Development of a Global Road Safety Model

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The i-safemodels project

- **Project partners**:
  - National Technical University of Athens,
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  - OSeven Telematics
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  - Tongji University
    https://en.tongji.edu.cn

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ανάπτυξη - εργασία - αλληλεγγύη

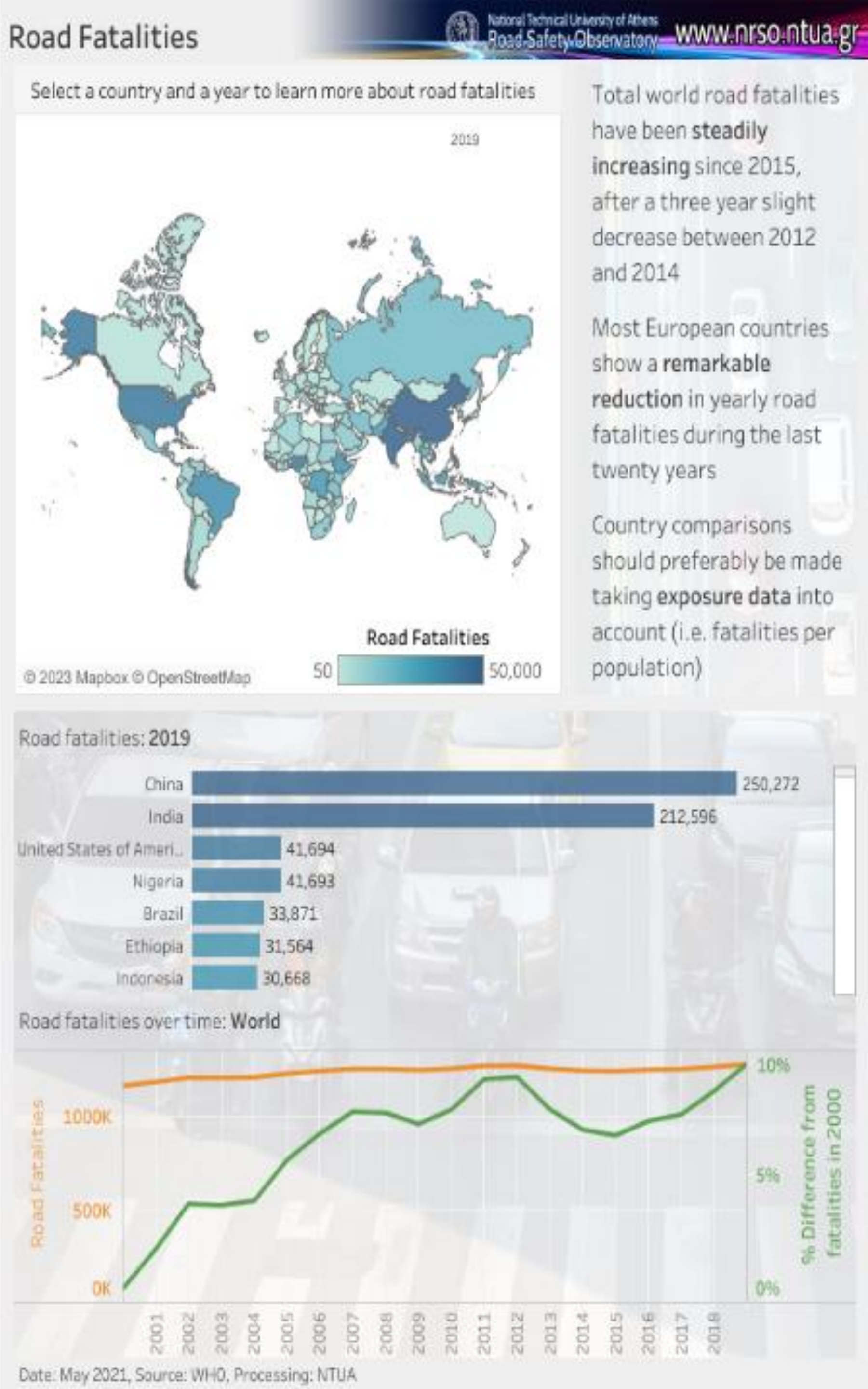
ΕΛΛΗΝΙΚΗ ΔΗΜΟΚΡΑΤΙΑ

ΓΕΝΙΚΗ ΓΡΑΜΜΑΤΕΙΑ ΕΡΕΥΝΑΣ ΚΑΙ ΤΕΧΝΟΛΟΓΙΑΣ

EPAnEK 2014-2020
OPERATIONAL PROGRAMME
COMPETITIVENESS•ENTREPRENEURSHIP•INNOVATION

Background

- Road safety constitutes a major societal and public health problem, with road crashes being one of the leading causes of death globally.
- More than 1.35 million people are killed in road crashes and up to 50 million are injured every year (WHO, 2018).
- Great discrepancies in road safety performance exist among the countries worldwide.
- Low- and middle-income countries bear the greatest burden of road crash fatalities and injuries.
- The UN General Assembly proclaimed the Decade of Action for Road Safety 2021-2030 and developed a Global Plan for the Decade of Action.



Objective

- The objective of the current study is to develop a **global road safety model** to be used for policy support:
  - Global assessments (i.e. monitoring the global road safety progress towards the UN road safety targets)
  - Individual country assessments of policy scenarios

- Data for **129 countries** with the highest population worldwide were collected:
  - Time series data for **road traffic fatalities** and **GDP per capita** for the period 2000-2019
  - Data for the latest available year for **45 road safety indicators**

Literature Findings

- The review of several road safety management systems has highlighted the existence of different levels and pillars in the road safety systems.

- A methodological approach was introduced in the SUNflower project based on a road safety target hierarchy of “social costs - final outcomes - intermediate outcomes - programmes/measures - structure/culture”.

- Another family of models link road safety outcomes developments with the development of exposure and / or the economy, as well as in relation to the road safety policies and measures.

- The SafeFITS project developed a road safety decision-making tool for national and local governments, through an improved version of the SUNflower pyramid.

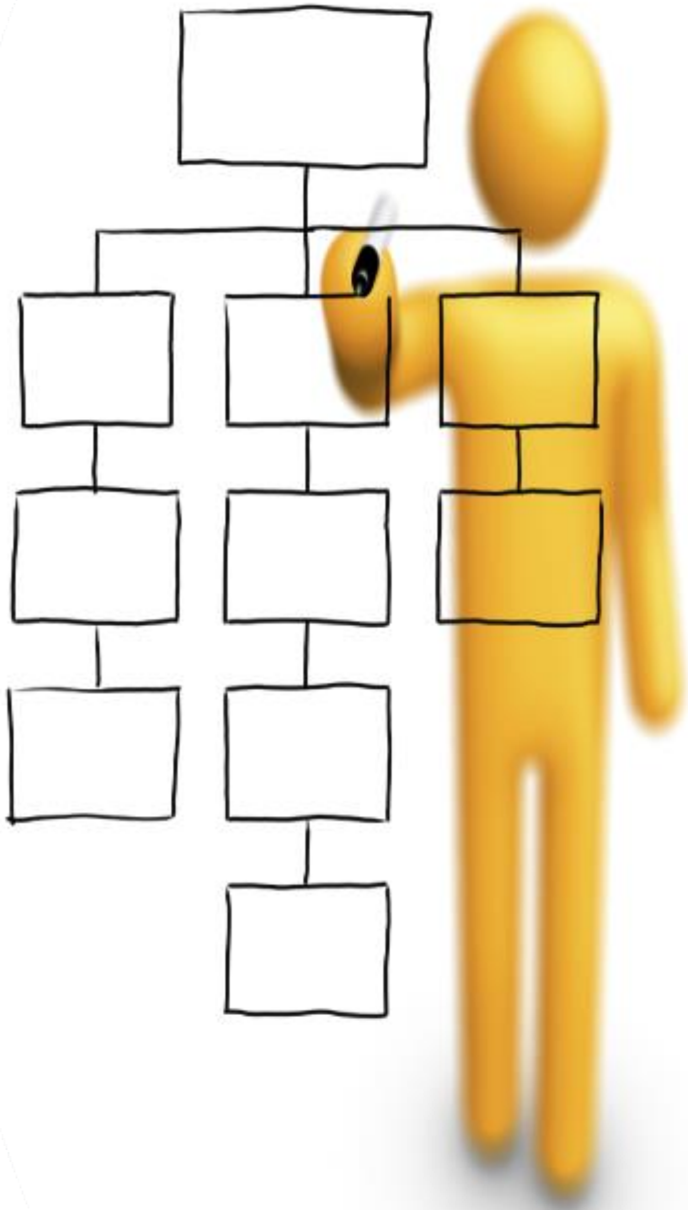
- The UN Global Plan of Action proposed national road safety activities in five pillars: Road Safety Management, Road Infrastructure, Vehicle, Road User and Post-Crash Services.

Methodology

1. Two-step cluster analysis, in order to classify the countries into groups of countries with similar characteristics.

2. Confirmatory factor analysis, it was selected to keep one composite indicator per road safety pillar: Infrastructure, Vehicle, Road User, Post-crash care, Country characteristics.

3. Generalized Linear Mixed Model, in order to correlate road safety outcomes with indicators through composite variables.



Data Sources

- **Global Health Observatory (GHO) of WHO**: road traffic fatalities, information and data on road safety management, road safety strategies, basic risk factors (i.e., speeding, drink-driving, use of protective systems, mobile phone use while driving) and post-crash care.

- **International Road Federation – World Road Statistics (IRF-WRS)**: road network length, length of paved roads, length of motorways, number of vehicles in traffic (in total and by vehicle type: passenger cars, motorcycles, heavy goods vehicles, buses), vehicle-kilometers travelled

- **World Bank database**: Area, Demographics, i.e., total population, population per age group, population per type of residence area (urban/rural), life expectancy at birth and at 65 years old, Gross Domestic Product.

Data Overview (1/2)

- Time series data for **GDP per capita** and **traffic fatality rates per population** (2000-2019)

- Road Safety Indicators for **129 countries** worldwide (data for the latest available year, mainly 2016)

  - Pillar 1. Infrastructure (5 indicators)
  - Pillar 2. Vehicle (6 indicators)
  - Pillar 3. Road User (19 indicators)
  - Pillar 4. Post-crash care (6 indicators)
  - Pillar 5. Road Safety Management and Country Characteristics (6 indicators)

Data Overview (2/2)

- Low data availability is observed for few variables, mainly regarding exposure data, performance indicators and post crash care.

- Missing data per indicator were retrieved from other data sources, ensuring that the different data sources can be used in a complementary way.

- In case that data were not available in other sources, the latest available data were used, if time-series data were available.

- If no data were available, missing values for each country were imputed with the mean value of the indicator of the group in which the specific country has been classified.

Cluster Analysis

- A two-step cluster analysis was performed
- Five clusters were defined, with an average silhouette measure of cohesion and separation equal to 0.6, based on 5 inputs:
  - vehicles per population,
  - road network density,
  - life expectancy at birth,
  - percentage of passenger cars in total vehicle fleet,
  - percentage of motorcycles in total vehicle fleet.
- Cluster 1: highest ratio of vehicles per population, high network density, high life expectancy at birth
- Cluster 2: densest road network, highest life expectancy at birth
- Cluster 3: medium motorization level, road network density lower than the global average, large proportion of passenger car
- Cluster 4: least motorized countries
- Cluster 5: highest ratio of motorcycles in the vehicle fleet

Cluster	Countries	N	% of Total
1	Australia, Austria, Canada, Czechia, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Korea, Rep., Lithuania, New Zealand, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland, United Kingdom, United States of America	25	19.4%
2	Belgium, Netherlands, Singapore	3	2.3%
3	Albania, Algeria, Argentina, Azerbaijan, Belarus, Bosnia and Herzegovina, Brazil, Bulgaria, Chile, China, Costa Rica, Croatia, Cuba, Ecuador, El Salvador, Georgia, Iran Islamic Rep., Iraq, Israel, Jordan, Kazakhstan, Kuwait, Kyrgyzstan, Lebanon, Mexico, Mongolia, Morocco, Oman, Panama, Republic of Moldova, Romania, Russian Federation, Serbia, Tunisia, Turkey, United Arab Emirates, Uruguay, Armenia	38	29.5%
4	Afghanistan, Bolivia, Burundi, Cameroon, Chad, Cote d'Ivoire, Egypt, Arab Rep., Eritrea, Ethiopia, Ghana, Guinea, Liberia, Madagascar, Mali, Mozambique, Niger, Nigeria, Papua New Guinea, Saudi Arabia, Senegal, Somalia, South Africa, Tajikistan, Uzbekistan, Yemen, Rep., Zambia, Zimbabwe, Angola, Central African Republic, Congo, Dem. Rep., Congo, Rep., Malawi, Mauritania, Sudan	35	27.1%
5	Bangladesh, Benin, Burkina Faso, Cambodia, Colombia, Dominican Republic, Guatemala, Honduras, India, Indonesia, Kenya, Lao PDR, Malaysia, Myanmar, Nepal, Nicaragua, Pakistan, Paraguay, Peru, Philippines, Rwanda, Sri Lanka, Thailand, Uganda, United Republic of Tanzania, Vietnam, Libya, Turkmenistan	28	21.7%
Total		**129**	**100.0%**

Estimation of composite variables

- Factor analysis **per road safety pillar** (constrained to yield to one factor per pillar)
- **45 road safety indicators** were included in the analysis
- For communalities **more than 0.3**, the extracted components represent the variables well

Composite Variable - Infrastructure

- All five indicators were considered for the estimation of this composite variable.
- This factor represents 42.37% of the overall variance in the data.
- The ratio of paved roads in the total road network and the Safe Urban Mobility indicator are those with the highest communalities.

[P1_Infrastructure]$_i$ *= 0.288*[Road Network Density]$_i$ + 0.277*[Motorways(%)]$_i$ + 0.362*[Paved Roads (%)]$_i$ + 0.259*[Infrastructure Safety]$_i$ + 0.334*[Safe Urban Mobility]$_i$,*

Composite Variable - Vehicle

- 4 out of 6 indicators were considered for the estimation of this composite variable (communality higher than 0.3).
- This factor represents 43.35% of the overall variance in the data
- The vehicle rate per population, the ratio of passenger cars in the vehicle fleet and the application of UN vehicle standards in the national legislation are those with the highest communalities.

$$[\boldsymbol{P2\_Vehicles}]_i = 0.303*[\text{Vehicles per population}]_i + 0.319*[\text{\% of passenger cars in vehicle fleet}]_i - 0.260*[\text{\% of motorcycles in vehicle fleet}]_i + 0.302*[\text{UN Vehicle Standards}]_i$$

Composite Variable – Road User

- **10 out of 19 indicators** were considered for the estimation of this composite variable.

- This factor represents **35.82%** of the overall variance in the data

- Indicators related to the **use of protective systems** (seat-belt and helmet) and the **assessment of traffic enforcement** are those with the highest communalities.

[P3_Road User]$_i$ *= 0.079*[Drink Driving Law]$_i$ + 0.093*[Seat Belt Law]$_i$ + 0.090*[Child Restraint Law]$_i$ + 0.106*[*Assessment of seat belt law enforcement*]$_i$ + 0.100*[Assessment of drink-driving law enforcement]$_I$ + 0.105*[Assessment of speed law enforcement]$_i$ + 0.107*[Assessment of helmet law enforcement]$_i$ + 0.108*[Seat belt use rates - driver]$_i$ + 0.114*[Seat belt use rates - front passenger]$_i$ + 0.112*[Helmet use rates - driver]$_i$*

Composite Variable - Post-crash care

- 3 out of 6 indicators were considered for the estimation of this composite variable.

- This factor represents 37.70% of the overall variance in the data.

- The indicators related to the density of hospitals and the ratio of available hospital beds per population are those with the highest communalities.

$$\boldsymbol{[P4\_Post\text{-}crash\ care]_i} = 0.279*[Hospital\ beds\ per\ population]_i + 0.406*[Hospital\ Density]_i + 0.367*[Rural\ Hospital\ Density]_i$$

Composite Variable – Country Characteristics

- 4 out of 9 indicators were considered for the estimation of this composite variable.
- This factor represents 38.73% of the overall variance in the data.
- The indicators related to the demographic characteristics of the countries are those with the highest communalities.

$$\textbf{[P5\_Country characteristics]}_i = -0.267^*[\%\text{ of population aged} < 15\text{ y.o.}]_i + 0.245^*[\%\text{ of population aged} > 65\text{ y.o.}]_i + 0.216^*[\%\text{ of urban population}]_i + 0.264^*[\text{Life expectancy at birth}]_i$$

Generalized Linear Mixed Model

- A panel dataset is constructed, including repeated measurements of the same set of individuals (i.e., countries) over time.
- Dependent variable is the logarithm of the fatality rate per population
- The main explanatory variable is the logarithm of GDP per capita, the repeated measures of which allow for the analysis of changes in the fatality rate over time
- Five composite variables (Infrastructure, Vehicle, Road User, Post-crash care, Country Characteristics) as control variables aiming to capture individual-level variation

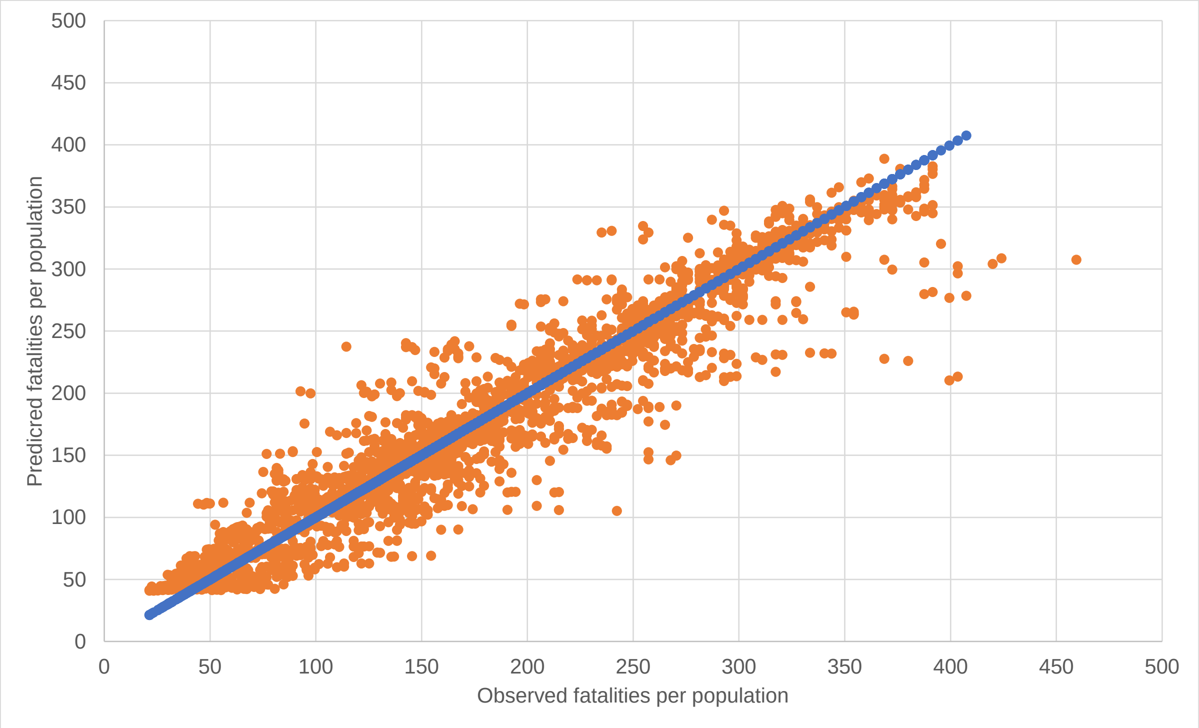
GLMM Results

- Increase in the GDP per capita leads to reduction of road fatalities per population
- All the parameter estimates of the composite variables, except the post-crash care composite variable, were found statistically significant.
- An increase in the composite variable score results in a decrease in the fatality rate
- The parameter estimate of the P5 Country Characteristics has a positive sign, which is attributed to the fact that demographic characteristics are included in this factor
- There is significant between-countries variation in the fatality rates per population

Fixed Effects							
	B	t-test	sig.	CI (95%)		F-test	Sig.
				Lower	Upper		
(Intercept)	**7.052**	49.678	0.000	6.774	7.330	53.983	0.000
LNGDPcap	**-0.210**	-10.774	0.000	-0.248	-0.171	116.087	0.000
P1_Infrastructure	**-0.007**	-2.073	0.038	-0.013	0.000	4.299	0.038
P2_Vehicles	**-0.093**	-2.214	0.027	-0.176	-0.011	4.902	0.027
P3_Road User	**-0.012**	-1.964	0.050	-0.025	-2.09E-5	3.858	0.050
P4_Post-crash care	-0.001	-0.087	0.931	-0.014	0.013	0.007	0.931
P5_Country characteristics	**0.011**	1.802	0.072	-0.001	0.023	3.248	0.072
Goodness of Fit							
Akaike's Information Criterion (AIC)	-231.12						
Omnibus Test							
Likelihood Ratio Chi-Square	-237.13						
df	6						
p-value	0.000						

Random Effects					
	Estimate	Z	sig.	CI (95%)	
				Lower	Upper
Variance	0.114	7.694	0.000	0.088	0.147

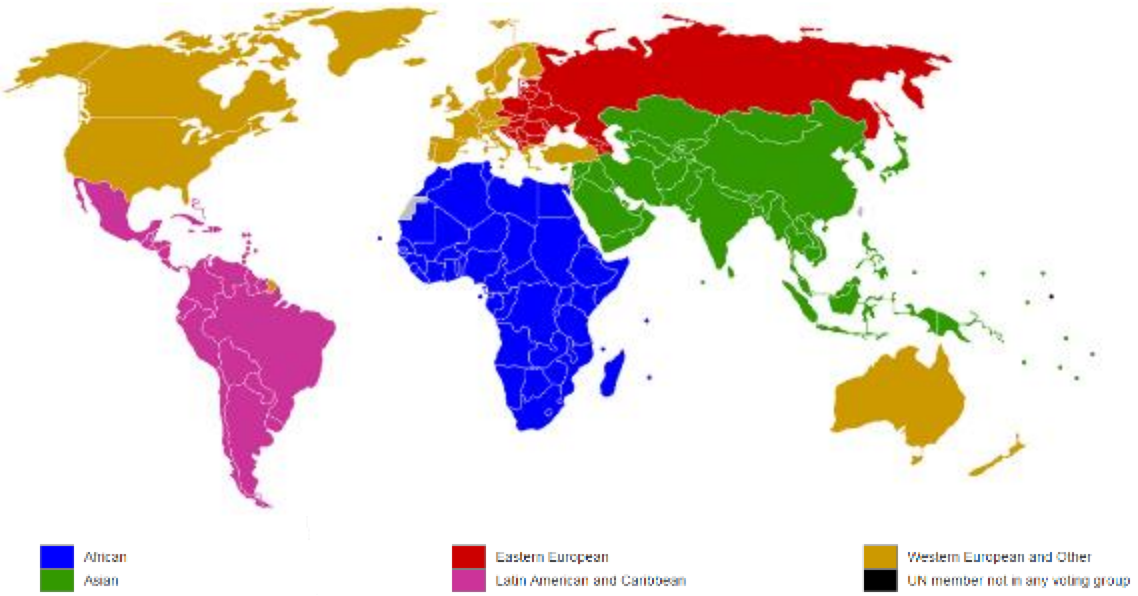
Statistical Model Assessment



- The model is satisfactory for almost all countries tested.
- The mean percentage prediction error is estimated at 13.9% of the observed value.
- 75% of values (country-years) in the dataset have less than a 20% prediction error

Mortality Change 2019-2030

- An overall decrease by 5.7% is predicted for road fatalities in 2030
  - African region: +14.6%
  - Asian Region: -9.8%
  - Eastern European Region: -15.61%
  - Latin American and Caribbean: -6.3%
  - Western European & Other: -10.9%



Conclusions (1/2)

- Data for 129 countries with the highest population worldwide were collected:
  - time series data for road traffic fatalities and GDP per capita for the period 2000-2019 and
  - data for the latest available year for 45 road safety indicators, covering the five road safety pillars introduced by UN (Infrastructure, Vehicle, Road User and Road Safety Management).

- A Generalized Linear Mixed Model was developed, using historical data of 20 years (2000-2019) for the fatality rates and the Gross Domestic Product per capita.

- The composite variables, calculated through the factor analysis, were also included in the analysis as control variables in order to capture any country-level variations.

- It was found that road safety is improved with the increase of the economic level of a country over time.

Conclusions (2/2)

- The model could be used to serve key purposes in road safety policy analysis, i.e., forecasting road traffic fatalities, testing policy interventions.

- Indicators related to infrastructure, road user (e.g., protective systems use rates) and post-crash care (e.g., number of available hospital beds) had the most missing values.

- This concerned to a greater extent the less developed countries (mostly African and Asian).

- Lack of historical data for almost all road safety indicators does not allow to explore the effects of their evolution over time on the fatality rate trends.

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