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METHOD OF ASSESSING THE IMPACT OF POLISH CONTAINER TERMINALS IN REDUCING THE EXTERNAL COSTS OF TRANSPORT

ABSTRACT

The paper attempts to identify the social costs and benefits of marine container terminal operations regarding feeder vessels services. It presents a method of valuation which takes into account the external costs of additional factors: the nature and direction of the shipping lines operated by the terminals and the size of port hinterland. Based on the proposed method, the impact of container terminals to reduce the external costs of transport has been assessed.

KEYWORDS

container terminal, sustainable transport, land-sea transport chains, external costs

1. INTRODUCTION

Assessment of social benefits is an important part of any application form for the European Union funds. So far there have appeared numerous publications that allow assessing external costs of transport. However, none of them directly refers to the operation of container terminals.

The Polish container terminals do not perform the same role as hub ports in Western Europe. Their operation is limited to providing service for the feeder vessels. Their operations contribute in reducing the external costs of transport: pollution, accidents, and congestion. The findings have indicated that Polish container terminals contribute to the reduction of CO_2 emissions, but they generate more harmful substances like sulphur dioxide, nitrogen dioxide, and particulate matter. The impact of these emissions on social costs is connected with the place of their formation.

According to the assumptions adopted in the White Paper on Transport [1], the European countries should strive for a sustainable development of transport. The idea of the European sustainable transport network is to reduce the external costs of transport, while keeping full economic effectiveness and optimum use of the existing infrastructure. The same document stresses the need to build more and efficient entry points into European markets which shall help to avoid unnecessary traffic crossings of Europe.

Large container vessels operating ocean lines can call at only several container ports in Europe. Most of the European sea container terminals can only operate feeder vessels. The use of feeder ships increases the number of transport junctions, which very often discourages cargo owners to make use of such transport chains. The main advantage of the chains is their influence on the release in road transport, which is responsible for the highest external costs.

The reduction of external costs of transport can be achieved by improving the competitiveness of land-sea transport chains, which can be shaped by internalization of external transport costs and maintenance costs of infrastructure, or by supporting investments improving the quality of land-sea transport chains infrastructure (road and rail infrastructure of the ports hinterland and capacity of the ports themselves).

The problem is how to assess the social benefits using land-sea transport chains instead of road transport, because there are no clear guidelines concerning the methods of such evaluations. In the 1990's research on connecting theoretical and practical aspects of determining external costs of transport has been started [2, 3, 4]. It was, however, only at the beginning of the 21^{st} century that practical tools for assessing the external costs generated in various modes of transport were published.

In 2002 in the *Proposal on the Granting of Community Financial Assistance to improve the Environmental Performance of the Freight Transport System* the value of external costs of various transport modes were estimated. [5]

Other values of external costs of transport have been proposed in the Marco Polo II Program. Both documents are commonly used in the estimation of external costs of transport, although they do not take into account many factors significantly affecting the actual amount, i.e. the country in which they occur (e.g. accident costs depend on hospitalization costs, costs incurred by the police, insurance, etc., which may vary depending on the country), the types of transport sectors (e.g. class of road vehicle exhaust gases emissions), etc.

The research conducted by Maibach et al. [6] indicates that much more accurate results can be obtained using the following studies:

– *Developing Harmonised European Approaches for Transport Costing and Project Assessment* (HEAT-CO (2006) – containing the methodology of calculating external costs of transport with regard to road and railway transport, depending on the place of costs formation. A number of documents and guidelines for EU funds refer to this publication [7]
– *Damages per tonne emission of $PM_{2.5}$, NH_3, SO_2, NOx and VOCs from each EU25 Member State (excluding Cyprus) and surrounding seas* (CAFE 2005) takes into account the external costs of pollution generated in sea transport [8].

The research concerning the influence of sea transport on external costs formation is less advanced than in the case of other transport modes. The main factor influencing the level of external costs which come from sea transport, due to the global character of pollution, is CO_2 emission, while gas emissions like nitrogen dioxide, sulphur dioxide and particulate matter affect external costs of transport to a much smaller degree. Their amount depends on the distance of a ship from the seashore [9].

Another problem are the external costs resulting from accidents in maritime transport. Although the likelihood of an accident in maritime transport is negligible, it may result in significant consequences for the environment. The most common types of accidents are groundings and bottom contacts, which often result in oil spill. Indirect costs of spills include costs of flora and fauna and natural resources damage, affecting also industries like fishing, aquaculture and tourism. After the Baltic Carrier oil tanker accident in 2001, 2,700 tons of oil was spilled. The effects on sea birds, fishes, water, sediment and biota were reported. It was estimated that 20,000 birds were killed, also shrimps, eels, and flounder had elevated levels of toxic substances [10].

Neither of these studies indicates how to estimate the social benefits of container terminal operations. This paper proposes methodologies for valuation of the social benefits of container terminal operations, which take into account the specific role of Polish container terminals in the land-sea transport chains, the type of hinterland transportation, the location of the load in the hinterland, and operated shipping services. In addition, based on the proposed methodology, the assessment of the impact of Polish container terminals to reduce the external costs of transport has been carried out.

2. PROPOSAL OF THE METHOD OF ASSESSING EXTERNAL COSTS AND BENEFITS OF CONTAINER TERMINAL OPERATIONS

Sea transport is considered to be one of the least polluting modes of transport, and moreover, owing to taking-over some parts of cargo traffic, it contributes to the reduction of congestion on European roads, and thereby – reduction of the number of road accidents. In particular, short sea shipping is considered as the best alternative for European road transport. Short sea shipping has many advantages: practically unrestricted transport capacity of shipping routes, mostly cost-free linear infrastructure, low fuel consumption of the ships per mass of the transported cargo, and thereby – low external costs of transport [11]. Total social costs of transport include four categories of costs: total costs of vehicles use, total costs of accidents, total costs of air pollution, and total costs of noise [12].

Container terminals are only links in transport chains, so they require different approach to evaluation of external costs of transport than railway lines. The assessment of social benefits of container terminals operations requires correct identification of transport chains in which the given terminal operates. Most of the Polish container terminals are served only by feeder services (the only exception is Deepwater Container Terminal in Gdańsk, operating ocean-going vessels since 2010). More than 90% of containers are transported to German, Dutch and Belgian ports, where they are transhipped onto ocean-going vessels [13].The transport chain in question is shown in *Figure 1*.

Container terminals, whether they serve ocean-going vessels or only the feeder vessels, must meet the increasing needs of container transhipments. Lack of efficient port infrastructure and suprastructure would discourage cargo suppliers or consignees to use such a complicated transport chain and would induce them to use road transport directly to the ports of Western Europe.

The comparison of the amount of external costs generated in road transport and competitive container land-sea transport chains enables evaluation of socially acceptable level of investment financing inside the ports, as well as the investments improving the access to a port.

The external costs calculation was based on container turnover in the Polish seaports in 2010 (ship-to-

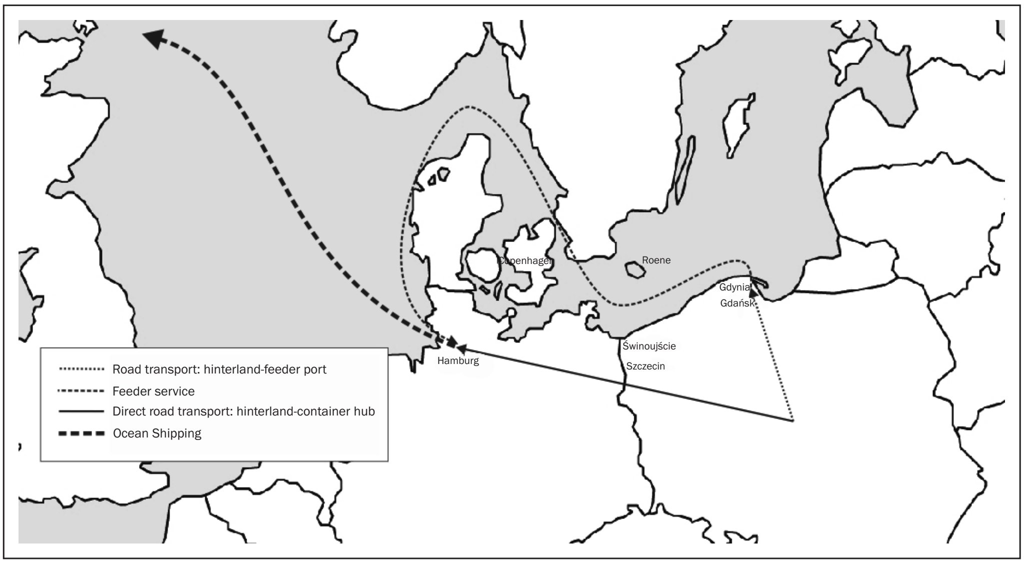

Figure 1 - Container transport chain in Poland

ship transhipments in Deepwater Container Terminal Gdańsk were omitted) and their directional structure.

The calculation includes the following substitution land-sea transport chains:

- road transport from hinterland to the Polish container port – transhipment to feeder vessel – sea transport to container hub in Western Europe: Hamburg, Rotterdam, Bremerhaven;
- direct road transport from the Polish hinterland to container hubs.

The external costs include: the costs connected with emission of harmful substances created while burning fuel such as particulate matter, sulphur oxides, carbon dioxide and nitrogen oxides strongly affecting human health and life, causing, among others, the increase in incidence of pulmonary, cardiovascular and cancerous diseases. The external costs also include the costs resulting from road accidents, like the costs of medical benefits and rehabilitation of road accident victims, losses in production caused by accidents, costs of special services, etc. The costs of congestion resulting in the extension of time of travel, exploitation costs of vehicles and maintenance costs of road infrastructure contribute to the external costs, too. [14]

External cost in direct road transport (EC_d) and external cost in land-sea transport chain (EC_{lst}) may be calculated by the following formula:

$$EC_d = \sum_{i=1}^{n} (EC_d)_i \tag{1}$$

$$EC_{lst} = \sum_{i=1}^{n} (EC_h)_i + \sum_{i=1}^{m} (EC_t)_i + \sum_{i=1}^{p} (EC_s)_i \tag{2}$$

$$(EC_{d/h})_i = \begin{cases} (E_{d/h})_i \cdot (K_{rt})_i, & \text{for air polution} \\ L_{rf\ d/h} \cdot (K_{rt})_i, & \text{for fatalities} \\ L_{rsi\ d/h} \cdot (K_{rt})_i, & \text{for severe injuries} \end{cases} \tag{3}$$

$$(EC_t)_i = (E_t)_i \cdot (K_t)_i \tag{4}$$

$$(EC_s)_i = (E_s)_i \cdot (K_s)_i \tag{5}$$

where:

- $(EC_d)_i$ – external cost of selected agent *i* in direct road transport to hub ports (€);
- $(EC_h)_i$ – external cost of selected agent *i* in hinterland road transport (€);
- $(EC_{d/h})_i$ – external cost of selected agent *i* in direct road transport to hub ports or in hinterland road transport (€);
- $(EC_t)_i$ – external cost of selected agent *i* in terminal (€);
- $(EC_s)_i$ – external cost of selected agent *i* in sea transport (€);
- i – type of external cost agent (e.g. SOx, NOx, PM, fatality, severe injury);
- n – number of external costs agents in road transport and hinterland road transport;
- m – number of external costs agents in terminal;
- p – number of external costs agents in sea transport;
- $(E_{d/h})_i$ – emission of agent *i* in direct road transport to hub ports or in hinterland road transport (t);
- $(E_t)_i$ – emission of agent *i* in terminal (t);
- $(E_s)_i$ – emission of agent *i* in sea transport (t);
- $L_{rf\ d/h}$ – number of fatalities in direct road transport to hub ports or in hinterland road transport;
- $L_{rsi\ d/h}$ – number of severe injury in direct road transport to hub ports or in hinterland road transport;
- $(K_{rt})_i$ – average cost of agent *i* or incident in road transport (€/t , €/incident);

$(K_t)_i$ – average cost of agent *i* in terminal (€/t);

$(K_s)_i$ – average cost of agent *i* in sea transport (€/t).

Air pollution in a link of selected transport chain $((E_{d/h})_i, (E_t)_i, (E_s)_i)$ can be based on Ecotransit Tool developed by the Institute for Energy and Environmental Research (IFEU), Heidelberg, and the Rail Management Consultants GmbH (RMCon) [15].

The number and type of accidents that may occur in hinterland transport to the Polish terminals and in direct transport to container hubs in Western Europe may be based on the guidelines contained in the Blue Book for road investments [16] according to the following formula:

$$L_{rf\ d/h} = PP_{d/h} \cdot (p_{rfa} \cdot L_f) \cdot 10^{-7} \quad (6)$$

$$L_{rsi\ d/h} = PP_{d/h} \cdot (p_{rfa} \cdot L_{sifa} + p_{rsia} \cdot L_{si}) \cdot 10^{-7} \quad (7)$$

where:

$L_{rf\ d/h}$, $L_{rsi\ d/h}$ – as above;

$PP_{d/h}$ – vehicle-kilometre in hinterland transport (PP_h) or in direct road transport to hub port (PP_d) (vehicle-kilometres);

p_{rfa} – probability of road fatal accidents ($1/10^7$ vehicle-kilometres);

p_{rsia} – probability of road severe injury accidents ($1/10^7$ vehicle-kilometres);

L_f – average number of fatalities in one road fatal accident;

L_{sifa} – average number of severely injured in one road fatal accident;

L_{si} – average number of severely injured in one road severe injury accident.

The number of road accidents is determined by the type of road infrastructure in the port hinterland. In case of the Polish seaports hinterland transport, due to the fact that the cargo is located near different road types, averaged measures are or have to be assumed. In the direct road transport to the ports of Western Europe, it was assumed that the transport took place on motorways.

External cost of contaminations and accidents may be based on HEATCO and CAFE guidelines. Due to the international nature of hinterland transport to hub ports, the average cost of each agent $((K_{rt})_i)$ may be established through the following formula:

$$(K_{rt})_i = \frac{\sum_{j=1}^{r} k_{ij} \cdot s_j}{\sum_{j=1}^{r} s_j} \quad (8)$$

where:

r – number of countries crossed in the road transport to hub ports;

k_{ij} – average cost of agent *i* or incident in country *j* (€/t or €/incident);

s_j – length of the road in country *j* (km).

Due to the fact that containers transloaded in Polish ports are delivered to/from hub ports such as Hamburg/Bremerhaven, Rotterdam and Antwerp, the calculation of vehicle-kilometre in road transport directly to hub ports should take into account the difference in distances between ports.

Considering the above, vehicle-kilometre in road transport to hub ports can be estimated as follows:

$$PP_d = \frac{P_p \cdot u_{rt} \cdot \sum_{x=1}^{3} (u_{Hx} \cdot s_{Hx} + u_{Rx} \cdot s_{Rx} + u_{Ax} \cdot s_{Ax})}{c} \quad (9)$$

where:

$$u_{Hx} + u_{Rx} + u_{Ax} = 1 \quad (10)$$

$$c = \frac{L_{TEU}}{L_{40'} + L_{20'}} \quad (11)$$

PP_d – vehicle-kilometre in direct road transport from the Polish sea ports (Szczecin, Gdynia, Gdańsk) to hub ports, *x* is 1,2,3 for the sea ports, respectively;

P_p – number of containers handled in Polish sea ports on relation to the hub ports (TEU);

c – average number of TEU carried on road vehicles (TEU/vehicle);

u_{rt} – share of road transport in hinterland transport to Polish sea ports;

u_{Hx} – share of containers transported by sea on relation between the Polish port *x* and Hamburg;

s_{Hx} – average road distance from the hinterland of the Polish port *x* to Hamburg;

u_{Rx} – share of containers transported by sea on relation between the Polish port *x* and Rotterdam;

s_{Rx} – average road distance from the hinterland of the Polish port *x* to Rotterdam;

u_{Ax} – share of containers transported by sea on relation between the Polish port *x* and Antwerp;

s_{Ax} – average road distance from the hinterland of the Polish port *x* to Antwerp.

L_{TEU} – number of containers transloaded in Polish sea ports in 2010 (TEU);

$L_{40'}$ – number of vehicles carrying 40’ containers to/from Polish sea ports in 2010 (vehicle);

$L_{20'}$ – number of vehicles carrying 20’ containers to/from Polish sea ports in 2010 (vehicle).

In 2010 Polish ports operated 1,050,680 TEUs out of which 237,041 were 20’ containers [17]. Assuming that 100% of 40’ containers and 50% of 20’ containers were carried singly, c = 1.8 TEU/ vehicle.

Vehicle-kilometre in hinterland transport to a selected Polish port (PP_h) may be calculated as:

$$PP_h = \frac{P_p \cdot u_{rt} \cdot s_h}{c} \quad (12)$$

where:

PP_h – vehicle-kilometre in hinterland transport to a selected Polish port;

P_p, u_{rt}, c – as above;

s_h – average road distance in hinterland transport (km).

An important element necessary to calculate vehicle-kilometre is the correct assessment of hinterland area of the examined terminal served by road transport. Unfortunately, the terminals do not collect data on origin/destination of cargo, so the average transport distance in the hinterland must be estimated.

In the calculations of 100km distance it was assumed, based on the following factors:

1. The nearest surroundings of Polish seaports are strong socio-economic centres, which generate both demand and supply of goods handled in the ports. Both regions (Pomeranian and West Pomeranian) generate about 30% of foreign trade cargo transported by sea [18]. Large part of the cargo is delivered to the port at a distance of no more than tens of kilometres.
2. The nearest rail terminals which operate containers directly by trains to the Western ports are located at 250-350km from the Polish sea ports (e.g. Gądki, Kobylnica, Warszawa Praga, Łódź Olechów). Therefore, containers located farther than 150km from sea ports are delivered to these rail terminals.

According to the definition of combined transport [19], in the case of vehicle transportation, the distance to a sea terminal should not exceed 150km. Containers located farther than 150km from the ports should be transported by rail. Polish sea ports offer numerous regular connections to the rail terminals in the hinterland.

3. RESULTS

The conducted comparative analysis of the examined transport chains demonstrated that the emission of CO_2 generated in direct road transport to the ports of Western Europe is almost two times higher than in intermodal land-sea transport chains (*Figure 2*).

The emissions of SOx, NOx and Particulate Matters are higher in land-sea transport chain than in direct road transport but their impact on human life and health is much lower than in road transport. It results from the fact that contamination generated by sea vessels is created primarily at the open sea (approximately 65% of ships sail at a distance of more than 25M from the sea shore [20]). The results of the research prove that pollution cost generated in road transport is almost 100% higher than in the examined land-sea transport chain (*Table 1*). Additionally, each container transferred from road transport system to the sea reduces the probability of road accidents. On the annual scale (according to the data for 2010) the approximate costs reach 10 million euro. However, the greatest benefits result from the reduction of road congestion. In the analysed case, owing to transportation through Polish container terminals, the congestion cost amounting to approximately 78 million euro annually has been avoided. Total savings are over 100 million euro per year.

Apart from the benefits for the natural environment, the container terminal operation also creates benefits of social nature that result from the increase in the number of serviced vessels. The shipowners, in addition to charges related directly to cargo handling, incur charges for the services of both active (towage, pilotage and agency fees) and passive type - for the use of port infrastructure (tonnage and quay dues). An important social benefit of port terminals is to increase employment. The port activity generates new jobs, both directly at the terminal, and the port environment. According to the research one job in the ports of Gdynia

Table 1 - External costs of transport in the tested transport chains (EUR)

Components of costs	Gdynia	Gdańsk	Szczecin	Total
External costs in land-sea transport chain, including:	22,453,804	4,923,461	1,795,168	29,172,433
Pollution costs	19,513,689	4,804, 690	1,426,601	25,744,980
Accident costs	1,218,774	49,234	152,783	1,420,791
Congestion costs	1,721,341	69,536	215,784	2,006,661
External costs in direct road transport, including:	114,677,662	12,798,070	9,567,321	137,043,053
Pollution costs	32,845,028	10,164,571	2,463,914	45,473,513
Accident costs	10,109,222	297,796	773,505	11,180,523
Congestion costs	71,723,412	2,335,703	6,329,902	80,389,017
The benefits from the transfer of cargo to land-sea transport chains	92,223,858	7,874,609	7,772,153	107,870,621

Source: own calculation based on formulae (1) to (12)

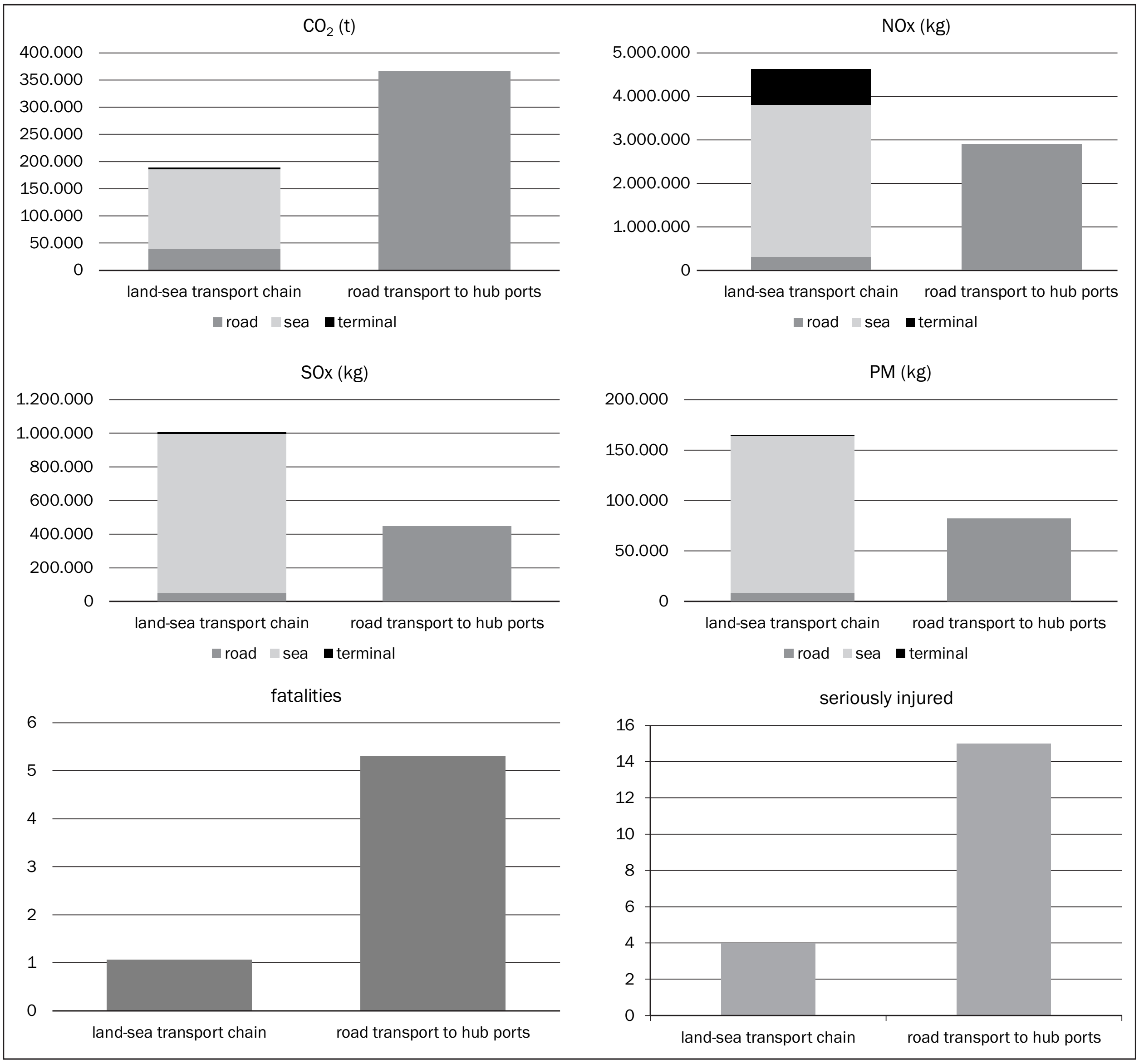

Figure 2 - Pollution, fatalities and serious injuries in tested road transport and alternative land-sea transport chain

and Gdansk generates three jobs in the immediate vicinity, which includes among others the activities of marine transport agencies, marine and coastal water transport and maritime education and thirteen jobs indirectly in the environment, in activities like manufacturing and repairing of ships, port-related industry, marine tourism and ports hinterland transport [21].

Another substantial element of social costs is internal costs. Transport participants bear direct costs of vehicle use and costs connected with the time of shipping since sea transport is by far slower than road transport. While a car covers the distance from Hambug to Poland within 24 hours, a feeder ship extends the total journey time up to 7 days. The time value of transport is dependent on the value of cargo. For some, cargo the value is so high that they decide to transport it by car directly to / from the ports of the West. For many, the decisive factor concerning the route is the price of transport. For them, land-sea transport chains are competitive with road transport.

For instance, transport cost of a 40' container on the Hong Kong-Gdańsk route is by 250-450 USD (170-310 euro) higher than on the Hong Kong-Hamburg route, whereas road transportation cost on the Gdańsk-Hamburg route is approximately 750-1,000 euro [22].

4. CONCLUSION

The assessment of benefits and social costs is an important component of any transport investment. In the case of container terminals, such an assessment must be considered from the point of view of the whole transport chain in which the terminal operates.

The method presented in this paper enables the evaluation of the benefits of marine container terminal operations. This method takes into account many factors, significantly affecting the amount of external costs, which include:

- nature and direction of the shipping lines operated by the terminals;
- size of port hinterland;
- share of road transport facilities in hinterland operation;
- type of roads.

The presented method also takes into account differences in the amount of external transport costs, depending on their country of origin. It used to evaluate social benefits of the Polish container terminals activity resulting from the reduction of external costs of transport.

Though the Polish container terminals do not perform the same role as hub ports in Western Europe, and their operation is limited to providing service for the feeder vessels, their operation contributes to the reduction of external costs of transport: pollution, accidents and congestion.

With regard to pollution, the benefits do not arise from the reduction in emissions, but are less harmful to society because it is created far away from residential areas. Particularly large benefits result from the smaller CO2 emission, 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. This is the amount for which a small container terminal could be built.

The adaptation of the proposed method to local conditions will enable the assessment of social benefits of any container terminal operations concerning feeder services.

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STRESZCZENIE

METODA OCENY WPŁYWU POLSKICH TERMINALI KONTENEROWYCH NA ZMNIEJSZENIE KOSZTÓW ZEWNĘTRZNYCH TRANSPORTU

W pracy podjęto próbę określenia korzyści i kosztów społecznych działalności morskich terminali kontenerowych obsługujących statki dowozowe. Przedstawiono metody wyceny powyższych kosztów z uwzględnieniem czynników tj.: charakter i kierunek linii żeglugowych obsługiwanych przez terminale oraz wielkość zaplecza portowego. Na podstawie zaproponowanej metody, oszacowano wpływ terminali kontenerowych na zmniejszenie kosztów zewnętrznych transportu.

SŁOWA KLUCZOWE

terminal kontenerowy, transport zrównoważony, lądowo-morskie łańcuchy transportowe, koszty zewnętrzne

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