exposure]}_{t_i} + M_i \times \text{[Road Safety Measures]}_{t_i} + N_i \times \text{[RSPI]}_{t_i} + \epsilon_i
\]

Where [Composite Variable]
Calculation of composite variables – Economy and Management

\[
\text{[Comp}_{EM}\text{]} = -0.250 (EM2_{lt15yo}) + 0.229 (EM3_{gt65yo}) + 0.228 (EM4_{UrbanPop}) + 0.224 (EM7_{NationalStrategy}) + 0.221 (EM8_{NationalStrategyFunded}) + 0.222 (EM9_{FatalityTargets})
\]

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

<table>
<thead>
<tr>
<th>Component</th>
<th>Loadings</th>
<th>Score coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>EM1_Popdensity</td>
<td>0.091</td>
<td>0.029</td>
</tr>
<tr>
<td>EM2_Lt15yo</td>
<td>-0.778</td>
<td>-0.250</td>
</tr>
<tr>
<td>EM3_gt65yo</td>
<td>0.714</td>
<td>0.229</td>
</tr>
<tr>
<td>EM4_UrbanPop</td>
<td>0.709</td>
<td>0.228</td>
</tr>
<tr>
<td>EM5_LeadAgency</td>
<td>0.284</td>
<td>0.091</td>
</tr>
<tr>
<td>EM6_LeadAgencyFunded</td>
<td>0.226</td>
<td>0.073</td>
</tr>
<tr>
<td>EM7_NationalStrategy</td>
<td>0.697</td>
<td>0.224</td>
</tr>
<tr>
<td>EM8_NationalStrategyFunded</td>
<td>0.626</td>
<td>0.201</td>
</tr>
<tr>
<td>EM9_FatalityTargets</td>
<td>0.692</td>
<td>0.222</td>
</tr>
</tbody>
</table>
Calculation of composite variables – Transport Demand and Exposure

\[ \text{Comp}_\text{TE} = 0.161 (\text{TE1}_\text{RoadNetworkDensity}) + 0.149 (\text{TE2}_\text{Motorways}) + 0.238 (\text{TE3}_\text{PavedRoads}) + 0.272 (\text{TE4}_\text{VehiclesPerPop}) + 0.267 (\text{TE5}_\text{PassCars}) - 0.221 (\text{TE7}_\text{PTW}) - 0.117 (\text{TE10}_\text{PassengerFreight}) \]

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

<table>
<thead>
<tr>
<th>Component</th>
<th>Loadings</th>
<th>Score coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>TE1_RoadNetworkDensity</td>
<td>0.497</td>
<td>0.161</td>
</tr>
<tr>
<td>TE2_Motorways</td>
<td>0.460</td>
<td>0.149</td>
</tr>
<tr>
<td>TE3_PavedRoads</td>
<td>0.734</td>
<td>0.238</td>
</tr>
<tr>
<td>TE4_VehiclesPerPop</td>
<td>0.839</td>
<td>0.272</td>
</tr>
<tr>
<td>TE5_PassCars</td>
<td>0.825</td>
<td>0.267</td>
</tr>
<tr>
<td>TE6_VansLorries</td>
<td>-0.132</td>
<td>-0.043</td>
</tr>
<tr>
<td>TE7_PTW</td>
<td>-0.681</td>
<td>-0.221</td>
</tr>
<tr>
<td>TE8_Vehkm_Total</td>
<td>0.269</td>
<td>0.087</td>
</tr>
<tr>
<td>TE9_RailRoad</td>
<td>0.136</td>
<td>0.044</td>
</tr>
<tr>
<td>TE10_PassengerFreight</td>
<td>-0.360</td>
<td>-0.117</td>
</tr>
</tbody>
</table>
Calculation of composite variables - Measures

\[ \text{Comp}_\text{ME} = 0.069(ME2_{ADR}) + \]
\[ 0.045(ME4_{SpeedLimits_urban}) + \]
\[ 0.064(ME6_{SpeedLimits_motorways}) + \]
\[ 0.088(ME7_{VehStand_seatbelts}) + \]
\[ 0.091(ME8_{VehStand SeatbeltAnchorages}) + \]
\[ 0.092(ME9_{VehStand_FrontImpact}) + \]
\[ 0.091(ME10_{VehStand_Sidimpact}) + \]
\[ 0.090(ME11_{VehStand_ESC}) + \]
\[ 0.087(ME12_{VehStand_PedProtection}) + \]
\[ 0.090(ME13_{VehStand_ChildSeats}) + \]
\[ 0.068(ME15_{BAClimits}) + 0.068(ME16_{BAClimits_young}) + \]
\[ 0.065(ME17_{BAClimits_commercial}) + \]
\[ 0.057(ME19_{SeatBeltLaw_all}) + \]
\[ 0.063(ME20_{ChildRestraintLaw}) + \]
\[ 0.034(ME22_{HelmetFastened}) + \]
\[ 0.038(ME23_{HelmetStand}) + 0.038(ME24_{MobileLaw}) + \]
\[ 0.035(ME25_{MobileLaw_handheld}) + \]
\[ 0.038(ME27_{PenaltyPointSyst}) + \]
\[ 0.040(ME29_{EmergTrain_nurses}) \]

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

<table>
<thead>
<tr>
<th>Component</th>
<th>Loadings</th>
<th>Score coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>ME1_{RSA}</td>
<td>0.245</td>
<td>0.025</td>
</tr>
<tr>
<td>ME2_{ADR}</td>
<td>0.681</td>
<td>0.069</td>
</tr>
<tr>
<td>ME3_{SpeedLaw}</td>
<td>0.229</td>
<td>0.023</td>
</tr>
<tr>
<td>ME4_{SpeedLimits_urban}</td>
<td>0.443</td>
<td>0.045</td>
</tr>
<tr>
<td>ME5_{SpeedLimits_rural}</td>
<td>0.200</td>
<td>0.020</td>
</tr>
<tr>
<td>ME6_{SpeedLimits_motorways}</td>
<td>0.634</td>
<td>0.064</td>
</tr>
<tr>
<td>ME7_{VehStand_seatbelts}</td>
<td>0.877</td>
<td>0.088</td>
</tr>
<tr>
<td>ME8_{VehStand SeatbeltAnchorages}</td>
<td>0.906</td>
<td>0.091</td>
</tr>
<tr>
<td>ME9_{VehStand_FrontImpact}</td>
<td>0.908</td>
<td>0.092</td>
</tr>
<tr>
<td>ME10_{VehStand_Sidimpact}</td>
<td>0.904</td>
<td>0.091</td>
</tr>
<tr>
<td>ME11_{VehStand_ESC}</td>
<td>0.891</td>
<td>0.090</td>
</tr>
<tr>
<td>ME12_{VehStand_PedProtection}</td>
<td>0.862</td>
<td>0.087</td>
</tr>
<tr>
<td>ME13_{VehStand_ChildSeats}</td>
<td>0.896</td>
<td>0.090</td>
</tr>
<tr>
<td>ME14_{DrinkDrivingLaw}</td>
<td>0.126</td>
<td>0.013</td>
</tr>
<tr>
<td>ME15_{BAClimits}</td>
<td>0.670</td>
<td>0.068</td>
</tr>
<tr>
<td>ME16_{BAClimits_young}</td>
<td>0.670</td>
<td>0.068</td>
</tr>
<tr>
<td>ME17_{BAClimits_commercial}</td>
<td>0.645</td>
<td>0.065</td>
</tr>
<tr>
<td>ME18_{SeatBeltLaw}</td>
<td>0.297</td>
<td>0.030</td>
</tr>
<tr>
<td>ME19_{SeatBeltLaw_all}</td>
<td>0.570</td>
<td>0.057</td>
</tr>
<tr>
<td>ME20_{ChildRestraintLaw}</td>
<td>0.628</td>
<td>0.063</td>
</tr>
<tr>
<td>ME21_{HelmetLaw}</td>
<td>0.236</td>
<td>0.024</td>
</tr>
<tr>
<td>ME22_{HelmetFastened}</td>
<td>0.334</td>
<td>0.034</td>
</tr>
<tr>
<td>ME23_{HelmetStand}</td>
<td>0.379</td>
<td>0.038</td>
</tr>
<tr>
<td>ME24_{MobileLaw}</td>
<td>0.375</td>
<td>0.038</td>
</tr>
<tr>
<td>ME25_{MobileLaw_handheld}</td>
<td>0.350</td>
<td>0.035</td>
</tr>
<tr>
<td>ME26_{MobileLaw_handfree}</td>
<td>0.295</td>
<td>0.030</td>
</tr>
<tr>
<td>ME27_{PenaltyPointSyst}</td>
<td>0.378</td>
<td>0.038</td>
</tr>
<tr>
<td>ME28_{EmergTrain_doctors}</td>
<td>0.178</td>
<td>0.018</td>
</tr>
<tr>
<td>ME29_{EmergTrain_nurses}</td>
<td>0.399</td>
<td>0.040</td>
</tr>
</tbody>
</table>
Calculation of composite variables - SPIs

\[ \text{Comp}_\text{PI} = 0.144 \times (\text{PI}_1\_\text{SeatBeltLaw\_enf}) + 0.155 \times (\text{PI}_2\_\text{DrinkDrivingLaw\_enf}) + 0.152 \times (\text{PI}_3\_\text{SpeedLaw\_enf}) + 0.160 \times (\text{PI}_4\_\text{HelmetLaw\_enf}) + 0.155 \times (\text{PI}_5\_\text{SeatBelt\_rates\_front}) + 0.146 \times (\text{PI}_6\_\text{SeatBelt\_rates\_rear}) + 0.150 \times (\text{PI}_7\_\text{Helmet\_rates\_driver}) + 0.127 \times (\text{PI}_8\_\text{SI\_ambulance}) + 0.116 \times (\text{PI}_9\_\text{HospitalBeds}) \]

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

<table>
<thead>
<tr>
<th>Component</th>
<th>Loadings</th>
<th>Score coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>PI1_SeatBeltLaw_enf</td>
<td>.756</td>
<td>.144</td>
</tr>
<tr>
<td>PI2_DrinkDrivingLaw_enf</td>
<td>.812</td>
<td>.155</td>
</tr>
<tr>
<td>PI3_SpeedLaw_enf</td>
<td>.795</td>
<td>.152</td>
</tr>
<tr>
<td>PI4_HelmetLaw_enf</td>
<td>.837</td>
<td>.160</td>
</tr>
<tr>
<td>PI5_SeatBelt_rates_front</td>
<td>.811</td>
<td>.155</td>
</tr>
<tr>
<td>PI6_SeatBelt_rates_rear</td>
<td>.766</td>
<td>.146</td>
</tr>
<tr>
<td>PI7_Helmet_rates_driver</td>
<td>.784</td>
<td>.150</td>
</tr>
<tr>
<td>PI8_SI_ambulance</td>
<td>.667</td>
<td>.127</td>
</tr>
<tr>
<td>PI9_HospitalBeds</td>
<td>.607</td>
<td>.116</td>
</tr>
</tbody>
</table>
Final Statistical Model

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

- **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 GNI per capita for 2013
- Four **composite variables**: the economy & management, the transport demand and exposure, the measures, and the SPIs

<table>
<thead>
<tr>
<th>Parameter</th>
<th>B</th>
<th>Std. Error</th>
<th>95% Confidence Interval</th>
<th>Hypothesis Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td>1.694</td>
<td>.2737</td>
<td>1.157 - 2.230</td>
<td>38,291</td>
</tr>
<tr>
<td>Comp_ME</td>
<td>-0.135</td>
<td>.0646</td>
<td>-0.261 - 0.008</td>
<td>4,358</td>
</tr>
<tr>
<td>Comp_TE</td>
<td>-0.007</td>
<td>.0028</td>
<td>-0.013 - 0.002</td>
<td>7,230</td>
</tr>
<tr>
<td>Comp_PI</td>
<td>-0.007</td>
<td>.0030</td>
<td>-0.013 - 0.001</td>
<td>5,652</td>
</tr>
<tr>
<td>Comp_EM</td>
<td>0.007</td>
<td>.0051</td>
<td>0.003 - 0.017</td>
<td>2,009</td>
</tr>
<tr>
<td>LNFestim_2010</td>
<td>0.769</td>
<td>.0462</td>
<td>0.678 - 0.859</td>
<td>276,322</td>
</tr>
<tr>
<td>LNGNI_2013</td>
<td>-0.091</td>
<td>.0314</td>
<td>-0.153 - 0.030</td>
<td>8,402</td>
</tr>
<tr>
<td>(Scale)</td>
<td>0.038</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Likelihood Ratio</td>
<td>1379.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>df</td>
<td>6</td>
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<tr>
<td>p-value</td>
<td>&lt;.001</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Statistical 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.
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.

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SafeFITS Model Demonstration

The overall model implementation includes 3 distinct steps:

• Step 1 – Countries Benchmark

• Step 2 – Forecast with no new interventions

• Step 3 – Forecast with interventions
Model limitations and future improvements

• 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. 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 direct 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 and intervention testing**.

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

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