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ESTIMATING SOME SOCIAL AND ENVIRONMENTAL EFFECTS FROM RAIL/ROAD SUBSTITUTION IN THE TRANS-EUROPEAN TRANSPORT CORRIDORS

ABSTRACT

This paper deals with estimating possible effects in terms of mitigating the social and environmental impacts which could be achieved by operating the rail freight train instead of the road truck services in the given Trans-European transport corridor during the specified period of time. In general, these impacts embrace noise, congestion, traffic incidents/accidents (Safety), and energy consumption and related GHG emissions (Greenhouse Gases). Each type of impact, specific to particular mode, is analyzed and modeled, thus enabling its quantitative estimation and intermodal comparison under the given circumstances. In particular, energy consumption and related GHG emissions and their costs have been under focus. The total costs of the above-mentioned impacts in the given case have also been estimated. Thus, they both represent a solid base for the assessment of the social-environmental feasibility of the future similar cases.

KEY WORDS

externalities, cost savings, freight transport, road/rail substitution, European corridors

1. INTRODUCTION

One of the main objectives of the EU (European Union) transport policy has been to provide an institutional framework for the medium- to long-term sustainable development of the transport sector. Such development implies continuous growth of the sector, which supports and continues to be supported by the growth of the economy and social welfare. At the same time, it also implies maintaining constant and/or decreasing the sector's negative impacts on the society and environment in terms of noise, congestion, traffic incidents/accidents (i.e. safety), and energy consumption obtained from non-renewable resources and consequent GHG emissions (Greenhouse Gases) and land use (take) under the prescribed limits (i.e. according to the specified targets). In the scope of such endeavours, during the past decades the EC (European Commission) transport policy has been directed to instigate modal shift in the inland Europe, which would result in gaining higher market share for the rail freight on the account of the road freight medium- to long-haul transport. Such policy has been supported by a rather substantive research aiming at showing the rail freight as socially and environmentally friendlier transport mode when compared to the road truck counterpart. It was expected to demonstrate particularly its overall advantages under conditions of internalizing the costs of the above mentioned social and environmental impacts (externalities).

In particular, the modal shift in the mega Trans-European transport corridors has been considered as an opportunity on the more global (European) scale. These mega Trans-European corridors have been considered as one relatively long linear part of land in which the rather regular freight transport services are provided individually or jointly (by different transport modes such as road, rail, and/or inland waterways). The regularity of transport services implies the time and spatial/geographical stability of freight flows to be served between particular origins and destinations along the given corridor.

In addition to corridors spreading throughout the EU countries which constitute the European Transport Networks, the second Pan-European transport Conference in Crete (March 1994) defined the ten Pan-European transport corridors as the passenger and freight transport routes in Central and Eastern Europe. These routes required substantive investments over the following ten to fifteen years in order to improve their performance and provide sufficient infrastructure capacity to handle the growing volumes of passenger and freight flows efficiently, effectively, safely, and more environmentally and socially friendly. Some additions were made at the third Conference in Helsinki in 1997, thus giving these corridors reference as the "Crete corridors" or "Helsinki corridors". Over time, different initiatives supported by the EU-funded research have emerged aiming at combining and integrating the two systems (the European Transport Networks and the Pan-European Corridors), mainly because most of the involved countries have become members of the EU. One of those initiatives has been related to the CREAM (**C**ustomer-driven **R**ail-freight services on a **E**uropean mega corridor based on **A**dvanced business and operating **M**odels) corridor.

In addition to this introduction, this paper consists of four other sections. Section 2 describes the social and environmental impacts of the freight trains and road trucks. Section 3 describes the main characteristics of the methodology for estimating these impacts and the related costs (externalities) Section 4 describes the application of the methodology to the CREAM freight train operations [1]. The last section summarizes some conclusions.

2. MAIN SOCIAL AND ENVIRONMENTAL IMPACTS

The social and environmental impacts of freight trains and road trucks operating in the CREAM corridor embrace noise, congestion, traffic incidents/accidents, and energy consumption as well as related GHG emissions (Greenhouse Gases).

2.1 Noise

In general, the freight train noise depends on its length, weight, and speed. Therefore, at the right angle, distance of 25m from the tracks and at the height of 3m (the noise measuring reference location), the longer, heavier, and faster freight trains generate higher level of noise. However, the exposure to this noise lasts shorter due to the higher speed. The road trucks generate noise measured at the reference location(s) similarly to that of the freight trains. This noise generally increases with the increase of the truck weight and speed. Again, the exposure is shorter thanks to the higher speed. The noise from both freight trains and trucks can be potentially harmful to the close population – in the short term due to the sleep disturbance, and in the long term due to diminishing the work productivity and increasing the frequency of different diseases [2].

2.2 Congestion

The freight trains operating in the CREAM corridor are assumed to be free of congestion under regular (non-disturbing) operating conditions. This can be achieved by scheduling them according to the timetable, which a priori prevents mutual interference and related delays of these and others, both freight and passenger trains operating along the same routes-sections. Nevertheless, because of the above-mentioned differences in the operating speeds and infrastructure constraints, some particularly long and/or slow trains may cause some upstream delays on the faster freight and/or passenger trains running behind them particularly in the dense segments of the corridor(s), even under regular operating conditions. These delays generally depend on the number of affected trains and the length of the imposed delay per train [2].

The road trucks usually operate on highways and motorways along the dedicated (far right) lane(s) within the given speed limits. Despite being relatively independent, they could, at certain locations of highways/motorways (such as entry/exit ramps), cause congestion thus affecting and causing time losses of other vehicles. This may also happen at the border crossings particularly in the southern part of the CREAM corridor [2].

2.3 Traffic incidents/accidents

Traffic incidents/accidents cause damage and loss of property for both the transport modes involved and the third parties, in addition to the loss of life and injuries of the affected people. According to the evidence so far, in all EU member states, the overall rate of incidents/accidents of both freight rail and road long-distance services have decreased over the past decade [3, 4]. The international rail and road freight services carried out in the CREAM corridor have certainly significantly contributed to the above-mentioned medium to long-term trends [3, 4].

2.4 Energy consumption and GHG emissions

The CREAM freight trains have mainly used the electric energy. The quantity of electricity consumption per train service mainly depends on the train's weight, operating speed and distance. The GHG emissions from these trains are indirect, depending on the composition of sources from which the electric energy for their locomotives is obtained (in this case, traction by diesel locomotives, which takes place at particular shorter segments of the corridor has not been considered). The contemporary and large intermodal terminals use the electric cranes for transshipments of loading units, thus making their emissions of GHG also indirect (the use of diesel-powered reachstackers has not been considered) [2].

Road trucks usually burn diesel fuel causing GHG emissions with both local and global impacts, the later for a long time after being deposited in the atmosphere [5, 8, 9, 10] .

3. METHODOLOGY

3.1 Objectives and assumptions

The objectives of this report are to investigate the potential effects in mitigating externalities, i.e. the social and environmental impacts, which could be achieved by fully deploying the rail freight train services instead of their equivalent road truck counterparts in the given corridor during the specified period of time. In general, these externalities include noise, congestion, traffic incidents/accidents, and energy consumption and consequent GHG emissions. For this purpose, a methodology for estimating the above-mentioned effects has been developed based on the following assumptions:

- The rail freight trains operate with sufficient capacity which enables them to catch the complete quantities of freight volumes, which would otherwise be taken over by the equivalent road truck services; this implies hundred percent market share of the rail freight trains under given circumstances;
- The intensity and scale of impacts, and their costs of both modes are assumed to be uniform and constant along the segments of the corridor where the CRAEM trains operate; and
- Apart from the real-life data on the volumes of the rail freight train services, other inputs on the social and environmental impacts and their costs are taken from the relevant secondary sources.

3.2 Basic structure

3.2.1 Noise

Freight trains

Noise generated by a rail (CREAM) freight train passing by an exposed observer in a given corridor is estimated by using the scenario approach including a train of a given length at the given speed passing by a recover, i.e. the noise even observer. The noise level perceived by the observer increases while the train is approaching them, it is the highest when the train is just passing by, and it decreases after the train has passed .

The length of train (the number of wagons + locomotive) influences crucially the duration of the highest noise level. The right angle distance between the train and the observer mainly influences the maximum level of noise exposure. The above-mentioned noise barriers additionally attenuate this maximum level of noise exposure.

Road trucks

Noise from a single or a convoy of trucks operating in the given context is also measured in terms of the duration and maximum level of exposure. The former decreases with increasing of the truck speed and increases with increasing of the length of truck(s) (i.e. the number of trucks in the convoy). The latter increases with increasing of the speed and decreases with increasing of the right-angle distance between the noise source and the recipient. In addition, the noise mitigated by the noise barriers need to be taken into account. They are usually set up to protect particularly noise-sensitive areas by absorbing maximum level of noise of about 20dB(A) (single barriers) and 25dB(A) (double barriers).

The above-mentioned estimates of noise exposure due to either trains or road trucks could be further generalized by including the frequency of impacts to noise events, which would approximately be proportional to the number and location of noise receivers, i.e. the number of population located nearby and consequently exposed to these events along particular corridor segments.

The cost of noise of both rail freight trains and road trucks is expressed as the total and relative terms. In the former case this was the cost of damage of the affected population by excessive noise and/or by the cost of the noise protective barriers on the noise sensitive locations along the rail lines and motorways/highways in the corridor. In the latter case, this cost could be expressed in the monetary terms per unit of service carried out near the given locations during the age of exploitation of the objects (barriers) (monetary units per t-km). In the specified (CREAM) case, the cost of noise of both modes is calculated as the product of this unit cost and the volume of services carried out.

3.2.2 Congestion

Freight trains

In the given context, the newly launched (CREAM) freight trains are scheduled within available free time slots along the corridor. Under such circumstances, they should not affect the existing services of both passenger and freight trains by imposing congestion and delays on them. Consequently, they could be considered as free of congestion. Nevertheless, if the above-mentioned scheduling is not possible, new train services could impose time losses on other trains running in the same direction along a given corridor segment. This occurs due to the slowing of other (faster) trains scheduled behind the newly launched freight trains until they are able to pass them safely at convenient intermediate stop(s) (station(s)). The time losses of all trains affected by a given newly launched freight train could be calculated as the difference between their nominal (scheduled) and affected time.

Road trucks

Congestion caused by road trucks occurs while other vehicles (cars) are waiting to overtake them. Anyway, a queue of other lighter vehicles could be formed behind the truck(s) which causes time losses of these vehicles. These time losses could be estimated as the product of the average waiting time per vehicle in the queue and the number of vehicles waiting to overtake one or more trucks running as a convoy.

The cost of the above-mentioned time losses at both modes are calculated as the product of the total lost time and the average value of unit of such (lost) time.

3.2.3 Traffic incidents/accidents

Freight trains

The number of potential fatalities (and/or severe injuries) by operating the given number of (CREAM) freight trains could be estimated as the product of the number of trains, their gross weight, operating distance, and the rate of incidents/accidents (in the number of events/fatalities/injuries per t-km), In this context, the incident/accident rate is taken as an average from the available statistics. This is a measure of the potential and not of the real occurrences.

Road trucks

Similarly as in the above-mentioned case of freight trains, the number of potential fatalities (and/or severe injuries) by a convoy of road trucks assumed to be substituted by trains could be estimated as the product of the number of trucks in the convoy, the gross weight of each truck, and the average accident rate, the latest used as an average from the available statistics (events/fatalities/injuries per t-km). Again, this is a measure of the potential rather than of the actual occurrences,

The cost of traffic incidents/accidents of both modes is calculated as the product of the quantity and the average cost per unit of quantity.

3.2.4 Energy consumption and air pollution/climate change

Freight trains

Energy consumption

The energy consumption of the freight (CREAM) train(s) carrying out the volumes of transport services, which otherwise would be carried out by the road trucks, is estimated and used as an input for calculating GHG emissions (Greenhouse Gases) in terms of CO_{2e} (Carbon Dioxide equivalents). These trains consume electrical energy, whose quantity is usually proportional to the train overall gross weight (locomotive + wagons + payload), cumulative constant and variable resistance to its movement along a given distance, and the length of this distance [6].

GHG emissions

A freight train pulled by an electrical locomotive does not directly emit GHG. However, these are emitted by producing the electrical energy consumed by the train. Thus the amount of GHG emitted by a train operating along a given distance could be calculated as the product of the energy consumed and the rate of GHG emissions (per unit of the energy produced (consumed)).

Road trucks

Energy consumption:

Road trucks consume diesel fuel whose quantity is proportional to the average rate of consumption (l/100km) and the operating distance.

GHG emissions

The GHG emissions from a road-truck operating along a given distance could be estimated as the product of the total fuel consumed and the GHG emission rate per unit of the fuel consumed. The emission rate per unit of fuel consumed (CO_2/l of fuel) usually relates to the on-wheel emissions including the emissions from producing fuel and the emissions from direct burning of fuel during providing the given transport service(s).

The total costs of GHG emissions of both modes are calculated as the product of the quantity and the average cost per unit of quantity.

4. APPLICATION OF THE PROPOSED METHODOLOGY

4.1 Input data

4.4.1 The geography of the CREAM corridor

The above methodology has been applied to the CREAM Trans-European corridor (Customer-driven Rail-Freight Services on the European Mega-Corridor Based on Advanced Business and Operating Models) [1] shown in *Figure 1*.

As can be seen, in the North, the corridor begins in the Netherlands and Belgium; spreads through Germany, Austria, Hungary, Romania, Bulgaria, Slovenia, Croatia, Serbia, and Macedonia, and ends in the southern Greece and Turkey. It is about 2,700 km long.

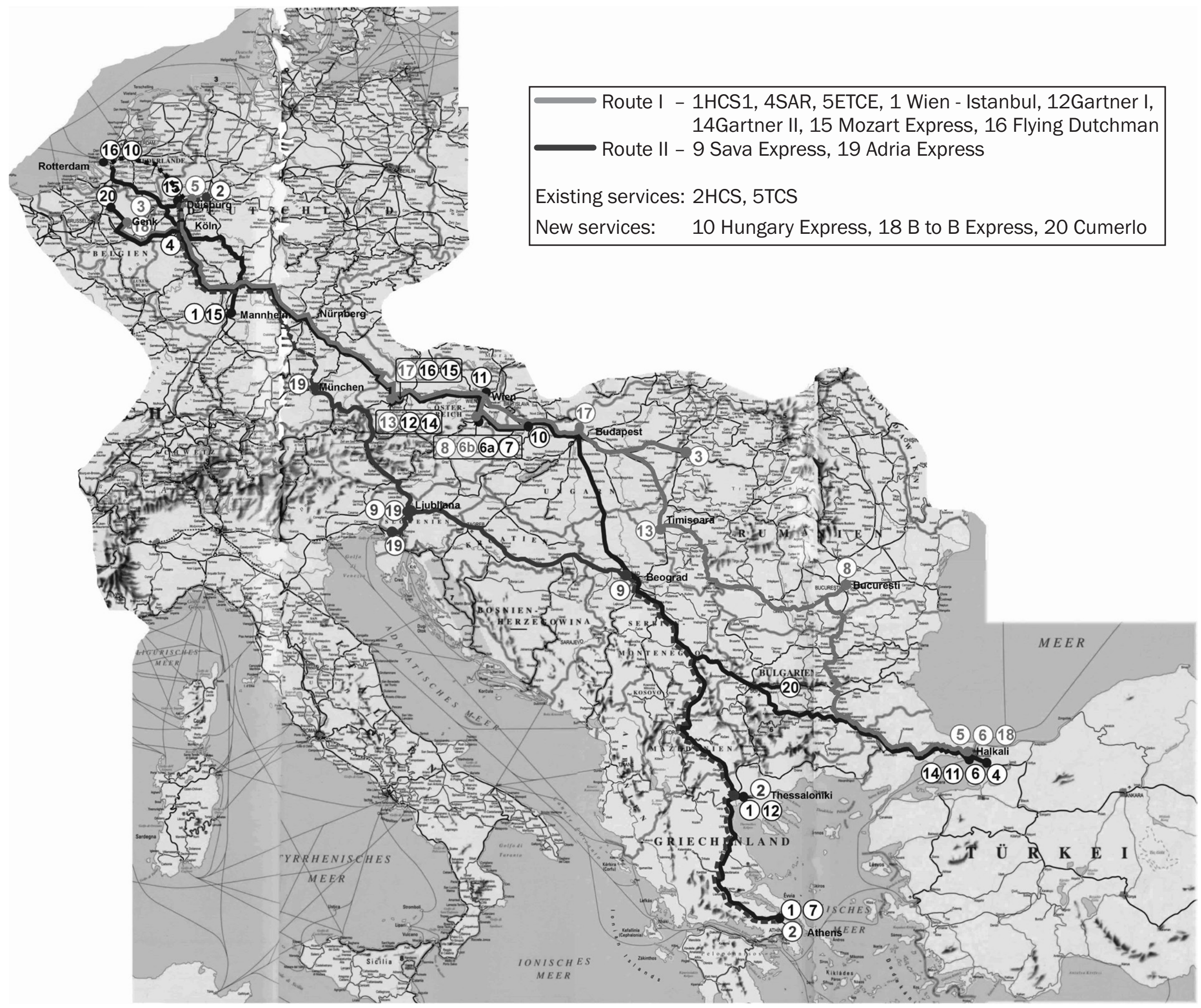

Figure 1 - A simplified geographical diagram of the given corridor (Compiled from EC, 2008) [1]

4.1.2 Volumes of CREAM train services

The volumes of services carried out by the CREAM trains in the given corridor are provided during the period 2006-2010 shown in *Figure 2*.

As can be seen, there has been a growing trend over time, with the annual volume generally growing over the observed period. The exception is the year 2009, presumably as a reflection of the global recession which started near the end of the year 2008.

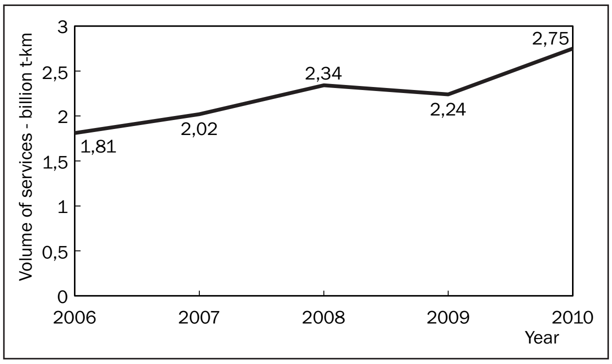

Figure 2 - The volumes of transport services carried by the CREAM trains during the period 2006-2010

4.1.3 Cost of particular impacts – externalities

In order to estimate the effects from exclusively using the CREAM train instead of the road truck services in monetary terms, the particular impacts of both

Table 1 - The average unit costs/externalities of particular rail freight and road truck vehicles/ services in the CREAM corridor

Externality	Road trucks (€ cent/v-km)	Freight trains (€ cent/v-km)
Noise	0.18	6.75
GHG emissions	4.70	34.4
Congestion	0.17	0
Traffic incidents/ accidents	0.30	0.19
Total:	5.35	41.34

Compiled from: CE Delft, 2008 [7]

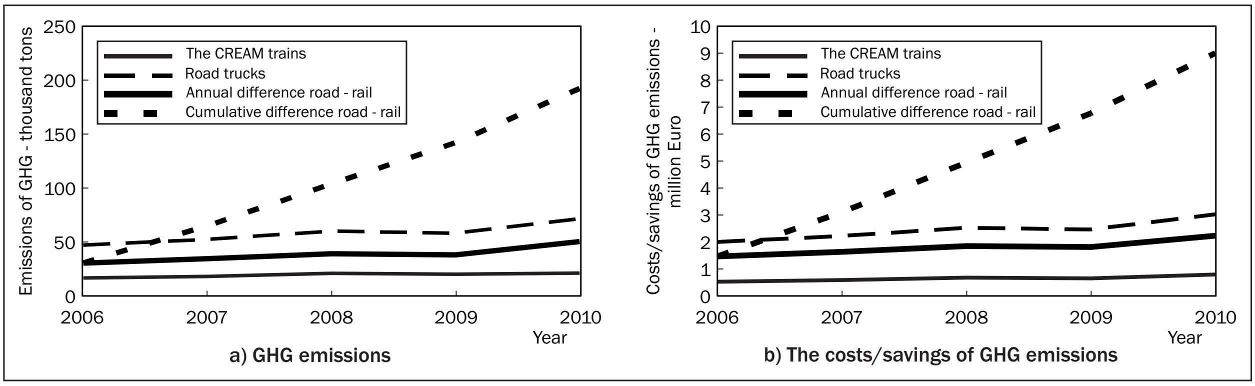

Figure 3 - The GHG emissions and related costs/savings by operating the CREAM trains and road trucks (2006-2010)

modes are expressed in the monetary terms per unit of output (veh-km) and given in *Table 1* [7].

Then, the corresponding averages in terms of € cent/t-km have been estimated by assuming the weight of a road truck of 40 tons and the weight of a CREAM train of 1,200 tons.

4.2 Discussion of results

The results are expressed in total GHG emissions and their costs, and the total costs of the above-mentioned impacts for both CREAM trains and equivalent road truck services. As mentioned above, if the difference between the impacts and costs of the latter and the former is positive, it can be considered as the saving, just thanks to operating the CREAM trains. The results are presented depending on the time (annually) and in the cumulative terms over the observed period (2006=2010), the latter to illustrate the cumulative effects already achieved as well as those that could be achieved if the CREAM trains continued to operate in the future under the similar conditions.

Figure 3(a,b) shows GHG emissions in terms of CO_2e and the related costs/savings during the observed period (2006-2010).

Specifically, *Figure 3*a shows that the annual GHG emissions by CREAM trains have increased/decreased in proportion with increasing of the volume of services over time. The emissions of their road truck counterparts, which would be operating instead, have increased in the similar pattern. In addition, the former emissions have amounted only to 30-36% of the latter, thus indicating prospective savings from 64% to 70% thanks to operating of the CREAM trains in the given context. Due to the long standing age of GHG in the atmosphere, the cumulative savings in these emissions have been of interest as well. They have continuously increased from about 30 thousand tons at the beginning (2006) to about 190 thousand tons at the end of the observed period (2010).

*Figure 3*b shows the costs/savings in these emissions as expressed in the monetary terms. For both CREAM trains and road trucks they vary in proportion to the annual volume of services. Again, they are higher for the road trucks, thus making the average annual savings of about 73% by operating the CREAM trains. In addition, the cumulative savings increases from about EUR 1.5 million at the beginning (2006) to about EUR 9 million at the end of the observed period (2010).

Figure 4 shows the annual and cumulative costs/savings in all above-mentioned externalities which have been achieved by operating the CREAM trains instead of road trucks under given conditions during the observed period (2006-2010).

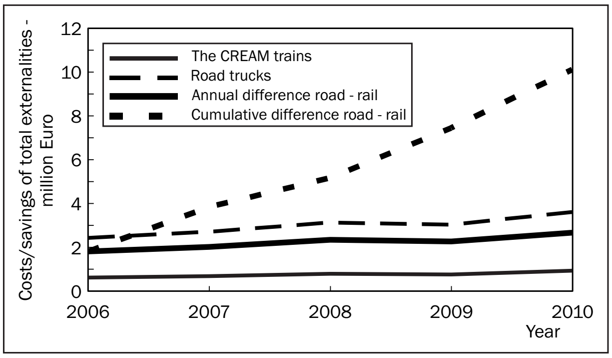

Figure 4 - The savings of total externalities by operating the CREAM trains and road trucks (2006-2010)

The externalities include noise, congestion, traffic incidents/accidents, and GHG emissions.

As can be seen, the total annual externalities, similarly as in the case of GHG emissions, have been higher in road trucks than the CREAM trains. The difference is again positive and in favour of the CREAM trains. Consequently, the cumulative savings increase - from about EUR 1.8 million at the beginning (2006) to about EUR 10.1 million at the end of the period considered.

5. CONCLUSION

This paper has dealt with estimating some social and environmental effects from full substitution of road freight by rail freight services in the mega Trans-European transport corridor during the given period of time. These savings have mainly included those in the quantities and related costs of GHG (Greenhouse Gases) in terms of CO_{2e}. The estimates have been based on the assessed energy consumption of both modes under given conditions. The savings in other impacts and their costs externalities such as noise, congestion, and traffic incidents/accidents have been estimated for comparing the overall effects.

For such a purpose the convenient methodology for calculating the particular impacts and related costs for both modes has been developed and applied to the given corridor – CREAM by using two types of inputs: The first relates to the volumes of CREAM train services carried out during the given period of time (2006-2010). The other relates to the quantity and costs of particular impacts mainly taken from the secondary sources.

The results have indicated that the annual impacts in terms of GHG emissions and their costs have increased/decreased in proportion to changes of the volumes of the CREAM train services, and their road truck counterparts. The difference in the absolute terms indicates that the savings achieved by operating the CREAM trains have been between 64-70% in the quantities of GHG and about 70% in their costs. The cumulative savings in both above-mentioned have constantly increased during the observed period.

Savings in the costs of all impacts considered have shown a similar trend at the annual and cumulative scale.

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SAŽETAK

PROCENA NEKIH DRUŠTVENIH I EKOLOŠKIH EFEKATA SUPSTITUCIJE DRUMSKOG TRANSPORTA ŽELEZNIČKIM NA TRANS-EVROPSKIM TRANSPORTNIM KORIDORIMA

Ovaj rad se bavi procenom mogućih efekata ublažavanja društvenih i ekoloških uticaja zamenom teretnog drumskog transporta železničkim na datim Trans-evropskim transportnim koridorima, tokom određenog perioda vremena. Uopšteno govoreći, ovi uticaji obuhvataju buku, zagušenja, saobraćajne incidente i nezgode (bezbednost) kao i potrošnju energije i, s tim u vezi, emisije GHG (gasova staklene bašte). Svaka vrsta uticaja, posebno za svaki vid transporta, analizira se i modelira, tako da se dolazi do mogućnosti njihovih kvantitativnih procena kao i međumodalne komparacije u datim uslovima. Posebna pažnja posvećena je potrošnji energije i sa njom povezanih emisija GHG te njihovim troškovima. Takođe, ukupni troškovi gore navedenih uticaja su za konkretan slučaj procenjeni. Na osnovu toga se dolazi do dobre osnove za procenu društveno-ekološke opravdanosti u budućim sličnim slučajevima

KLJUČNE REČI

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