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ORIGINAL SCIENTIFIC PAPER

Accident Costs in Regard to the Length Of Motorway – Croatian Experience

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Abstract: The basic objective of this research is to explore the contribution of development of motorway networks to minimization of accident costs. Results of the study are based on Croatian experience. The possibility of a statistically negative correlation between gradation in the total motorway length and traffic accident costs will be investigated through observation of variations in the total length of motorway and the number and type of accidents that occured. Different scientific methods were applied in the research, including the method of induction and deduction, the method of abstraction and the method of correlation and regression analysis. The resulting knowlegde may be of help to traffic authorities, both on micro and macro levels.

Key words: road traffic, motorways, accidents, costs.

INTRODUCTION

Traffic accidents are a major issue in transport policies around the world. For example, traffic accidents reap more than 30 000 fatalities per year in the European Union. It is estimated that for each death on European roads, there are 4 permanently disabling injuries, such as damage to the brain or spinal cord, 8 serious injuries and 50 minor injuries [10]. The number of non-fatal accidents is much higher. There is an estimate of 1,2 million road traffic deaths per year on world roads, and about 50 million injured [9], most of them in developing countries. Over the past few decades, there has been a decrease in the number of traffic accident casualties, in spite of the substantial increase in the transport volume [1]. Similar trends can be perceived in Croatia as well. Road fatalities in EU in 2012 have fallen by 63,1% since 1991, in Croatia by 51,49 %. Accidents involving personal injury have fallen by 25% in EU since 1991, in Croatia by 27,2% since 2001. Perhaps this relative increase in road safety is due to implementation of a broad range of safety enhancing measures in vehicles and infrastructure, and to better traffic behaviour. Safety problems and the occurrence of accidents are a feature of transport, in particular of road transport. In European rail, air and water transport accidents in general occur less frequently than in road transport.

These accidents have an enormous cost. Since 2000, the length of motorway network in Croatia has increased three times. Accordingly, the fundamental premise of this study is that the enhancement of Croatian roads measured in length of motorway network has contributed to reduced number of traffic accidents, their consequences and costs. Consequently, the task of this study is to determine the exact contribution of additional length of motorways to reduction of road accident costs in Croatia. This approach, however, by no means seeks to either diminish or jeopardize the Law on Road Traffic Safety (2008) or the Croatian National Programme for Road Safety 2011-2020. (NN, 59/11).

The application of the method of abstraction, and an emphasis on road quality as the main factor in reduction of road accident costs, acknowledges the necessity of including these effects in discussion about total transport costs, or construction costs of modern motorways.

PROBLEM AND STATISTICAL DATA

Table 1, based on Greene et al. [4], provides a schematic outline of different types of cost involved in transport.

Table 1. Structure of transport costs

External costs	Environmental costs	Fauna and flora
		Energy
		Noise
		Pollution of air, water and soil
		Landscape
		Vibration
	Congestion	
	Accidents	

	Use of space	
Total costs		
	Infrastructure costs	
		Fuel
		Maintenance
Internal costs		Repairs
	Private costs	Insurance
		Taxes
		Depreciation

Source: Based on Greene et al [4]

Transport authorities on micro and macro levels are obliged to be acquainted with transport costs. However, not only do they need to have an insight in the amount of costs, but also in the cost function, which shows that costs vary in relation to various parameters [6]. More developed transport systems tend to have lower transport costs since they are more reliable, safer and able to cope with high frequency traffic.

The total external costs of transport in the EU plus Norway and Switzerland in 2008 amount to more than € 500 billion, or 4% of the total GDP. About 77% of the costs are caused by passenger transport and 23% by freight. Road transport modes have by far the largest share in these costs (93%). This can be explained by the large share of road transport in the overall transport output, as well as higher average external costs per passenger-km or tonne-km [3]. Accident costs, comprising both fatal and non-fatal damage costs, form an important part of external transport costs. In 2004, the estimated annual costs of traffic injuries both direct and indirect in the EU-15 countries exceeded 180 billion € [8]. Real costs in terms of deaths, injuries and social and economic consequences far exceed these estimates. According to the lowest estimates of insurance experts and economic analysts, due to traffic accidents, Croatia suffers a direct loss of social values in the amount of at least two percent of GDP, while indirect losses are manifold. The EU Directive 2008/96/EC on road safety requires Member States to carry out the calculation of average social accident costs (a+b+c). The costs (a+b+c) cover all social costs of the accident, with a representing the cost of death or injury to the exposed individual and b representing the cost for relatives and friends of the exposed individual. Parameter c represents the costs for the rest of society. This includes various direct and indirect economic costs and is assumed to be in the order of 10% of value of safety *per se* (i.e., of the value of life for a fatality).

Traffic accidents cost greatly, it is a cost which depends on the numbers of fatalities and injuries, and there is also a monetary value which can be placed on human life and injury. Assessing this value is a controversial and sensitive issue. The EU Directive 2008/96/EC on road safety requires Member States to carry out the calculation of average social accident costs (cf. table 2).

Table 2: Average social transport costs, at market prices (PPP) in € 2010.

Country	Fatality	Severe injury	Slight injury
Austria	2395000	327000	25800
Belgium	2178000	330400	21300
Bulgaria	984000	127900	9800
Croatia	**1333000**	**173300**	**13300**
Cyprus	1234000	163100	11900
Czech Republic	1446000	194300	14100
Denmark	2364000	292600	22900
Estonia	1163000	155800	11200
Finland	2213000	294300	22000
France	2070000	289200	21600
Germany	2220000	307100	24800
Greece	1518000	198400	15100
Hungary	1225000	164400	11900
Ireland	2412000	305600	23300
Italy	1916000	246200	18800
Latvia	1034000	140000	10000
Lithuania	1061000	144900	10500
Luxemburg	3223000	517700	31200
Malta	2122000	269500	20100
Netherlands	2388000	316400	25500
Poland	1168000	156700	11300
Portugal	1505000	201100	13800
Romania	1048000	136200	10400
Slovakia	1593000	219700	15700
Slovenia	1989000	258300	18900
Spain	1913000	237600	17900
Sweden	2240000	328700	23500
Great Britain	2170000	280300	22200

Source: [5]

As seen in Table 2, there is a significant difference in average social accident costs between countries. These costs in Croatia are considerably lower than the EU average (cf. Table 3).

Tablica 3. Descriptive statistics for social transport costs in EU-28

Variable	Descriptive Statistics (Spreadsheet1)					
	Mean	Std.Dev	Minimum	Maximum	N	No.cases Missing
Fatality	1790179	572413,2	984000,0	3223000	28	0
Severy injury	242025	87028,9	127900,0	517700	28	0
Slight injury	17814	5968,3	9800,0	31200	28	0

The immanent approach to development of road networks consists of phase one - investment in the length of the road network up to a certain, optimal level of development, followed by phase two – investment in the quality of the road network. Improvement in quality of the road network through increase of 1) the percentage of length of motorways in the total length of road network, 2) the length of motorways per 1000 km^2, 3) the length of motorways per 1 million inhabitants, considerably affect traffic safety and thus reduce external transport costs, notably accident costs. To prove this hypothesis in scientific terms and to investigate and elaborate on Croatian experience in the period between 2000 and 2012, the following statistical data were used as a starting point (cf. Table 4).

Table 4. Number and type of traffic accidents and the length of motorways in Croatia from 2000 to 2012

Year	Number of recorded accidents	Fatality	Severe injury	Slight injury	Length of motorways, km
2000.	73387	655	4497	19004	411
2001.	81911	647	4604	17489	429
2002.	86611	627	4481	19442	455
2003.	92102	701	4878	21275	554
2004.	76540	608	4395	19876	742
2005.	58132	597	4178	17595	792
2006.	58283	614	4308	18828	877
2007.	61020	619	4544	20548	959
2008.	53496	664	4029	18366	1043
2009.	50388	548	3905	18018	1097
2010.	44394	426	3182	15151	1126
2011.	42443	418	3409	14656	1254
2012.	37065	393	3049	12961	1254

Source: prepared by the author from [2]

This 12-year period was chosen specifically because Croatian transport policy since 1999 has been exclusively focused on infrastructure [7]. Namely, the length of motorways in 2012 increased 3,28 times compared to 1999, while in the same period, the number of traffic accidents was almost two times lower.

RESEARCH RESULTS AND DISCUSSION

Using statistical data from Table 4, Pearson's coefficient of correlation has been calculated to determine if there is a correlation between the number and type of accidents and the length of motorways (cf. Table 5).

Table 5. Correlation between the number and type of accidents and the length of motorways

Variable	Correlations (Spreadsheet"!) Marked correlations are significant at p < ,05000 N=13 (Casewise deletion of missing data)						
	Means	Std.Dev.	Number of accidents	Fatality	Severe injury	Slight injury	Length of motorways
Number of accidents	62751,69	17778,98	1,000000	0,802452	0,887263	0,772191	-0,924861
Fatality	578,23	101,52	0,802452	1,000000	0,942845	0,895606	-0,770742
Severe injury	4112,23	574,57	0,887263	0,942845	1,000000	0,918631	-0,831244
Slight injury	17939,15	2410,26	0,772191	0,895606	0,918631	1,000000	-0,643926
Length of motorways	845,62	308,47	-0,924861	-0,770742	-0,831244	-0,643926	1,000000

As seen in Table 5, it is clear that there is a statistically significant negative correlation between the length of motorways measured in kilometres and the number of accidents ($r=-0,92$; $p < 0,05$), between the length of motorways and the number of fatal accidents ($r=-0,77$; $p < 0,05$), between the length of motorways and the number of severe injury accidents ($r=-0,83$; $p < 0,05$), between the length of motorways and the number of slight injury accidents ($r=-0,64$; $p < 0,05$).

The method of correlation analysis indisputably established a strong negative correlation between the number and type of traffic accidents and the length of motorways measured by number of constructed kilometres, so what follows is an investigation of connection between social accident costs and the length of motorways. In order to do that, and to set an appropriate econometric model for Croatia, accident costs were derived from average data for certain types of accidents from Table 2, ie average cost of accidents resulting in fatalities was 1,333,000 €, average cost for serious injuries 173,000 € and for minor injuries 13,000 € (cf. Table 6).

Table 6. Annual losses due to road traffic accidents in Croatia

Year	Fatality	Severe injury	Slight injury	Total Average social accident costs	Length of motorways, km
2000.	873115000	779330100	252753200	1905198300	411
2001.	862451000	797873200	232603700	1892927900	429
2002.	835791000	776557300	258578600	1870926900	455
2003.	934433000	845357400	282957500	2062747900	554
2004.	810464000	761653500	264350800	1836468300	742
2005.	795801000	724047400	234013500	1753861900	792
2006.	818462000	746576400	250412400	1815450800	877
2007.	825127000	787475200	273288400	1885890600	959
2008.	885112000	698225700	244267800	1827605500	1043
2009.	730484000	676736500	239639400	1646859900	1097
2010.	567858000	551440600	201508300	1320806900	1126
2011.	557194000	590779700	194924800	1342898500	1254
2012.	523869000	528391700	172381300	1224642000	1254

Source: Author's calculation

When total average accident costs in this period are considered, significant oscillations with prominent tendency of decrease could be observed (M=1,72 billion €; SD=0,261 billion €; min= 1,22 billion €, max=2,06 billion €). After conducting correlation analysis (cf. Table 5), we decided on a one-dimensional model of linear regression in the following form:

$$Y = a + bX + u \quad (1)$$

Where:
X – independent variable – length of motorways (LM),
Y – dependent variable – average social accident costs (SAC),
u – deviation from the functional relation,
a, b – parameters.

In assessing the value of parameters in function (1) the method of regression analysis was applied, while the numerical computation was performed by *Statistica* software (cf. Table 7).

Table 7. Regression analysis

N=13	Regression Summary for Dependent Variable: Social accident costs (Sp R= ,79479278 R2= ,63169556 Adjusted R2= ,59821334 F(1,11)=18,867 p<,00117 Std.Error of estimate: 1657E5					
	Beta	Std.Err. of Beta	B	Std.Err. of B	t(11)	p-level
Intercept			2,291433E+09	138911147	16,49567	0,000000
Length of motorways	-0,794793	0,182981	-6,733688E+05	155027	-4,34357	0,001168

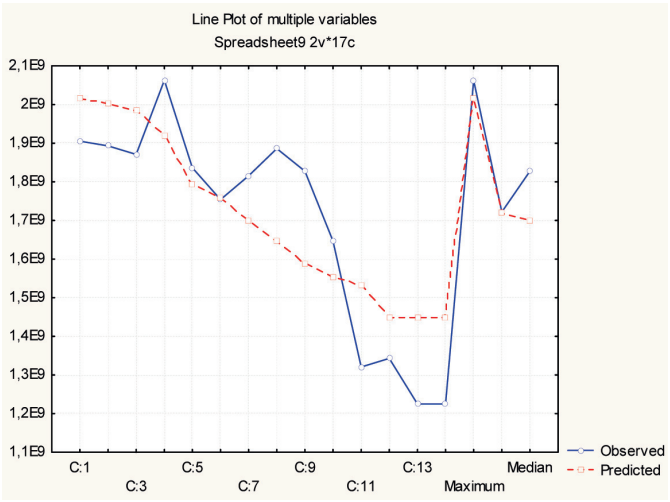
Regression analysis of the correlation between average social accident costs and the length of motorways gives the following model of simple linear regression:

SAC =2 291 432 984,6 – 673 368, 8 LM (2)

Results of regression analysis (cf. Table 7) indicate that there is a statistically significant correlation between total average social accident costs and the length of motorways (R=0,79; F(1,11=18,867; p<0,01). Correlation between the total average social accident costs and the length of motorways is negative, indicating that the decrease in social accident costs is linked with an increase in the length of motorways. An increase in the length of motorways of 1 km leads to decrease in social accident costs about 673 368,8 € in the first year (B=-673368,8; SE=155,027; p<0,01). Decrease in social accident costs with 79% of variance can be explained by the length of motorways.

Chart 3 shows a comparison between the actual and model predicted values of the dependent variable. Chart 3 also shows a satisfactory adaptation of the model to the real data.

Chart 1. Comparison between the econometric model and the real data for the total social accident costs in Croatia from 2000 to 2012.



CONCLUSION

Problems of safety and the occurrence of accidents is a feature of traffic, particularly of road traffic. One of consequences of these accidents is an immense cost, a cost which depends on the numbers of fatalities and injuries and the monetary value which can be placed on human life or injury. Economic damages from road traffic accidents are estimated in hundreds of millions of euros, noting that more developed transport systems tend to have lower transport costs. This study has proven the statistically significant negative correlation between social accident costs and the length of motorway network in Croatia over the last decade. The conducted regression analysis has confirmed that a newly constructed kilometer of a motorway results in decrease of social accident costs in the amount of 673 688 €.

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