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INFLUENCE OF ROAD NETWORK STRUCTURE AND MOBILITY FLOWS ON THE SCALE OF TRAFIC FATALITIES

Abstract

This paper is adapted from the literature (EWGT 2012 -Kazimierz Jamroz * - 15th meeting of the EURO Working Group on Transportation), according to the EU guidelines for getting "Best Practice" as a guide material to be used in the opening of the horizon in the Road Safety Study related to the description of the effect of selecting the "Road Network Structure", which should be the basis of "policy making" for defining the National Plan of Infrastructure Development of the Road Network of Albania, the change in "Mobility Flows" defined in the National Transport Plan, and the "Death at Traffic Accidents" (VAT) scale. The conclusions of this article are based on the study data of a number of countries around the world and therefore have a general value over which it has become possible to develop some non-linear factors analysis models that help identify these effects and make a decision Strategic Seas required for: Economic Development of the Country, Predicted Road Network Systems, Motorization Rate (1000 Population Vehicles), and Infrastructure Development .

We have to bear in mind that the 2010 "White Paper" of the EU Commission for the EU Road Safety Objectives for 2020 as the main objective is foreseeing the halving of "Mortality in Traffic Accidents". The same objective has been set in the "National Road Safety Plan 2011-2020" for our country.

Through this reference we do not want to show that we have done science, but we want to recommend a good scientific direction, demonstrated in an international forum, the 15th meeting of the EURO Working Group on Transportation, to be used as a good experience the studies of this field and our country.

Introduction

For the assessment of road safety with non-linear models based on the "VAT" scale, we need to have data on: population mobility measured by kilometers of traveled vehicles "VKTPC", the total density of road networks related to demography " DDR ", the percentage of paved roads" PPR "and the percentage of highways and" expressways "within the road network" PME

Albania's road network, including the interurban main roads, secondary and urban interurban roads, is about 18,600 km. As far as road infrastructure is concerned, over the last 10 years, Albania has made very important investments in building the main segments of the Albanian National Road Network . The National Transport Plan foresees completion of the construction of the national road network, including strategic arteries such as the North-South Highway

The development of the SEETO (South-East Europe Transport Observatory), up to TEN-T (Trans-European Transport Network) standards with the aim of attracting international traffic flows and increasing the movement in the region through this network remains an important goal of regional transport co-operation administered under the auspices of SEETO. This network has recently been confirmed as the Comprehensive TEN-T Network in Southeast Europe.

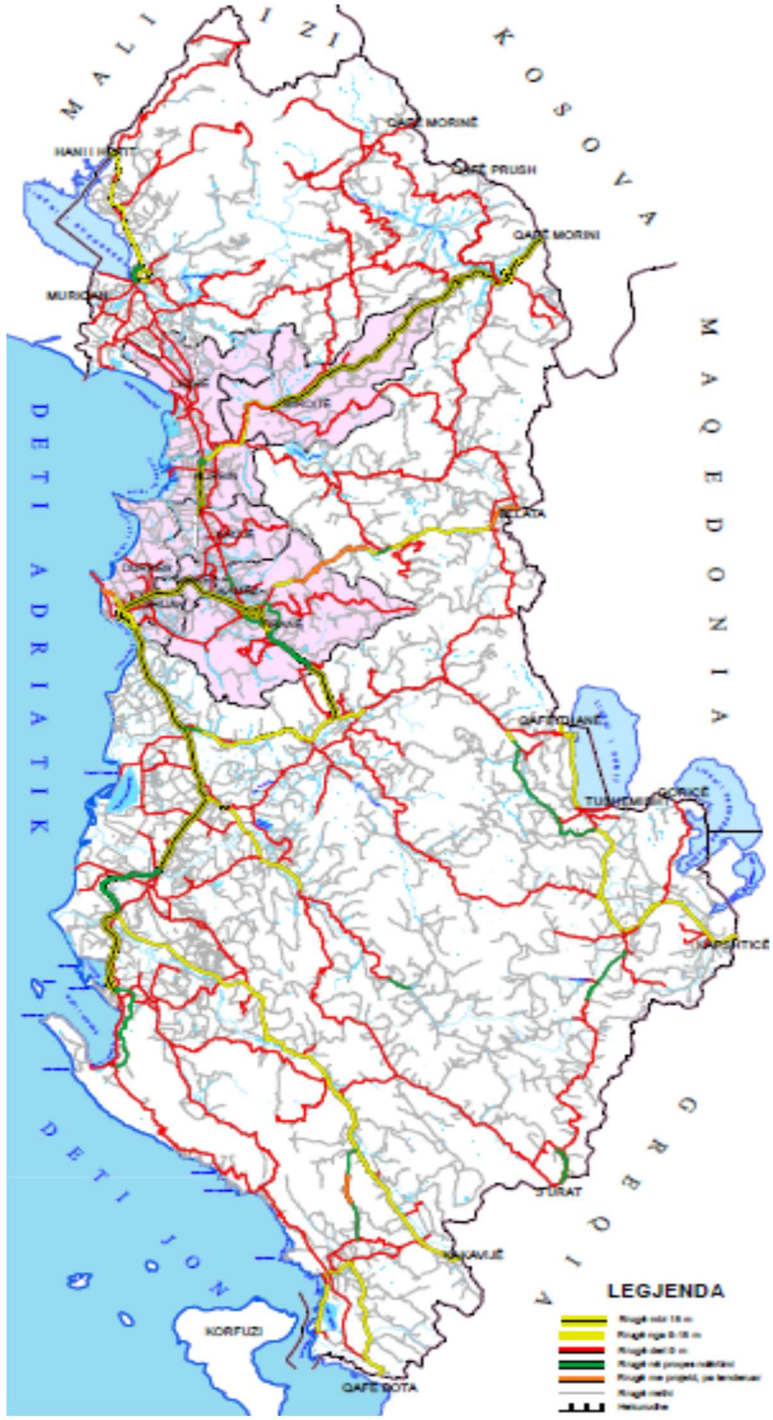
M A L I I Z I
K O S O V A
M A Q E D O N I A
D E T I A D R I A T I K
D E T I J O N
G R E Q I A
KORFUZI
QAFË BOTA
LEGJENDA

Figure 1 Structure of Albania's Road Network

Data on Accidents and Road Transport in Albania (IST)

year	**2013**	**2014**	**2015**	**2016**	**2017**
Accidents	2,075	1,914	1,992	2,033	1,978
Killed	**295**	**264**	**270**	**269**	**222**
Injure	2,503	2,353	2,422	2,510	2,389
Registered road transport vehicles	445,956	490,899	522,008	563,106	535,570
Road transport vehicles carrying out annual technical inspection	307,609	346,404	376,028	401,499	421,573

Road safety levels measured with the road fatality rate differ significantly from to country with even stronger differences between '**developing**" and "**developed**" countries. The increase in road deaths over the last decade has been the highest in Asian countries. Developed European countries, on the other hand, have had significant success with their fatality reduction targets (**WHO**). One of the main factors of success is explained by the impacts on the road infrastructure, and in particular on the reorganization of the structures and quality of population mobility

Road safety improvement is an important priority for the UN, a number of other international organisations and national agencies in this decade. One of the pillars of the UN's strategic plan is the safer road. This raises the question of what road and road safety strategy the national level authorities should pursue to reduce fatalities. As we see in the table below, although in the "National Road Safety Plan" we have predicted the halving of the number of accidents and especially of those with deaths, we have a stagnation of this phenomenon, failing to reach the target defined because the growth of development and development of road infrastructure does not respond to the growth rate of the motorcycle scale from 445956 in 2013 to 535570 vehicles in 2017 contributes to increasing the mobility of the population

When considered at the strategic level of a country, the following are the relevant factors:

- **the structure of the road network (SRN),** and
- **mobility of the country's population MCP)**.

The objective of this work is to identify the effects of selected measures of a country's road network structure and population mobility on the road fatality rate. as the highest severity of road accidents , taking advantage of the World's "Best Practice" (PM), from "Recommended Practices" (PR) and "Standards" (S)

We are based on the study of world literature [1, 2], where we find the concept of how a country's "road safety" changes if measured by "mortality rate in road accidents".

Based on the literature and the results of the author's own work fatality rate. According to this concept ***a country's road safety performance changes non-linearly in relation to changes in social and economic development***. As the economic potential of a country grows, so do the activity of its population and the number of vehicles. While the length of paved roads increases as well, the pace of increase is usually much slower than expected. ***With relatively low standards of safety, no safety management,*** poor road safety funding and no safety culture, the number of fatalities is increasing quite rapidly to reach its maximal value at breakpoint.

The maximal value of the road fatality rate depends :

- from livel of the mobility of the population,
- structure of the road network,
- demographic,
- social factors,
- and motorization,

Once the breakpoint is exceeded, there is an initial rapid fall in the road fatality rate as a result of new road infrastructure, launch of safety management systems, better health care, new road user behaviour and population mobility.

The aforementioned literature uses Several basic measures are used to assess the effects of selected road safety factors concerning the road network. They look at the structure of the road network and the mobility of the population.

The features of a road network include
- **"length",**
- **"spatial structure",** and
- **"functional structure"**.

This work examines the functional structure, i.e. the proportion of different types of roads in the overall network. These are roads in general, paved roads, motorways and expressways. Three measures of road network functional structure are analysed: density of roads related to demography DDR, proportion of paved roads PPR and proportion of motorways and expressways PME calculated with the following formulas (1-3):

$$DDR = \frac{LR}{P} \qquad (1)$$

$$PPR = \frac{LPR}{LR} \cdot 100 \qquad (2)$$

$$PME = \frac{LME}{LR} \cdot 100 \quad (3)$$

where: *DDR* – demographic density of roads (km/1 M population), *PPR* – proportion of paved roads (%), *PME* – proportion of motorways and expressways (%), *LR* – total length of roads (km), *LPR* – length of paved roads (km), *LME*– length of motorways and expressways (km), *P* – population (M population). Transport infrastructure, including road infrastructure, has an important effect on economic growth. Because transport provides a service, it is stimulated by the needs of the economy. Transport and economy are interrelated; economic development relies on transport infrastructure but because it is capital intensive its development depends on the country's economy. The road network has a significant impact on traffic volumes generated by the transport of people and goods. Roads attract settlement, industry, services, etc. and are the backbone of villages, towns and conurbations. A country's road traffic is measured by vehicle kilometres travelled which is the product of the distance covered by vehicles VKT.

It also measures the mobility of the country's population VKTPC (formula 4).

$$VKTPC = \frac{VKT}{P} \quad (4)$$

where: *RFR* – road fatality rate related to demography per year in a specific area (fatalities/1 M population/year), F – number of killed in road accidents per year in a specific area (fatalities/year). where: *VKTPC*– average vehicle kilometres travelled per year per capita (km/population/year), *VKT* – national vehicle kilometres travelled per year (M km/year).

Fatality (mortality) is a common measure of public health and means the number of deaths in a given area and period. In the case of road safety fatality can be referred to demographic or motor traffic data. Road safety is frequently measured with the road fatality rate RFR which is defined as the relationship between fatalities F and population P in a unit of time. The rate is described with the following formula (5).

$$\mathbf{RFR= F : P} \qquad \mathbf{(5)}$$

where: *RFR* – road fatality rate related to demography per year in a specific area (fatalities/1 M population/year), F – number of killed in road accidents per year in a specific area (fatalities/year).

Methodology

Empirical fatality data were sourced from a number of databases: Eurostat, FAO, IRF, IRTAD, OECD, TI, UN, WB and WHO. In addition other sources provided other country parameters by the years such as geographic, demographic, economic, social, motor traffic, road and transport variables. The number of countries that do not hold reliable data on deaths in road accidents and those who have not shown changes in the road death rate over the years. has been reduced, this data is reported annually and by INSTAT for Albania.

The road fatality rates of the countries selected for the study (including Australia, France, Japan, the Netherlands and Sweden) are similar. Altogether 22 countries were studied in the period 1960 – 2010 comprising a set of 859 country years, this is the purpose of this study, because drawing such conclusions, with only one-year data from our country's data, with the negligible funds we can provide for studies in this area, and above all, with the lack of qualified experts in this field, these conclusions would not be convincing for decision-makers

In order to choose the most significant independent variables, an analysis was conducted to establish the power of inter-dependencies between independent variables (X) and selected safety measures (Y). To study the relations between variables *X* and *Y*, Pearson's R linear correlation coefficient was used which measures the power of a straight line relation between two measurable features. Neural networks were used to define the strength of the relationship between non-linear variables. As a result of an in-depth analysis, a group of 30 factors was narrowed down to 9. They included measures of the road network structure and mobility.

The literature includes several cases of RFR modelling, usually adopted as the F/P relation. The models used included simple regression[3], the exponential equationand [4] Kuznetz model [5]. The particular analytical form of the approximating function depends on its ability to illustrate empirical data.

The power-exponential function was selected due to its ability of data approximation. The power-exponential function is the product of the power and exponential function. This function is known to have been used for modelling road safety measures [6], [7] .

Results

For the purposes of this paper the RFR was modelled on the power-exponential function generally described with the formula (6) (Jamroz, 2011):

$$RFR = \beta_o \cdot GDPPC^{\beta_1} \cdot VTKPC^{\beta_2} \cdot DP^{\beta_3} \cdot exp(-\beta_4 \cdot GDPPC - \beta_5 \cdot VTKPC - \beta_6 \cdot LEI - \beta_7 \cdot CPI + \beta_8 \cdot ACPC + \beta_9 \cdot DDR + \beta_{10} \cdot PPR - \beta_{11} \cdot PME)$$

where: *GDPPC* – gross national product per capita (thousands ID/inhabitant/year), (PPP, constant 2005, international $),

DP – density of population (inhabitants/km2/year),

LEI – life expectancy index,

CPI – corruption perception index,

ACPC – alcohol consumption per capita (l/inhabitant/year),

b, b $_1$**, b** $_2$, ,**b**$_n$. – equation coefficients.

The parameters of the equations given in the model (6) were calculated using STATISTICA (StatSoft,2008), a computational package. Table 1 shows the equation parameters for selected models representing the country's characteristics and transport systems. Table 1 The parameters of selected RFR models The parameters of the equations given in the model (6) were calculated using STATISTICA (StatSoft, 2008), a computational package. Table 1 shows the equation parameters for selected models representing the country's characteristics and transport systems.

Table 1 The parameters of selected RFR models

Parameter	Variable	Model				
		RFR_1	$RFR_{2.a}$	$RFR_{3.a}$	$RFR_{2.b}$	$RFR_{3.b}$
β_0		1.15	3.564	132.48	7.14	155.36
β_1	GDPPC	3.023	2.381	1.555	1.859	1.383
β_2	**VKTPC**		0.385	0.438	0.868	0.632
β_3	DP			0.077		0.073
β_4	GDPPC	0.200	0.193	0.115	0.163	0.105
β_5	**VKTPC**				0.098	0.041
β_6	LEI			4.023		3.869
β_7	CPI			0.029		0.033
β_8	ACPC			0.016		0.016
β_9	**DDR**			0.013		0.012
β_{10}	**PPR**			0.001		0.001
β_{11}	**PME**			0.081		0.077
BP (break point)		15.1	12.3	13.5	11.4	13.2
R^2		0.507	0.573	0.801	0.588	0.803
p		<0.01	<0.01	<0.015	<0.01	<0.045

The Table gives statistics of the quality of the models (p, R2). The variables used have a high degree of significance ($p < 0.05$) and meet the Wald test at significance level of 5% which shows that the independent variables are significant in the non-linear models. The R2 coefficient of determination was within 0.507 to 0.803.

An analysis of the coefficient shows that models with one variable explain only 51% of the variability, models with two variables explain 57 – 59% of the variability and models with additional variables explain 80% of the variability of the functions.

The available data (for baseline group of 22 countries) do not show the early stages of social and economic development (for GDDPC < 5 thou. ID/inhab./year) or high income per capita (for GDPPC > 50 thou. ID/inhab./year). Figure 1 shows the change in RFR versus GDPPC as parameter of scale (for model RFR3.a) versus actual data.

As you can see, RFR changes together with the changing levels of the country's socioeconomic development following the power-exponential function. In the early stages of socio-economic development the numerical value of RFR increases rapidly until it reaches its maximum (at breakpoint BP which occurs for GDPPC = 11.4 – 15.1 thou. ID/inhab. depending on the model) and then starts to decline at first quite rapidly and then gradually slower asymptotically to the GDPPC axis.

The result is a simple RFR change model using the power-exponential function with GDPPC as the parameter of scale representing the country's level of social and economic development (Fig. 1).

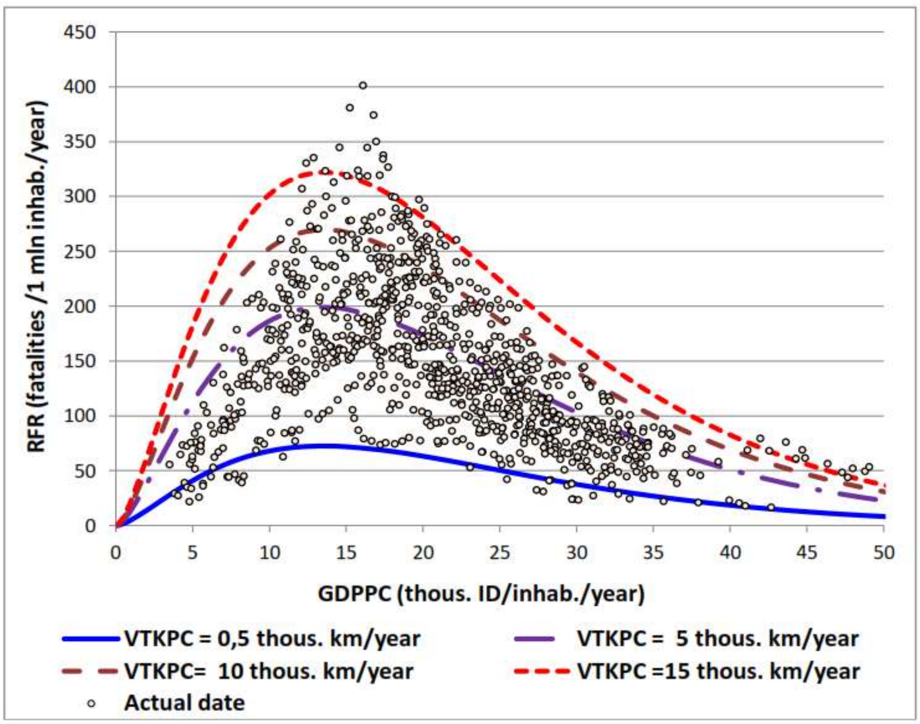

Fig. 1 Changes of the RFR in relation to GDPPC compared to actual data for 22 countries (model RFR3.a)

A sensitivity analysis attempts to determine the change in the model output value RFR that results from modest changes in model input values (determinants).

The sensitivity analysis can be used as part of a first order uncertainty analysis. Elasticity is the measurement of how changing one determinant variable affects RFR. We would use partial derivatives to calculate the various elasticities according to the formula (7):

$$\varepsilon_i^{RFR} = \frac{\partial RFR(\boldsymbol{x})}{\partial x_i} \cdot \frac{x_i}{f(\boldsymbol{x})} \tag{7}$$

To find the combined effect of changes in two or more determinants of RFR we simply add the separate effects.

This allows a determined of the impact, thus describing the significance of eachvariables.

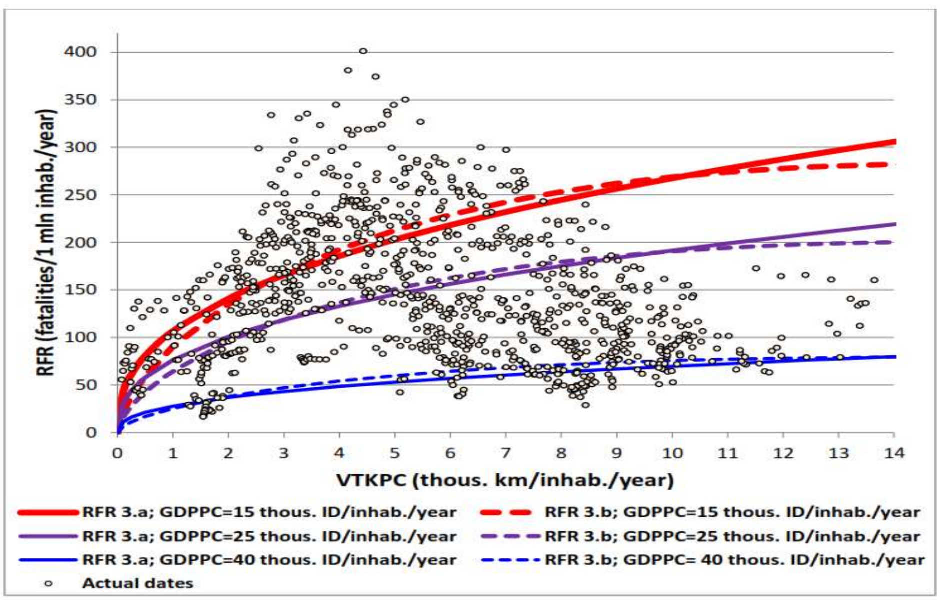

Fig. 2 Change of RFR in relation to VTKPC compared to actual data for 22 countries (model RFR3.a and RFR3.b), The variables in question (VTKPC, DDR, PPR and PME) have a significant effect on the fatality rate RFR and how it changes

The numerical value of RFR (for the same numerical value of parameter of scale GDPPC) changes as follows:

- **it increases** when the following increase: average vehicle kilometre travelled per capita **VTKPC**, population density DP, alcohol consumption per capita ACPC, demographic density of roads **DDR** and percentage of paved roads **PPR**,
- **it decreases** as the following increase: life expectancy index LEI, corruption perception index CPI and percentage of motorways and expressways in total roads **PME**.

The average vehicle kilometre travelled per capita **VTKPC** is the relation between vehicle kilometres travelled and the country's population. This rate is within 0.1 – 13.7 thou. km/inh./year. VTKPC increases together with the country's economic growth asymptotically towards saturation which may differ from country to country depending on its transport policy, size and land use. As the VTKPC increases the RFR increases following the exponential function (average interval elasticity at 0.8%). Figure 2 shows the diagrams of how the RFR changes in relation to GDPPC and VTKPC for average values for the other parameters.

This diagram confirms the significant effect VTKPC has on RFR. The figure also shows the diagrams of the relationships according to two models of change of RFR vs. VTKPC (power model RFR 3.a and powerexponential model RFR 3.b). The shapes of the diagrams for both models within the range of GDPPC< 11 thou ID/inhab. are not significantly different. However, as the average vehicle kilometres travelled continue to increase in the case of the power-exponential model (RFR3.b), the breakpoint occurs for VTKPC = 15.5 thou. km/inhab./year. Unfortunately, this is just a hypothesis which cannot be proved due to a lack of data for VTKPC of this range.

The **DDR** (density of paved roads) is the relation between paved roads and the area of the country. The rate ranges between 0.3 and 55 km/ 1M inhab. It increases together with the country's socio-economic development.

The increase is initially quite fast and continues asymptotically towards saturation. As the DDR increases, the road fatality rate increases following the exponential function (average interval elasticity is 0.47%). This is the result of, among other things, a higher number of junctions, approaches and other points of collision when the road network becomes longer.

The proportion of paved roads in the road network **PPR** is the relation between the length of paved roads and the entire road network. This rate is within the range of 1.3 – 100%. PPR increases together with the country's development (at first very quickly, then slowly asymptotically towards saturation). As PPR increases, the road fatality rate RFR increases following the exponential function (average interval elasticity is 0.12%). This is the result of, among other things, higher vehicle speeds using improved roads.

The proportion of motorways and expressways in the road network **PME** is the relationship between the length of motorways and expressways and total length of roads. This rate is within the range of 0 – 5.5 % for the countries under analysis. The start of motorway and expressway construction is not until a certain level of the national product is exceeded. PME increases together with social and economic growth and increases asymptotically towards saturation which is different for different countries. With a higher PME, the RFR decreases following the exponential function (average interval elasticity is - 0.34 %). The reason why the fatality rate drops in a country when a new motorway or expressway is built is that these roads offer high technical, operational and safety standards and attract traffic from secondary networks with much lower technical and
safety standards. The width of influence of a motorway or expressway can be from ten to several tens ofkilometres from its axis.

Conclusion

The road fatality rate described with the power-exponential function helps to identify the effects of demographic, economic, social and transport factors which are key when strategic road safety decisions are made in a country. From among the transport factors analysed in this paper those with the strongest impact on increase of road deaths are: the mobility of the population VTKPC, road network density DDR and percentage of paved roads PPR in the road network. Percentage of motorways and expressways PME, on the other hand, can reduce road deaths significantly.

Understanding these effects can help transport decision makers with selecting road safety policies designed to e.g.: reduce car trips by shifting part of the travel to other safer modes (plane, train), reduce speeds (speed limits, traffic calming, etc.) and improve safety standards (traffic segregation, safe junctions, etc.) on paved roads, build a new motorways and expressways.

The results open space for more research which must be conducted to create simple tools to help decision makers with effective decisions to improve road safety.

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