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REVIEW PAPER

Estimation of External Costs of Transport in Canton Sarajevo for 2014

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Abstract: The main aim of this paper is to raise awareness of the necessity to estimate the external costs of transport, and in particular in urban area of Canton Sarajevo. It does not provide full extent of the costs as it focuses only on two components, air pollution and accidents. It focuses on the concise methodology for estimation of external expenses of air pollution from road and air transport and road traffic accidents, using official statistical data for modeling emissions (COPERT 4, Copert Street Level, IPPC Tier 3A methodology) and for accounting road traffic accidents. Statistical significance of correlation between traffic flow and measured concentration of pollutant at Otoka location is determined by Pearson's correlation coefficient. Air pollution and traffic accidents are monetized according to the Synapse Energy Economics cost estimation of metric ton of CO2, and Nicholas School of the Environment, Duke University, for other pollutants, while estimation methodology for both air pollution and traffic accidents is done in line with Handbook on External Costs of Transport, European Commission.

Key words: air pollution, external expenses, traffic accidents.

INTRODUCTION

Transport is a backbone of any economic growth. However, most forms of transport have significant side effects that rise to various resource costs that can be expressed in monetary terms, which is understandable to all. Costs of delays, productivity losses due to injuries and deaths cause by traffic accidents, health costs caused by air pollution, abatement costs due to climate impacts of transport, are few of many social and environmental pressures. In the event of imposition of costs to a society as a result of certain activity, economists use the term of an external cost. The external costs of transport are generally not borne by transport users alone but by the entire society and environment as well.

The main aim of this paper is to raise awareness of the necessity to estimate the external costs of transport, and in particular in urban area. It does not provide full extent of the costs as it focuses only on two components, air pollution and accidents. Sarajevo Canton has been exposed to persistent and immense air quality deterioration from 2006 to date, resulting with such an extreme air pollution that led the local authorities to close schools for a certain period in December 2015. At the time the measures and activities of local representatives had no positive effect, and no strategic approach, and particularly for the traffic and transport, no clue whatsoever.

METHODOLOGY

Statistical correlation significance between road transport intensity and measured concentration of pollutants in the air was calculated according to the data provided by traffic counters and automatic meteorology station at Otoka location, municipality Novi Grad. The data was collected on hourly, daily, monthly and annual basis. Road traffic counter data was taken from official report Directorate for roads in Sarajevo Canton. Automatic meteorology station is under the authority of Cantonal Public health Institute.

Hourly reading is particularly important as the road traffic intensity fluctuates significantly by the hour. Concentration of air pollutants readings and speed of wind (as very significant ambient factor) are averaged throughout a year for every hour of 24 hour scale, and then compared to traffic data.

The methodology used in this paper is based upon Handbook on External Costs of Transport of the European Commission – DG Mobility and Transport.

As it is focused on air pollution and traffic accidents, official statistics data has been a foundation for modeling air pollution[1,2], while local monetizing data has been supplemented by figures and estimates provided by relevant international and local authorities respectively [3,4,5,6,7]. Emission of pollutants in Sarajevo Canton for the year 2014 from road transport is estimated in a model in COPERT 4, Copert Street Level (CSL), and previous research of the author [8].

RESULTS

Statistical correlation between road transport intensity and air pollutants at Otoka

Air pollutant concentration data collected was put in database and statistically analyzed. Statistical correlation was tested by Pearson's correlation coefficient, Table 1. It has been determined that the correlation between road transport intensity and measured concentration of pollutants in the air is significant and correlation is higher for winter months than in summer months.

Table 1. Pearsons coefficient- correlation between road transport intensity and measured concentration of pollutants

Pearson Correlation Coefficient	
January	**June**
X Values	*X Values*
∑ = 987109	∑ = 1040321
Mean = 31842.226	Mean = 34677.367
$\sum[X - M_x]^2 = SS_x$ = 643521847.419	$\sum[X - M_x]^2 = SS_x$ = 630079848.967
Y Values	*Y Values*
∑ = 17082.2	∑ = 11210.8
Mean = 551.039	Mean = 373.693
$\sum[Y - M_y]^2 = SS_y$ = 637472.834	$\sum[Y - M_y]^2 = SS_y$ = 238836.379
X and Y Combined	*X and Y Combined*
N = 31	*N* = 30
$\sum[X - M_x][Y - M_y]$ = 11000286.329	$\sum[X - M_x][Y - M_y]$ = 5637538.773
R Calculation	*R Calculation*
$r = \sum[[X - M_y][Y - M_x]] / \sqrt{[[SS_x][SS_y]]}$	$r = \sum[[X - M_y][Y - M_x]] / \sqrt{[[SS_x][SS_y]]}$
r = 11000286.329 / √[[643521847.419][637472.834]] = 0.5431	r = 5637538.773 / √[[630079848.967][238836.379]] = 0.4596
Meta Numerics [cross-check]	*Meta Numerics [cross-check]*
r = 0.5431	r = 0.4596

Figure 2, providing average hourly readings throughout a year show that emission are significantly correlated with road transport intensity at the location. However, average hourly values of the wind speed determine that it poses a significant factor in air pollution measured concentration. The Figure 2 shows numerically determined influence the wind speed has on air pollution levels at the location, under non-fluctuant road traffic intensity. One may conclude the spatial obstacles to the wind flow, positioned without proper land-use modeling examination, may significantly increase air pollutant concentration at a location. It is particularly important where the urban canyons are predominant in spatial distribution.

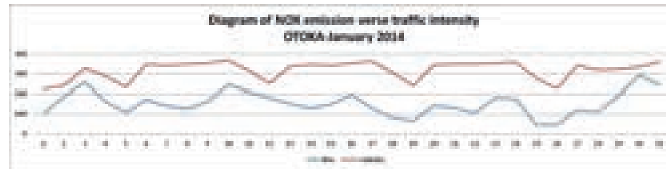

Figure 1. January 2014 – Daily NOx emission verse traffic intensity [vehicles x 100], author

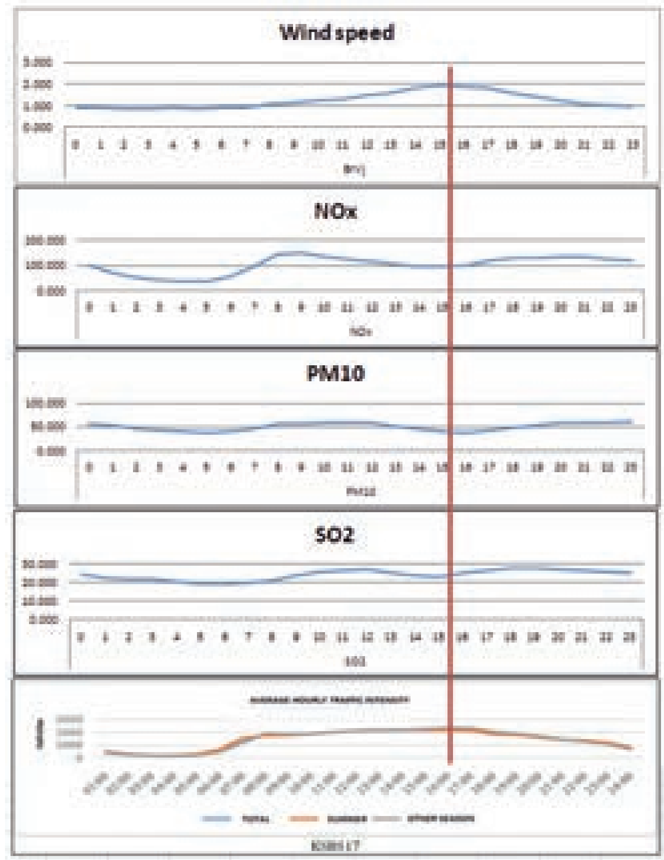

Figure 2. Hourly readings of air pollutants, wind, and traffic, author

Road traffic intensity has statistically significant influence on air pollution levels, and air flow velocity has significant influence on concentration of air pollutants at the observed location.

Emission of pollutants from road transport in Canton Sarajevo

Previous research of the author [8] determined the quantity of the emission of pollutants from road and air traffic in Canton Sarajevo. Table 2, has shown that incoming traffic from outside Sarajevo significantly increase local fleet's emission and these values have been taken into monetizing the emission of pollutants.

Table 2. Road traffic emission for year 2014, author

POLLUTANT	CO	CO2	NOx
Average speed [km/h]	23.24	23.24	23.24
Total road mileage with vehicles counted [km]	77.27	77.27	77.27
Total road mileage in Canton Sarajevo [km]	212.00	212.00	212.00
Copert street level - Estimated emission [t]	1249.58	239308.52	826.08
COPERT 4 estimated value [urban only]	850.2173638	184202.9802	763.730143
Ration of incoming traffic from outside Sarajevo	32%	23%	8%

Definition of a carbon price and estimated value of social cost of road and air transport

Transport is an integral and an essential part of any form of entrepreneurship, and is therefore to be incorporated into any policy of carbon-pricing.

In the environmental science research there are a number of the terms refereeing to the "carbon price" or "CO2 price" used in various contexts, whereas in the environmentally conscious economics, pricing emissions is labeled as "internalizing an externality", or the external (not paid by the polluting entity) cost of pollution damages that is assigned a market price, making it internal to the enterprise. Synapse Energy Economics, provides definition of terms and elaborates pertaining use.

Carbon allowances, allowances are certificates that give their holder the right to emit a unit of a particular pollutant. A fixed number of carbon allowances may be issued by local authority (in developed countries, not in BiH) or put on the market for trade in a way. The price that enterprises are to pay for the allowances increases their operational price tag of business, thus giving an advantage to those with "greener" operations.

Carbon tax, in the similar way internalizes the externality of carbon emission, but instead of selling or giving away rights to pollute, it creates an obligation for firms to pay a fee for each unit of carbon that they emit. They represent an opportunity cost of emissions to the holder, and becoming an incentive for emission reduction. Of course, with bureaucratic apparatus finances acquired in this way may not be used to reduce for mitigation but rather to fill the gaps in the overloaded budgets.

Effective price of carbon are referred to as the notional, hypothetical, or voluntary price that may be looked into at legal entity level, such as enterprise or local government institution.

Marginal abatement cost, and perhaps with some similarities Average policy cost as looks more into benefits, of carbon refers to an estimate of the expected cost of reducing emissions of a pollutant. Estimation of a marginal abatement cost looks into all of the possible solutions to controlling emissions, being technologies or poli-

Table 3. Social cost of pollutants, Source: Drew T. Shindell, The social cost of atmospheric release, Nicholas School of the Environment, Duke University, USA

Valuation; discount rate	CO_2	CH_4	N_2O	HFC-134a	BC	SO_2	CO	OC	NO_x	NH_3
Climate[a]; 5 %	10	490	2800	19,000	13,000	-900	42	-1800	-56	-240
Climate[a]; 3 %	32	910	9200	36,000	20,000	-1400	90	-2800	-220	-380
Climate[a]; 1.4 %	67	1400	19,000	56,000	30,000	-2100	160	-4200	-400	-560
Regional climate, aerosols; 5 %	0	0	0	0	19,000	3000	0	6100	90	820
Regional climate, aerosols; 3 %	0	0	0	0	26,000	4400	0	8700	350	1200
Regional climate, aerosols; 1.4 %	0	0	0	0	34,000	5900	0	12,000	600	1600
Additional climate- health1[b]; 5 %	16	1600	8300	62,000	110,000	4500	140	9000	7	1200
Additional climate- health1[b]; 3 %	45	2800	24,000	110,000	150,000	5700	260	11,000	30	1500
Additional climate- health1[b]; 1.4%	87	4000	47,000	160,000	190,000	6900	430	14,000	50	1900
Composition-hcalth; 5%	0	550	0	0	62,000	33,000	200	51,000	67,000	22,000
Composition-hcalth; 3%	0	670	0	0	62,000	33,000	240	51,000	67,000	22,000
Composition-hcalth; 1.4%	0	740	0	0	62,000	33,000	250	51,000	67,000	22,000
Median total; 5 %	27	2700	12,000	85,000	210,000	40,000	410	64,000	67,000	24,000
Median total; 3 %	84	4600	37,000	160,000	270,000	42,000	630	68,000	67,000	25,000
Median total; 1.4 %	150	6000	62,000	210,000	310,000	43,000	820	71,000	67,000	25,000
Median total; declining rate	110	4700	47,000	160,000	280,000	42,000	730	69,000	67,000	25,000

cies, listed by their cost per unit of pollution reduction. Starting from the least expensive option, going down the scale one identifies financially most feasible (at a market price) way to reduce emissions to the designated target, and in that way identifying the "marginal" cost of targeted level of pollution reduction.

Table 4. Revised Social Cost of CO2, 2010 – 2050 [in 2007 dollars per metric ton of CO2] Interagency Working Group on Social Cost of Carbon, United States Government, upon Executive Order 12866

Discount Rate Year	5.0% Avg	3.0% Avg	2.5% Avg	3.0% 95th
2010	10	31	50	86
2015	11	36	56	105
2020	12	42	62	123
2025	14	46	68	138
2030	16	50	73	152
2035	18	55	78	168
2040	21	60	84	183
2045	23	64	89	197
2050	26	69	95	212

Figure 3, Table 3 and Table 4 show the estimated value of social cost per metric ton of CO_2. It is evident that the social cost shall rise significantly in coming years [9] and therefore immediate mitigation action is required. These damages are addressing decreased agricultural yields, harm to human health and lower worker productivity, all related to climate change. For calculation purposes the value of 37 US$/35EUR per metric ton of CO_2 is considered, in line with US Environmental Protection Agency [10]. It has to be noted that there are recent studies at Emmett Interdisciplinary Program in Environment and Resources in Stanford's School of Earth Sciences suggest that this cost is as high as 220 US$ [11].

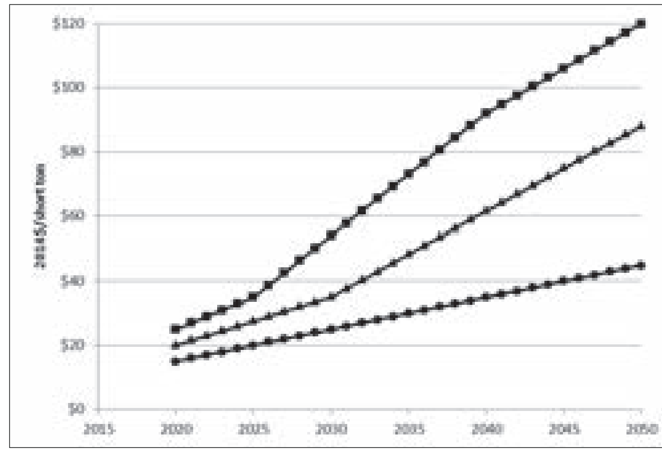

Figure 3. Synapse Energy Economics, Inc. 2015 Carbon Dioxide Price Forecast

Therefore, estimated road transport emission of 239308 t CO2 accounts for social cost in the amount of approximately 8,6 million EUR. Air transport contributes with the estimated emission of 12632 t CO2, thus accounts for social cost in the amount of approximately 0,5 million EUR.

Air and road transport cause social cost of roughly estimated value of 9 million EUR for the year 2014.

Table 5. Number of traffic accidents in Federation B&H in 2014, Federal Ministry of Interior

Area	Traffic accidents			Killed			Grave injuries			Minor injuries		
	2012	2013	2014	2012	2013	2014	2012	2013	2014	2012	2013	2014
Kanton Sarajevo	9.877	10.536	**10.974**	21	24	**19**	170	165	**180**	876	1.001	**1.003**
SBK	2.731	2.944	**3.094**	19	17	**19**	147	117	**120**	392	445	**477**
BPK	74	94	**81**	2	0	**2**	2	7	**10**	20	30	**27**
Posavski kanton	252	253	**247**	3	3	**3**	25	24	**23**	58	82	**60**
ZHK	528	608	**740**	10	5	**7**	32	32	**40**	340	357	**420**
HI IK	1.860	1.944	**1.995**	18	25	**25**	105	119	**127**	702	747	**911**
USK	2.463	2.691	**2.247**	22	23	**23**	129	130	**123**	641	746	**813**
Tuzlanski kanton	3.418	2.840	**2.720**	36	38	**33**	216	187	**194**	1.405	1.383	**1.455**
ZDK	4.027	4.126	**4.411**	27	28	**24**	131	182	**165**	600	664	**697**
Kanton 10	728	645	**701**	8	13	6	37	49	**40**	146	143	**145**
FEDERACIJA BiH	25.958	26.681	**27.210**	159	176	**161**	994	1.012	**1.022**	5.180	5.598	**5.856**

However, there is a need to include other pollutants into the calculations. A recent study [12] suggests that other pollutants have much higher social and environmental cost, as shown in Table 3. NOx is estimated at 300 US$ per metric ton for environmental, plus additional 50US$ for health related issues. CO is estimated at 260 US$ for health related issues. SOx is estimated at 6,900 US$, while CH4 is estimated at 6000 US$. Therefore the costs should include:

- for CO
  - Air transport – 10,500 EUR
  - Road transport – 320,000 EUR
- for NOx
  - Air transport – 14,500 EUR
  - Road transport – 275,000 EUR
- for SOx
  - Air transport – 22,000 EUR
  - Road transport – 331,200 EUR
- for CH4
  - Road transport – 225,000 EUR

It comes to additional 1,2 million EUR, and therefore the total cost of air pollution from air and road transport is around 10 million EUR. It has to be noted there are other cost that are to be taken into consideration, but the main aim of this paper is to raise awareness that shall hopefully result in more detailed approach in spatial and transport in urban area.

Estimation of social cost of traffic accidents

There are many issues regarding the socio-economic aspects of traffic accidents and consequent injuries [3,4,5]. The accuracy of official road accident statistics, long-term impacts of an injury, and social disparities are only few of many. The burden of traffic accidents is borne not only by those directly affected in traffic accidents but also by their families. The European Federation of Road Traffic Victims proposes the creation of free assistance centers for victims, where they would receive professional assistance and advice in dealing with legal issues, medical issues and psychology.

Socio-economic losses resulting from the traffic accident in the Federation B&H have been calculated using the gross output or Human Capital methodology, comprised of administrative expenses, property damage, medical treatment costs, lost output and human costs. According to the estimation the traffic accidents are estimated as follows:

- fatal injuries – 190,100 EUR
- severe injuries – 90,180 EUR
- minor injuries 16,490 EUR

However, in Republic of Srpska these estimations, done in cooperation with Swedish National Road Consulting AB – SweRoad, are quite different.

- fatal injuries – 317.317 EUR
- severe injuries – 34.094 EUR
- minor injuries 1.666 EUR

While there are many methodologies, this paper uses the figures, used by the official authorities of Federation B&H [5], responsible for transport management, provided by the Federal Ministry of Interior is shown in Table 3.

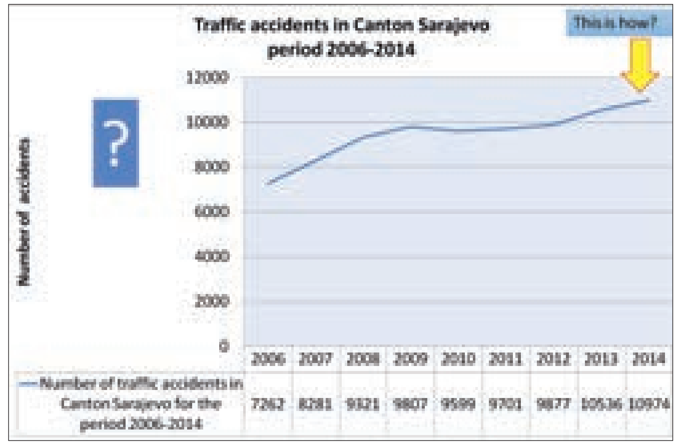

Figure 5. Number of traffic accident in Canton Sarajevo for the period 2006-2014, Federal Ministry of Interior

Figure 5 shows that there is a steady increase of number of traffic accidents in Canton Sarajevo. Comparing the year 2014 to 2006 the number of traffic accidents has increased by 51%.

Using the cost values of traffic accidents provided above, in line with the numbers provided in Table 4, the cost of traffic accidents in Sarajevo Canton for 2014 is estimated as follows:

- fatal injuries – 190,100 EUR x 19 = 3,611,900 EUR
- severe injuries – 34.094 EUR x 180 = 6,136,920 EUR
- minor injuries 1.666 EUR x 1003 = 1,670,998 EUR
- It totals to the sum of 11,419,800 EUR.

In 2013, an amount of 367,909,320 EUR was a result of financial transactions from sale of fuel and lubricants. Out of that sum it is roughly estimated that 47,027,262 EUR is the tax collected for the local authorities, which is to be used for highways, water, environmental protection etc.

CONCLUSION

External costs of traffic are significant and are to be carefully studied. So far, little or no attention was paid to the monetization of air pollution from road and air transport in Canton Sarajevo. As evident, the cost of air pollution is similar to the cost of traffic accidents. Nonetheless, along with traffic accidents these costs are growing and posing significant burden to the local government and its institutions, while the finances wasted through inadequate traffic solutions could be used for rectification of the most chronic issues detriment to the sustainability of transport system in the Canton.

These are public transport of passengers, traffic flow and congestion, and spatial planning.

The burden of air pollution and traffic accidents is borne not only by those directly involved in traffic but also by their families, elderly and children. A strategic approach should take all these chronic issues into consideration, and then incorporate it in transport and land-use models of the city, open to public for debate, thus providing effective guidelines for addressing the issues. Furthermore, there is a necessity for the creation of free assistance centers for victims of traffic accidents, where they would receive professional assistance and advice in dealing with legal issues, medical issues and psychology.

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