

# Comparison of External Costs in Multimodal Container Transport Chain

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## COMPARISON OF EXTERNAL COSTS IN MULTIMODAL CONTAINER TRANSPORT CHAIN

### ABSTRACT

*The proposed paper discusses multimodal container transport due to savings in external costs. Relevant data have been analysed by reviewing previous research and published works for making a synthesis of one's own conclusions. The research findings showed that there is no significant difference in the share of external costs of container transport and transport of other types of cargo in great European seaports as well as in energy consumption of multimodal rail-inland ship container transport and the same transport mode of bulk cargo. Intermodal terminals have also their own external costs. In spite of a double railway operational cost, it is important to include the railway in the intermodal terminal. The inland waterway transport has much higher external costs than sea transport. Multimodal container transport does not necessarily lower external costs. The savings are more common if the location and type of intermodal terminal are selected properly, and the sea transportation is involved in the multimodal transport chain.*

### KEY WORDS

*multimodal transport; container transport; external costs;*

### 1. INTRODUCTION

Nowadays, international transport is based on complex networks of services that involve a plurality of stakeholders and transport solutions in order to make efficient connection between globalized origins and possible destinations [1, 2]. The port efficiency and its competitiveness depend a lot on the connections between the port and its own hinterland [3].

External costs of transport are traffic caused social costs, which are not internalized in the transport sector, but compensated from other sources of public sector or community. They reflect the cost of all expenses that occur as a result of the exploitation of the transport system [4]. External transport costs are divided into three main categories: the cost of traffic accidents,

the cost of pollution and the congestion costs [5]. In reducing the external costs it is important for transport users to be aware of the cost to society of their choice of transport mode. By calculating the external costs for each mode of transport the authorities can develop the strategic plan to redirect the transport to the environmentally more acceptable mode [6]. Based on the research by Digeisi et al. [8], it was concluded that the road sector generates 93% of total external costs, rail accounts for 2%, the aviation passenger sector 4% and inland waterways 0.3%. The same authors assert that the use of multimodal transport occurs with the reduction of external costs.

Multimodal transport reflects the combination of various modes of transport (water, road, rail and air), primarily through the use of containers. Containers allow safe transport and fewer risks [9]. Intermodal transport is a form of multimodal transport which is "the movement of goods in one and the same loading unit or road vehicle, which uses successively two or more modes of transport without handling the goods themselves in changing modes" [10]. Combined transport is intermodal transport mostly by rail, inland waterways or sea, and the road transport is reduced to the initial and/or final legs [12]. The road transportation included in multimodal transport chain shares in the external costs in a greater to a lesser degree. Environmental impacts of multimodal transport are lower than in road transportation which carries the negative social cost and perception [13]. There are efforts in EU transport policy to redirect road transport into a more acceptable transport mode [14].

Containerization is defined as "a method of distributing or transporting merchandise in a standard unit, thereby supporting an inter-modal transport system involving combinations of the road, rail and maritime modes" [15]. Container transport takes place within the road, rail, inland waterway, and maritime traffic networks. A node where the networks intersect is

called the container terminal where the containers can be reloaded between different modes of transport [16].

The structure of this work consists of several authors' reports of the external costs in different types of freight transport and external costs in the multimodal freight transport with special attention to the share in the container transport. Although lower external costs are expected in multimodal transport, sometimes there are unexpected results as well. Analysing the previously published works, relevant data have been identified, elaborated and reasoned. The paper points out the conditions to be met in multimodal container transport chain in order to lower the share of external costs.

## 2. EXTERNAL COSTS IN DIFFERENT TYPES OF FREIGHT TRANSPORT

External costs are predominantly connected with road transport. According to the Austrian annual report 2005 [17] they were 11.6 times higher than in railway transportation and 15.4 times higher than in ship transportation (Figure 1). There are efforts to remove the freight from the roads as much as possible.

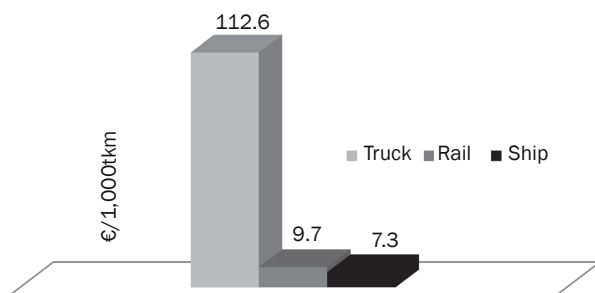


Figure 1 – Share of external costs in different types of freight transport

Source: [17]; modified

### 2.1 Environmental impacts

In total emission of transport-caused carbon dioxide (CO<sub>2</sub>) in 2000 in Croatia, the road transport participated with 82.91%, railway transport with 0.86% and all other transport modes with 16.18% [18]. According to EEA [19] in total transport sector emissions, the road transport participates with 83.33% of NMVOC, 55.55% of PM<sub>2.5</sub>, and 59.09% of PM<sub>10</sub> emission. The share of rail transport is <5% of both PM and absence of NMVOC emission. The share in SO<sub>x</sub> emission is negligible in both transport modes. Other environmental impacts of various transport types are shown in Figure 2.

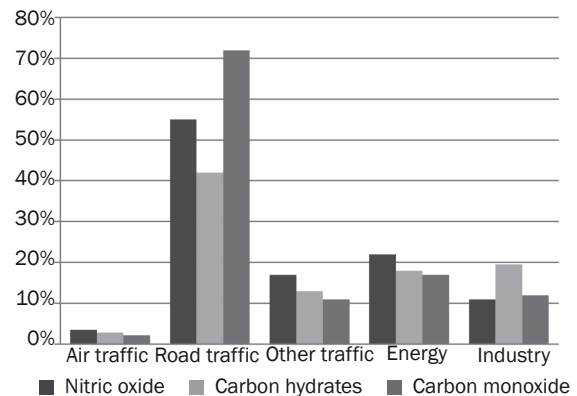


Figure 2 – Environmental impacts of various types of transport

Source: [20]; modified

### 2.2 Congestion and accident related external costs

Almost exclusively traffic congestion, accidents and respective external costs are connected with road transportation. In other kinds of transportation the accidents happen sporadically, and lately, there has been congestion, sometimes, in air traffic [20]. A share of these kinds of external costs in total transportation costs is significant and should be counted on them. As an example, the values of external costs of congestion in road transportation are graphically represented in Figure 3. They participated with 25-45% of total costs and amounted to € 2-15/1,000 tkm [21]. The upper column indicates passenger traffic; the lower column refers to cargo transport.

Total internal and external costs of accidents in traffic are 3-4% of GDP of a country [23]. According to CE Delft [11] the share of accidents of total road freight transport external costs was € 17/1,000 tkm. The external costs of accidents (tEC) are principally calculated by formula:

$$tEC = PL + LL - PC \quad (1)$$

where *PL* reflects direct property losses; *LL* reflects labour value losses, and *PC* reflects internalized private costs. Direct losses are the values of lost properties. Labour value losses include the costs of total or partial impossibility of casualties to create the social value in the whole remaining labour ability period. Private costs include losses of life, losses of spirit and Social Service Agency Costs (Emergency Health Service, police, firemen, transportation, etc.). They are all internalized by means of insurance, so they can be taken away of the total external costs [24]. The average social accident costs in Croatia in 2010 were € 1,333,000 for fatalities, € 173,300 for severe injury and € 13,300 for slight injury [25].

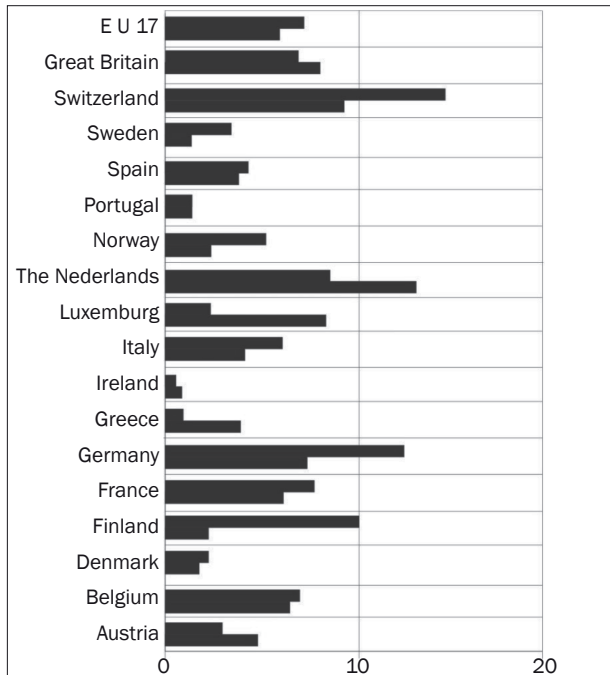


Figure 3 – External costs of congestion in Europe in 1995  
Source: [22]; modified

### 2.3 Share of external costs in freight transport

The share of external costs in freight transport by cost category and mode are shown in Figure 4. There is the evidence (arrow) that the external costs of accidents participate only in road transport (€ 3.5/1,000tkm). The road transportation also predominates in air pollution.

Depending on various methodologies and taking into account various parameters, there are the values of external costs strongly different among different investigations (Table 1). However, all of them confirmed the need to shift the road transport into rail and waterways transport in order to make the external costs significantly lower. The costs of congestion are generally not taken into account and they are estimated in the range of 0.5-3.7% of GDP [27]. It is also important to note that inland waterways' external costs are significantly higher than in sea transportation. The values of external costs depend on characteristics of each line for which they are calculated.

Table 1 – Share of external costs in different types of freight transport

Transport branch	External costs [€/1,000tkm]				
	Hinšt [21]	Bäck [17]	Maibach [28]	Ortolani [30]	Wei [29]
Road	87.8	112.6	88		12.6
Railroad	17.9	9.7	19	3-5.6	8
Inland waterways	22.5				
Sea waterways		7.3	12		0.36

The share in the percentage of external costs in various transport show predomination of road transport in the range of 60.1-87% (Table 2).

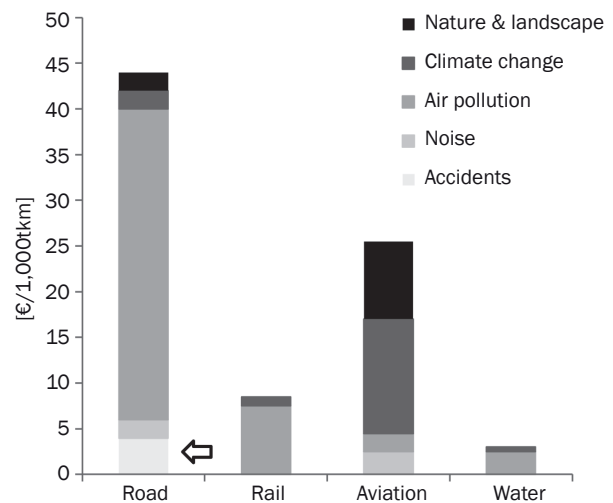


Figure 4 – Average external costs of freight transport by cost category and mode  
Source: [26]; modified

Table 2 – Share of external costs in different types of freight transport

Transport branch	External costs [%]			
	UIC [6]	Bäck et al. [17]	Wei [29]	Hinšt [21]
Road	83.7	87.0	60.1	68.5
Air	14.0			
Railroad	1.9	7.5	38.2	14
Water	0.4	5.6	1.8	
Inland water				17.6

### 2.4 External costs in container transport

Although external costs of container railway transport in EU are relatively low (€ 3-5/1,000tkm) and there are benefits from absence of congestion and accidents, they are actually much higher because of external costs of hinterland container terminals [30]. Similarly, seaway container transport has 66% higher external costs than seaway bulk transport [31]. Container vessels have short port stays, but produce high emissions during their stays [32].

### 3. EXTERNAL COSTS IN MULTIMODAL FREIGHT TRANSPORT

According to research by Burkhard et al. [33] multimodal transport reduces the number of accidents in the range of 60-80% as well as the emission of CO<sub>2</sub> by 40-50%. There is a benefit in marginal social costs of 33-72%. The principle and final calculation of external costs should be carefully considered. Principally, there are benefits of multimodal transport as results of data shown in figures and tables. Practically, they depend on the line, distance, frequency, type of freight, shape of freight, mode of multimodal transport and type and location of the intermodal terminal. Smaller share of road transport leads to less external costs but not always and not unlimited. The evidence will be shown in examples of various modes of multimodal transport.

#### 3.1 Multimodal transport – mode railway instead of road transport

According to Ortolani et al. [30] in three cities and surrounding region in Northern Italy collecting and disposal of industrial liquid waste were completely designed as road transport network. After changing the mode of transport, including rail, the road transport was reduced up to 60%. The benefits are shown in Figure 5. Total costs were 24% lower exclusively for lower external costs even on short distances. The saving was made by lower cost of the environment and congestion. However, increasing the share of rail transport over 40%, the costs of the environment also rose due to “operating between three train stations close to the disposal centers”. It shows how the direction of the line can influence the external costs in multimodal transport.

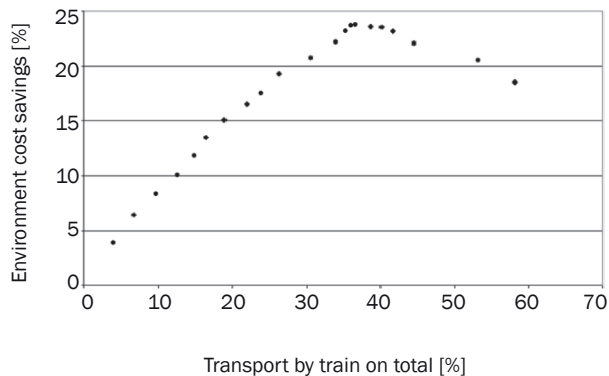


Figure 5 – Environmental cost savings vs. Rail transport ratio  
Source: [30]

#### 3.2 Multimodal container transport – road-rail mode with intermodal rail terminal

In research done by Janic [34] a cost-benefit analysis was used to investigate the differences between exclusively container road transport and intermodal road-rail container transport. The results are presented in Figure 6. They depended on the distance and frequency.

The internal costs of both transport means became equal at the distance of 900 km, and the total cost equalized after 1,000 km if the frequency of trains is 5 per week. It means that the external costs of intermodal transport on a distance of more than 800 km were still higher than in road transport. With the frequency of 25 trains per week, equal cost point is moved at 200 km beforehand. High railway multimodal transport costs are the result of double operational costs of rail: operational costs of transport and the terminal.

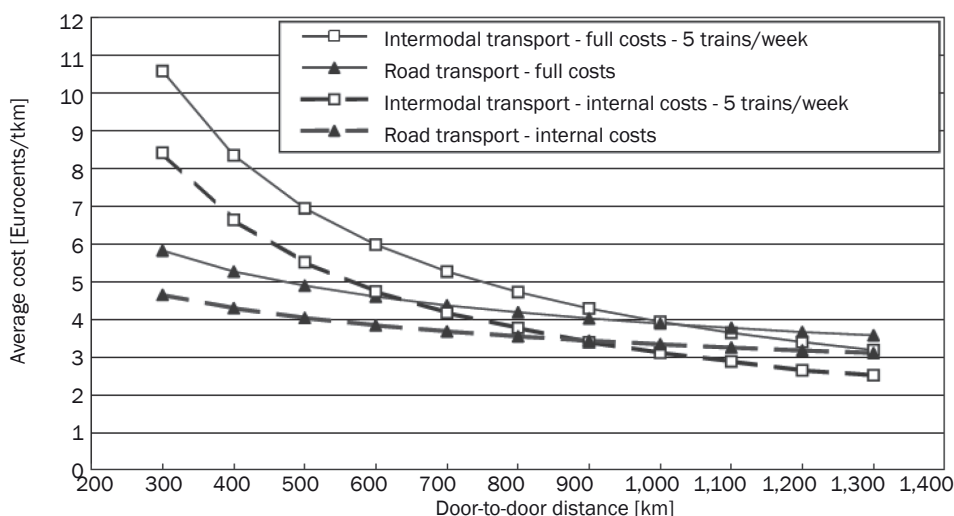


Figure 6 – Dependence of the average external, internal and full costs of given intermodal and road transport network on the door-to-door distance  
Source: [34]

### 3.3 Multimodal transport – potential savings in the mode sea-rail instead of sea-road

In a ten-year analysis by Rožić et al. [35] container transport growth in the Port of Rijeka, Croatia and the share of rail container transport are shown (Figure 7). Despite strong growth of total throughput of containers in the Port of Rijeka, the railway container transport has remained practically the same for years. The potential annual benefit of future inland container terminal of the Port of Rijeka is shown in Table 3. Annual savings would be € 4 million on Rijeka - Hungarian border route and additional € 4 million on Rijeka – Serbian border route. The results show the importance of inland container terminal in savings of external costs despite the costs appearing on the terminal itself.

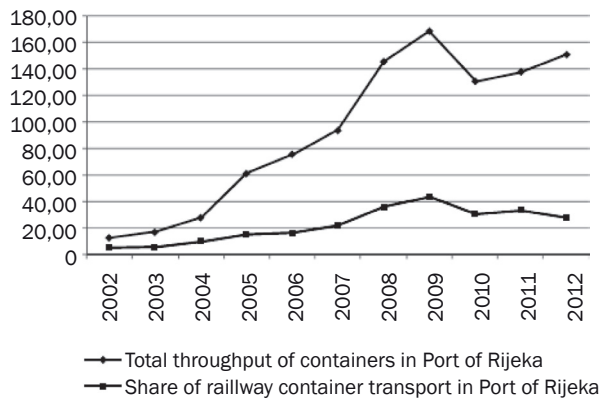


Figure 7 – Review of total throughput of containers and share of railway container transport in the Port of Rijeka  
Source:[35]

Table 3 – Total annual cost saving of container transport by rail after inland terminal construction (in €)

Location	Amount	Location	Amount
Delnice	0	Čačinci	3,326,126.98
Ogulin	0	Varaždin	3,498,670.97
Karlovac	20,190.21	Slavonski Šamac	3,584,193.66
Zagreb	59,780.16	Čakovec	3,839,621.59
Dugo Selo	306,443.58	Tovarnik	3,951,481.34
Sisak	780,622.382	Županja	4,224,779.78
Kutina	1,028,389.19	Osijek	4,234,615.03
Bregi	2,032,161.70	Vinkovci	4,319,677.86
Koprivnica	2,198,688.08	Nemetin	4,502,090.42
Slavonski Brod	2,427,483.71	Drenovci	4,599,470.09
Virovitica	2,729,961.36	Knin	6,992,365.14
Volinja	2,779,081.80	Solin	10,078,457.90
		Split	10,082,991.10

Source: [35]; modified

### 3.4 Multimodal transport –road-sea mode with road container terminal instead of road

According to Kotowska [36] the investigation estimates the impact of container terminals to reduce the external costs of transport for the Ports of Gdansk, Gdynia and Szczecin on the route towards Hamburg. The externalities are shown in Figure 8.

Considering pollution, the benefits do not arise from the reduction in emissions but are less harmful to society because they are away from residential areas. Moreover, the emissions of nitric oxides (NOx), sulphur oxides (SOx) and particulate matters (PM) were higher in land-sea transport chain. Particularly large benefits result from the smaller CO<sub>2</sub> emissions, the number of road accidents and road congestion in the examined land-sea transport chains, as compared to competitive road transportation. The total savings of external costs are over 100 million euro per year, which is enough to build a new small container terminal. The terminal produces damages of large emissions of NOx. The results of research actualize the importance of the location of the intermodal terminal as well as the route of multimodal transport chain in the light of external costs.

### 3.5 Limitations of multimodal container transport

The articles taken by NEA et al. [37] and Caris et al. [38] show the structure of road transport costs where congestion and accidents have a significant share. In spite of this, the total costs were principally not higher than rail transport because there were great railway infrastructure costs (Figure 9). The air pollution of Rhine waterway transport (black) was the same as road or rail diesel transport. Lower costs in multimodal transport cannot be expected if sea transport is not included in the transport chain network.

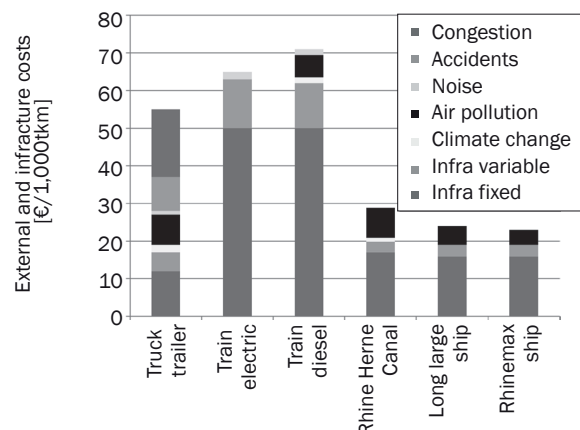


Figure 9 – External and infrastructure costs of container transport

Source: [37]; modified



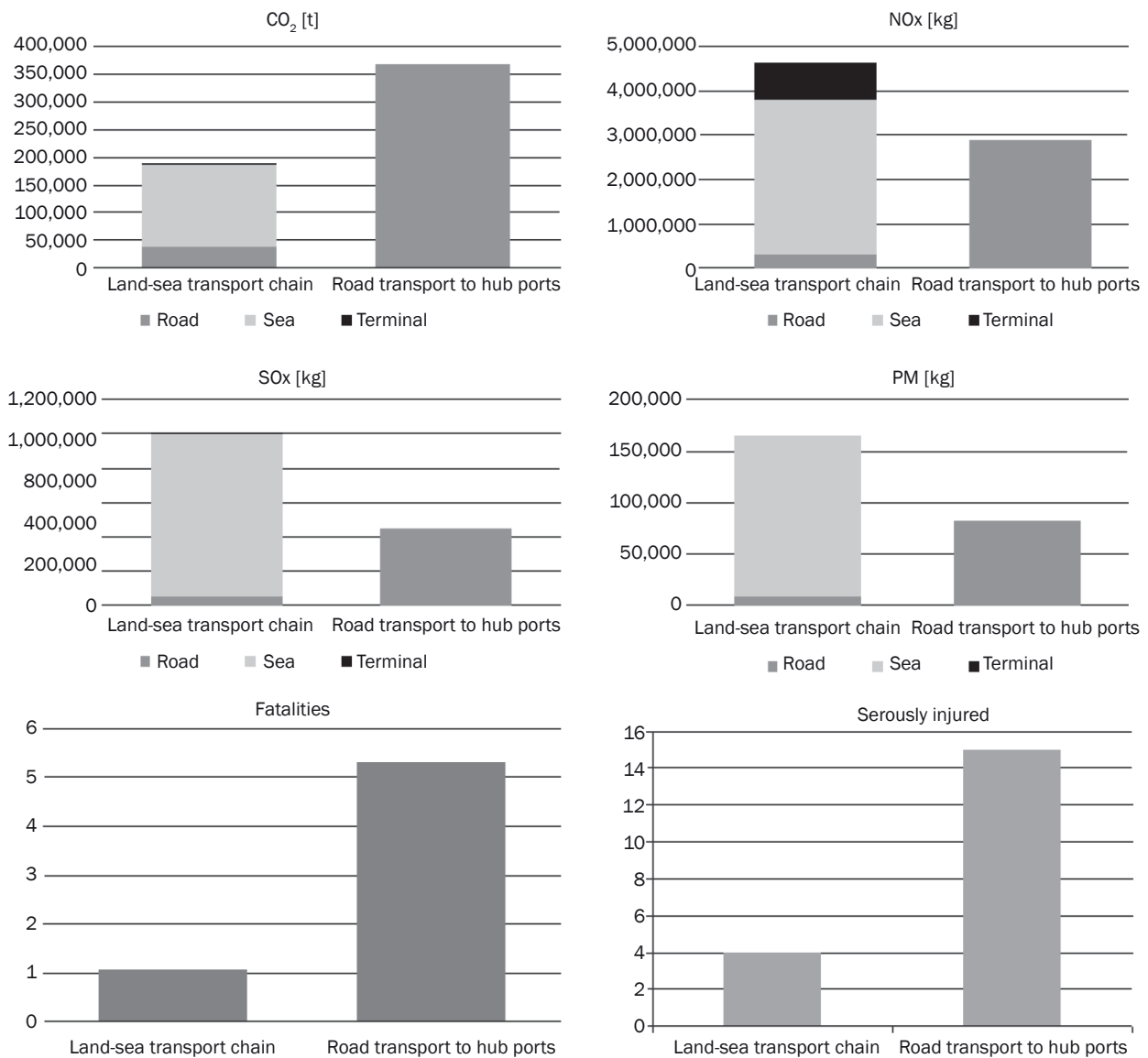


Figure 8 – Pollution, fatalities and serious injuries in tested road transport and alternative land-sea chain  
Source: [36]

### 3.6 Share of external costs of multimodal container transport

According to the research of PLANCO [39] the energy consumption for bulk and container transport is shown in Figure 10. Energy consumption in multimodal rail-inland ship transport of bulk and container cargo is equal. Inland waterways container transport cost is lower than competitive mode but the external costs of air pollution rise to 90% while road and rail are only 25% and 17%, respectively. External cost calculation requires taking into account as many variables as possible to get a real frame for making decisions.

In the research taken by Meersman et al. [40] the external costs are calculated and compared according to the type of transported cargo in big European ports.

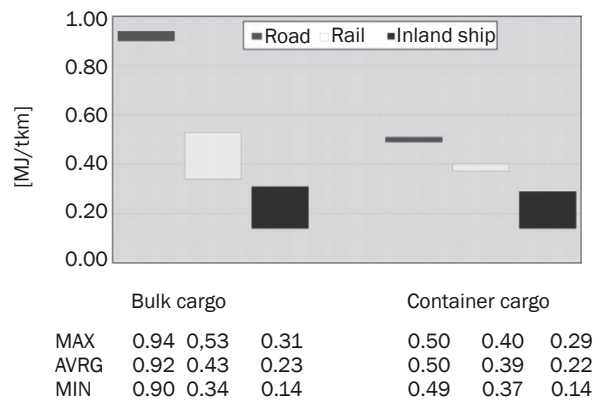


Figure 10 – Spread and averages of primary energy consumption on selected transport relations  
Source: [39]

Based on the results it can be concluded that there is no significant difference in the share of external costs of container transport and transport of other types of cargo in big European ports. All of them accounted for about 50% of total costs (Table 4).

Table 4 – Share of external costs of container transport and other freight transport in the Port of Antwerp and the Port of Bordeaux

Cargo	External costs [%]	
	Antwerp	Bordeaux
Container	46	54
General cargo	52	52
Dry bulk	49	55
Liquid bulk	53	50

Source: [40]; modified

### 3.7 Intermodal terminal

The benefit of inland container terminal lies not in the lower pollution level but in the displacement of the pollution out from the urban area. Lower external costs arise from lower congestion and smaller consequences of accidents [38]. Climate change costs are expected to increase for all modes between 2009 and 2020. Although CO<sub>2</sub> emissions per ton kilometre decrease for all modes, this is outweighed by the increase in the shadow price of CO<sub>2</sub>. For accident costs, the expected relative reduction is the same for road and rail transport (9%). The total external costs per ton kilometre decrease by 8% for road transport, while for rail and inland waterway transport a smaller reduction of 1-2% is estimated, especially caused by the smaller reduction in air pollution costs of these latter modes compared to road transport [37]. According to Sulbaran and Sarder [41] it is of great importance for the railway to be included in the intermodal terminal. If so, the emissions are much lower, especially of NO<sub>x</sub>, PM<sub>10</sub>, PM<sub>2.5</sub>, carbon monoxide (CO) and reactive organic gas (ROG), so the external costs are also lower (Figure 11).

Rudolf [42] considers that in general, for container terminals, nearly 80% of the costs are independent of the number of ships and the volume of the handled merchandise. For bulk merchandise, fixed costs are lower and represent 60% of the invariable costs with the volume [43]. Several pieces of evidence show how well-connected hinterlands might increase port competitiveness [1] and how the organization of intermodal transport might enlarge port catchment areas [44]. The location and the organization of logistics parks or inland ports and the accuracy in designing a logistic system can significantly reduce the external costs in transport [45]. It can also make a significant long-term

sustainable influence both on economy and the environment [46].

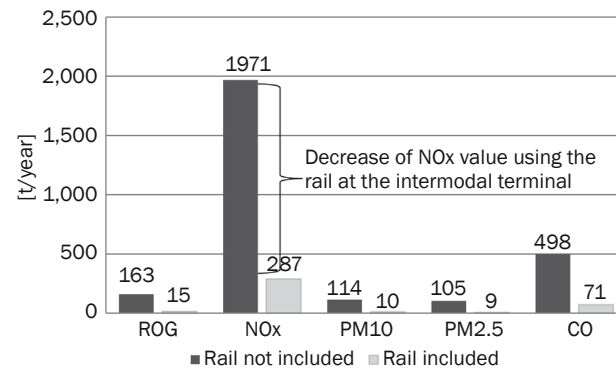


Figure 11 – Study of intermodal terminals  
Source: [41]; modified

## 4. CONCLUSIONS

The share of external costs in multimodal container transport chain has been investigated to find out which of the requirements should be met to keep it as low as possible. It was also important to show the limits of this kind of transport. Multimodal container transport does not necessarily lower the external costs. An intermodal terminal as part of multimodal transport has its own external costs which should be considered. In case of road intermodal container terminal, external costs will hardly be lower. Neither will the railway intermodal container terminal in road-rail mode significantly lower the costs, especially on distances shorter than 1,000 km. There is a double railway operational cost: transportation and terminal cost. Sometimes, the environmental costs rise if the share of railway transport exceeds the limits defined by characteristics of the line. However, if the sea transport is included in multimodal transport chain, the savings will be significant, as opposed to the inland waterway transport.

According to cited authors there was no significant difference in the share of external costs of container transport and transport of other types of cargo in big European ports accounting for 50% of total costs. Energy consumption in multimodal rail-inland ship transport of bulk and container cargo was also approximately equal. There is some evidence of seaway container transport to have 66% higher external costs than seaway bulk transport. They are mostly connected with intermodal container terminal especially if located in port areas. As for rail, the emissions are significantly lower if the freight station is included/situated in the terminal. The multimodal container transport key factor is the type and the location of the intermodal terminal in the hinterland. Most savings come from re-



duced congestion and accident costs as well as from the displacement of emission sources. The parameters for the intermodal terminal location choice become a challenge for future investigation research. Including sea transportation and minimizing road transportation in multimodal transport chain, significant savings can be expected. In this respect, the maritime transport would be able to play an increasing role.

The values of external costs depend on the characteristics of each line for which they are calculated.

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## **USPOREDBA VANJSKIH TROŠKOVA U MULTIMODALNOM TRANSPORTNOM LANCU PRIJEVOZA KONTEJNERA**

### **SAŽETAK**

*U radu se razmatra multimodalni prijevoz kontejnera glede ušteda na vanjskim troškovima. Relevantni podaci analizirani su na temelju dosadašnjih istraživanja i objavljenih radova. Rezultati istraživanja pokazuju kako nema značajne razlike u udjelima vanjskih troškova u kontejnerskom transportu i transportu drugih vrsta tereta u velikim europskim morskim lukama kao ni u potrošnji energije u tipu željeznica-unutarnje vode multimodalnog prijevoza kontejnera i rasutog tereta. Intermodalni terminali također imaju vlastite vanjske troškove. Unatoč dvostrukim željezničkim operativnim troškovima važno je da željeznička infra- i suprastruktura bude uključena u intermodalni terminal. Prijevoz tereta unutarnjim plovnim putovima ima puno veće vanjske troškove od prijevoza morem. Multimodalni prijevoz kontejnera ne smanjuje nužno vanjske troškove. Uštede su vjerojatnije ako se lokacija i vrsta intermodalnog terminala ispravno odabere i ako se prijevoz morem uključuje u multimodalni transportni lanac.*

### **KLJUČNE RIJEČI**

*multimodalni prijevoz; kontejnerski prijevoz; vanjski troškovi;*

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