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EVALUATION OF FREIGHT TRANSPORT MODES BASED ON EXTERNAL COSTS

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Abstract: External costs represent the costs which are incurred by activities of company or person whereby they are borne by someone not involved in those activities. The purpose of this paper is a comparative analysis of negative external costs arising from the realization of freight road, rail and inland waterway transport. The main goal of this paper is to quantify the external costs caused by different modes of freight transport, based on the characteristics of the transport means and the characteristics of the goods being transported, as well as the length of the goods transport. The implemented methodology is a unique tool by which it is possible to redirect users towards transport modes that are more acceptable from the aspect of sustainability.
Keywords: modes of transport, external costs, internalization

INTRODUCTION

Transport plays an important role in economic and social development of every country as well as in the development of global market [1]. But, every mode of transport has positive and negative effects on society. Transport results in negative external effects such as emissions, noise, congestion and infrastructural wear and tear [2].

In the EU, external costs of transport (road, rail and IWW (inland waterway)) are recorded in the amount of EUR 571 billion without congestion and EUR 841 billion, including congestion. The results of research in EU indicate on the main factors of external costs: accidents (29% of external effects), congestion (27%), air pollution (14%), climate (14%), noise (7%), well–to–tank (5%) and habitat damage (4%) [3].

In contrast to the positive effects, negative effects, i.e. costs of the negative effects of transport do not bear directly those who caused them but they are falling at the expense of the Society. The Society submits external costs in order to increase public health capacity in order to protect endangered plant and animal species and to rehabilitate the social environment. As a consequence of this, there are making wrong decisions in the transport market, as well as inefficient use of available resources and loss of well–being. In order to prevent this is done internalisation of external costs.

The internalisation of external costs through market–based instruments is generally regarded as an effective way to limit the negative effects of transport. The principle of internalisation of external costs involves adding external costs to the individual cost of pollutants. The internalisation of external costs affecting the price increase of the product pollutants and the reduction in demand for their products. Pollution prevention is more profitable than pollution control, and waste minimization, recycling and reuse are more profitable than disposal and control of waste.

In order to make internalisation of external costs, it is necessary to estimate external costs in the transport sector. Starting from 2004, several research projects and models have been implemented in Europe to define and evaluate external costs in the transport sector [4]. Among the most important are: HEATCO (Developing Harmonised European Approaches for Transport Costing and Project Assessment, 6th Framework Programme), CAFE CBA (Clean Air for Europe Programme, Cost Benefit Analysis of Air Quality), TREMOVE policy assessment model, ASSET (ASsessing SEnsitiveness to Transport) GRACE (Generalisation of Research on Accounts and Cost Estimation, 6th Framework Programme).

Some results of these projects are summarized in the IMPACT project in 2008 from which it emerged Handbook on estimation of external costs in the transport sector [5]. Updating the latest date related to external costs is provided in the Update of the Handbook on External Costs of Transport [6]. On the basis of manuals it is possible to calculate unit costs of pollutants in the form of €/tonne which take into account the negative consequences of traffic functioning such as: harmful impact on human health (mortality, morbidity), the impact of emissions of harmful substances on facilities and materials, negative impact on the biosphere, a detrimental effect on biodiversity and ecosystems, impact on the generation of greenhouse gases.

Updated study External transport costs in the EU shows that average external transport costs for road are much higher than for rail. Per passenger kilometer costs of cars are about four times higher than in rail transport. The situation is similar to freight transport. Since the dominant cost categories are accidents and emissions (climate change and air pollution), special

attention will be given to them in the paper. The purpose of this paper is the quantification and analysis of the external costs of freight transport. The aim of the paper is to conduct a comparative analysis of external costs of road, rail and IWW freight transport, from air pollution, accidents and climate change.

METHODOLOGY – QUANTIFICATION OF EXTERNAL EFFECTS

— Air pollution

Air pollution caused by traffic activities leads to different types of external costs. The most important external costs are health costs due to cardiovascular and respiratory diseases caused by air pollutants. The most important air pollutants related to traffic are particles (PM_{10}, $PM_{2.5}$), Nitrogen Oxides (NO_x), Sulfur Dioxide (SO_2), Volatile organic compounds (VOC) and Ozone (O_3) as indirect pollutants.

For road transport, the most important impact on costs are emission standards for vehicles which again, partly depend on the age of the vehicle. The emissions of road vehicles, then, depend on vehicle speed, fuel type and fuel combustion technology and exhaust gas treatment technologies, load factors, vehicle size, type of drive and geographical location of the road. The quantification of external cost of pollutant emissions in road transport when transporting goods can be carried out depending on a particular category of vehicle and its emission class, i.e. euro standards. The costs of air pollution depend on the area through which a particular vehicle carries out the transport of goods. Costs are expressed in €c per vehicle–kilometer. The highest cost of air pollution are recorded for passing through city zone while the lowest cost of air pollution are recorded on highway [6].

The key cost impacts for rail transport are: vehicle speed, load factors, a combination of power generation plants and the geographical location of plant installations. Calculating air pollution costs involve the use of linear functions and calculations that are included in the top–down model, also linear functions, marginal costs of air pollution are approximately equal to the average cost of air pollution. External costs of air pollution from road, rail and IWW transport can be calculated on the basis of the form:

$$C_m = \sum_{c,i}\left(Vk_{m,c,i} \cdot MC_{m,c,i}\right) \quad (1)$$

where:
C = Air pollution costs per trip (€/trip),
Vk = Vehicle kilometres (vkm/trip),
MC = External marginal air pollution costs,
i = Type of infrastructure (urban road, interurban road, motorway),
c = Country,
m = Mode.

— Accidents

Accident externalities represents the most important external costs of road transport [7]. These social costs include the costs of material damage, administrative costs, treatment costs, production losses and non–material costs (shortening life expectancy, suffering, pain, sadness, etc.) [8].

The most important impacts on costs in road transport, in addition to mileage, vehicle speed, road type, the characteristics of the driver (such as driver behavior, experience, speed), the volume and speed of traffic, time of day (day / night) and interact with weather conditions, the level of infrastructure maintenance, the degree of utilization of the capacity of the infrastructure, and the level of segregation of road traffic lanes.

The following form can be used to calculate the cost of traffic accidents in road transport [9]:

$$\mathbf{C_m = \sum_{c,i}\left(Vk_{m,c,i} \cdot MC_{m,c,i}\right)} \quad (2)$$

where:
C = Accident costs per trip (€/trip),
Vk = Vehicle kilometres (vkm/trip),
MC = External marginal accident costs,
i = Type of infrastructure (urban road, interurban road, motorway),
c = Country,
m = Mode.

According to German statistics, the share of fatal HGV (Heavy goods vehicle) accidents on highways is 50% of all fatal HGV accidents, which is very high compared to other countries. Combined with traffic flow data, this gives a marginal value in the case of an accident for highways that are higher than for other types of roads. In the original data in Switzerland, the share of motorway accidents was only 20% [6].

The main impacts on rail transport costs are traffic volumes, weather conditions, maintenance levels and level of segregation between systems, especially between road and rail transport and between different types of trains. To calculate the cost of accidents in railway transport can use the form [9]:

$$\mathbf{C_m = \sum_{c}\left(Vk_{m,c} \cdot MC_{m,c}\right)} \quad (3)$$

where:
C = Accident costs per trip (€/trip),
Vk = Vehicle kilometres (vkm/trip),
MC = External marginal accident costs,
c = Country,
m = Mode.

In the rail and IWW transport sectors of the EU, accidents are much less common than in road transport. Therefore, the cost estimation of accidents must be based on the average number of accidents in the past few years. The latest estimates of this type have been carried out [8] and according to them, the

average cost of accidents of freight rail transport is 0.2 € per 1000 vkm. All incident costs can be considered as external, because the marginal costs are equal to average costs [6].
For inland waterways and maritime transport, information about accident costs is completely lacking. However, the number of casualties in water transport is considered insignificant [8].

— Climate change

The main effects of the greenhouse gases in relation to transport are Carbon dioxide (CO_2), Methane (CH_4) and Nitrogen oxide (N_2O). These emissions contribute to global warming by acting with different effects such as sea level rise, impact on agriculture (due to changes in temperature and precipitation), health effects (increased heat stress, expansion areas vulnerable to parasites and increase disease devolution e.g., malaria, etc., ecosystems and biodiversity, increasing extreme weather effects, etc. The general approach to estimating average costs caused by climate change for different transport modes consists of four steps [8]:

≡ Estimation of total GHG emissions per vehicle type by country,
≡ Calculate the total CO_2 equivalent of GHG emissions using the Global Warming Potentials.
≡ Multiplication of total tons of CO_2 equivalent of GHG emissions with an external cost factor expressed in €/tonne to estimate the total external costs associated with global warming per country. Due to the global impact on the damage caused by global warming, the same cost factor can be applied in all countries.
≡ Calculate the average climate change costs (per tkm/pkm) by dividing the total costs per vehicle type per country by the number of tkm/pkm per country.

As for the external costs of air pollution as well as for the external costs of climate change, marginal costs are equal to average costs. Marginal costs of climate change for different types of vehicles and transport modes can be calculated by multiplying the emission factors.

RESULT OF RESEACH – EXEMPLARY TRANSPORT LINK BUDAPEST – FRANKFURT AM MAIN

This paper presents the calculation of external costs (air pollution, accidents and climate change) caused by different modes of transport (road, rail, IWW) between the ports of HUBUD Budapest and DEFRA Frankfurt am Main. The assumed cargo that is being transported is 20 TEU (Twenty–foot equivalent unit) containers. Transport is considered for the following vehicle categories:

≡ Truck (Rigid HGV), Gross vehicle weight 24–40t, Emission class Euro V,
≡ Short train, Train weight 500t, electrified and diesel,
≡ Euro ship container 0–1500t.

The distances for each mode of transport through a particular country are given in Table 1.

Table 1. The length of the routes of different transport modes through a particular country

	Road	Rail	IWW
Hungary	177,91	182,08 (electrified) 5,27 (diesel)	–
Austria	328,52	360,67 (electrified)	–
Germany	453,87	450,61 (electrified)	–
Total (km)	960,30	998,63	1268,80

Based on the above procedures, the adopted characteristics of the transport vehicles and using the updated data from [6] and [8], the following results were obtained (table 2).

Table 2. External costs of air pollution, accidents and climate change in €

	Air pollution	Accidents	Climate change	External costs
Road	1351	2302	593	4246
Rail	79	132	167	378
IWW	267	0	330	597

From the standpoint of external costs, it can be concluded that the railway mode of transport is the best for the transport of 20TEU containers between Budapest and Frankfurt am Main, because it causing the least air pollution, accidents and climate change. If the containers were transported by road, rail and IWW, the external costs would amount to EUR 4246, 378 and 597 respectively.
Based on the comparing transport modes, external freight costs for road transport are about 11 times higher than rail transport and about 7 times higher than IWW transport.

CONCLUSIONS

The transport system allows the functioning of the world economy at all levels, but it also causes a series of direct and indirect effects, which from the standpoint of human society can be judged also and negatively. The consideration and quantification of these effects were the first step of the economists to model alternative development scenarios and their costs, to be later transferred to their internalization in the short and medium–term policy. During previous research conducted is understood that the cost of transport includes not only what the state or users pay for transport services, but they include a much wider set of cost.
According to statistics, the dominant categories of external costs are costs incurred by traffic accidents, climate change costs and air pollution costs.
A comparative analysis of the representative negative external costs which arise from the realization of freight road, rail and IWW transport should influence on redirecting of users or decision makers to an

acceptable mode of transport. An example of transporting 20 TEU containers and quantifying the use of three transport modes shows that external costs are the highest use of trucks while at least external costs are caused by the rail.

When choosing a particular mode of transport for the transport of goods is necessary to consider, as far as possible, all costs and not only the cost of transport services.

Note:

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References

[1] Petro, F., Konečny, V. (2017). Calculation of emissions from transport services and their use for the internalisation of external costs in road transport, Procedia Engineering, vol. 192, p. 677–682.

[2] Ljungberg, A. (2016). Marginal cost–pricing in the Swedish transport sector – An efficient and sustainable way of funding local and regional public transport in the future? Research in Transport Economics, vol. 59, p. 159–166.

[3] Essen, H., Infrastructure Charging and Internalisation of Transport Externalities. https://ec.europa.eu/transport, accessed on 2019–04–11.

[4] Ivković, I. (2012). Research of performances of the Compressed Natural Gas powered bus in terms of safety and environmental influence, Doctoral Dissertation, University of Belgrade, Faculty of Transport and Traffic Engineering.

[5] Maibach, M., Schreyer, C., Sutter, D., Essen, H.P., Boon, B.H., Smokers, R., Schroten, A., Doll, C., Pawlowska, B., Bak, M. (2008). Handbook on estimation of external costs in the transport sector – Produced within the study Internalisation Measures and Policies for All external Cost of Transport (IMPACT), CE Delft.

[6] Korzhenevych, A., Dehnen, N., Bröcker, J., Holtkamp, M., Meier, H.,Gibson, G., Varma, A., Cox, V. (2014). Update of the Handbook on External Costs of Transport, European Commission – DG Mobility and Transport, Ricardo –AEA, Issue 1.

[7] Dementyeva, M., Koster, P.R., Verhoef, E. T. (2015). Regulation of road accident externalities when insurance companies have market power, Journal of Urban Economics, vol. 86, p. 1–8.

[8] Essen, H., Schroten, A., Otten, M., Sutter, D., Schreyer, C., Zandonella, C., Maibach, M., Doll, C. (2011). External Costs of Transport in Europe – Update Study for 2008, CE Delft, Delft.

[9] Schroten, A., Essen, H., Anthes, R. (2011). External Cost Calculator, Methodology report, CE Delft, Delft.

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