Method of Assessing Social Benefits of the Development of Inland Shipping Infrastructure in Poland

Izabela Kotowska
Maritime University of Szczecin, Poland

Keywords: inland shipping, external costs of transport, social costs.
The first attempts to assess the external costs of transport were taken by the European Commission as early as 1995, when the Green Paper highlighting the significant social consequences of road transport and the need to internalize the external costs of transport, was published. For the first time the evaluation of the external costs of road and rail transport resulting from such phenomena as: accidents, noise, air pollution was proposed and estimated their size. In 1994, the external costs, including the costs of air pollution (excluding the cost of global warming), the cost of road accidents, noise and congestion accounted for over 4% of world GNP, half of which was the cost of traffic congestion.

Another publication, which outlines the external costs of transport, was the White Paper published in 2001, presenting the costs of air pollution, climate change, noise, accidents and congestion related only to road transport. According to the estimates presented in the White Paper, only the costs of accidents in the European Union in 2000 caused the loss of 2% of GDP per year. The direct cost of traffic accidents, which is possible to be assessed, amounted to 45 billion Euros, while indirect costs (including psychological and moral injury of victims and their families) were increased by about three quarters.

In 2002 the European Commission and the Council published the proposal of the grant system promoting the intermodal transport solution. In the publication, for the first time, external unit costs generated by other than road and rail branches of transport, were presented. The following components of external costs were taken into account: congestion, use of infrastructure, accidents, noise, pollutants and climate costs (C02).

Since the beginning of the 21st century a number of programs aiming at assessing the external costs of transport have been realized. On the basis of some of them, e.g. UNITE, RECORD, INFRAS/WW, in 2005 a method of evaluating external costs of transport to be used by Marco Polo Program II, was developed. At present the method is frequently applied in many scientific publications for assessing the social advantages of transport (Table 1).

All the so far presented methods of calculating external costs of transport do not consider two significant elements:

- Due to different development levels of particular EU countries the external costs generated by transport are not identical in all of them.
- Pollution emission computed according to the performed forwarding works depends upon the type of means of transport, their capacity, fuel consumption and their emission regulations.

In 2006 HEATCO guidelines were published - proposal of Harmonized guidelines, containing consistent methodological framework for project appraisal. In contrast to the previously mentioned publications on the social costs of transport, HEATCO does not include the cost per transport work done equally for all means of transport of the modes of transport but includes unit costs of pollutants emissions and costs of individual accidents. At the same time it differentiates values depending upon their place of

---

**Table 1.** Marginal average external costs of transport by mode (EUR/1000tkm)

<table>
<thead>
<tr>
<th>Cost element</th>
<th>Road</th>
<th>Rail</th>
<th>Inland waterway</th>
<th>Short Sea Shipping</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accident</td>
<td>5.44</td>
<td>4.3</td>
<td>1.46</td>
<td>1.40 (Negligible)</td>
</tr>
<tr>
<td>Noise</td>
<td>2.138</td>
<td>2.8</td>
<td>3.45</td>
<td>0.90 (Negligible)</td>
</tr>
<tr>
<td>Pollutants</td>
<td>7.85</td>
<td>8.9</td>
<td>3.80</td>
<td>4.60</td>
</tr>
<tr>
<td>Climate Costs</td>
<td>0.79</td>
<td>2.6</td>
<td>0.50</td>
<td>4.60 (Negligible)</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>2.45</td>
<td>4.3</td>
<td>2.90</td>
<td>3.70</td>
</tr>
<tr>
<td>Congestion</td>
<td>5.45</td>
<td>11.3</td>
<td>0.235 (not applicable)</td>
<td>Negligible</td>
</tr>
<tr>
<td>Total</td>
<td>24.12</td>
<td>4.3</td>
<td>12.35</td>
<td>15.00 (Maximum)</td>
</tr>
</tbody>
</table>

Source: [10,14]
LOGISTICS

Method of Assessing Social Benefits of the Development of Inland Shipping in Poland

Due to specific features of inland shipping, such as safety, low energy consumption, high degree of reliability and high deadweight and capacity of vessels, the European Commission is striving to develop the use of inland waterway transport as an alternative transport mode and to make it the key transport mode within the European intermodal transport system. [23, 24]

According to the above-presented methods accepted by the European Commission, external costs generated by inland shipping are several times lower than in road transport. Unfortunately, these estimates do not take into account the capacity of different modes of transport by inland waterway, which depends on the classes of waterways, the specific fuel consumption, speed and direction of sailing traffic (upstream or downstream).

This section proposes the method of valuation of social benefits arising from the transfer of cargo from road to inland waterway vessels taking into account the size and fuel consumption for each class of the waterways as well as the specific conditions in Poland.

Social benefits resulting from the reduction of external costs of transport ($B_{ij}$), due to the transfer of cargo by road to inland shipping, is the difference of external costs generated by road transport ($C_{rt}$) and inland waterway transport ($C_{ij}$) in respect to the assigned weight load:

$$B_{ij} = C_{rt} - C_{ij}$$ (1)

In case of road transport external costs include costs of environmental pollution and greenhouse gas emissions ($CP_{ji}$), the costs resulting from road traffic accidents ($C_{art}$) and the cost of road congestion ($CC_{rt}$):

$$C_{rt} = \sum_{i=1}^{n} CP_{ji} + C_{art} + CC_{rt}$$

Inland waterway transport external costs generated ($CP_{ij}$) include the cost of pollution and climate change, however, they do not refer, due to their negligible impact, to the cost of congestion and accidents:

$$C_{ij} = \sum_{i=1}^{n} CP_{ji}$$ (3)

where:

- $C_{ij}$ refers to external costs generated by inland waterway vessel / barge $j$
- $CP_{ji}$ refers to costs of pollutants emissions and generated by the ship / barge $j$ in inland shipping
- $n$ refers to number of analyzed pollutants, $n = 5$ for particulate matter, sulphur oxides, carbon dioxide, nitrogen oxides, non-methane volatile organic compounds

The costs of pollutants emissions is generated by the substance and ship / barge / road vehicle $j$ can be determined on the basis of the average fuel consumption per unit of transport work ($FCAVE_{ij}$), average exhaust gases ($e_{ij}$) emitted by inland waterway vessels [25], or road vehicles registered in Poland [26] and unit external costs generated as a result of pollution ($c_{ij}$) [12]:

$$CP_{ji} = FCAVE_{ij} \cdot e_{ij} \cdot c_{ij}$$ (4)

For particulates, the costs generated by their emission in urban areas are several times higher than outside these areas. Since in Poland 23% of national roads are located in urban areas [27], the average cost of particulates emissions in road transport ($C_{PM}$) in Poland can be defined as the cost weighted average in urban ($CM$) and non-urban areas:

$$C_{PM} = CM \cdot c_{PM} + CZ \cdot c_{PM}$$ (5)

where:

- $CM$ refers to the share of urban roads in national roads in Poland
- $CZ$ refers to the share of non-urban roads in national roads in Poland

Emission of carbon dioxide is of global importance; therefore, the cost of its emissions should not be differentiated according to the country of its formation, as is the case with the previously described contamination. According to the guidelines contained in the IMPACT [19], the average carbon price is 26 €/t. Although this figure reflects the cost of social impact, it is worth noting...
In the years 2011-2013 in the European emissions trading market price of a ton of CO2 was much lower than its estimated cost and ranged between 3 and 12 €/ton.

In this method, the basis for determining the external costs is the assessment of fuel consumption by a pushed convoy in inland shipping on individual classes of waterways and trucks in the alternative road transport. Assuming a maximum capacity of convoys in each class of waterways, based on the average fuel consumption of the waterway units and road vehicles as well as their average operating speed, it is possible to determine the average fuel consumption per transport work \( (FCAVE_j) \) in accordance with the following formula.

In inland shipping:
\[
FCAVE_j = \left( \frac{FCUS_j}{vUS_j} + \frac{FCDS_j}{vDS_j} \right) \cdot \frac{\rho FO}{2 \cdot CAP_j} \tag{6}
\]

In road transport:
\[
FCAVE_j = \frac{FCRV_j \cdot \rho FO}{CAP_j} \tag{7}
\]

where:
- \( FCAVE_j \) - average fuel consumption of the vessel/barge/truck \( j \) per the transport unit of work (kg/ton-km)
- \( FCUS_j \) - average fuel consumption per vessel/barge \( j \) up stream (dm3/h)
- \( FCDS_j \) - average fuel consumption on board inland vessel \( j \) downstream (dm3/h)
- \( vUS_j \) - average speed of the inland vessel \( j \) up stream (km/h)
- \( vDS_j \) - average speed of the vessel downstream inland \( j \) (km/h)
- \( CAP_j \) - average fuel consumption of the road vehicle \( j \) per the transport unit of work (kg/ton-km)
- \( \rho FO \) - density of fuel oil (kg/dm3)
- \( CAC_j \) - payload of ship/barge/vehicle \( j \) (tons)

Another significant factor from the point of the social costs of transport is the cost of road accidents \( (C_{acc}) \) the value of which is:
\[
C_{acc} = p_{rfa} \cdot c_{fa} + p_{rsia} \cdot c_{rsia} \tag{8}
\]

where:
- \( C_{acc} \) - the cost of road accidents (EUR/tkm)
- \( L_f \) - number of fatalities in road accidents on national roads in 2010
- \( L_i \) - number of severe injured in road accidents on national roads in 2010
- \( i \) - length of road section \( i \) [km]
- \( N_{ij} \) - number of vehicles \( j \) on road section \( i \) [1/day]
- \( n \) - number of types of vehicles, \( n=7 \) for motorbikes, cars, vans, trucks, trucks and trailers, buses and tractors respectively
- \( m \) - number of identified road sections

The last indicated factor - congestion can cause several effects like travel time increases (this category commonly accounts for 90% of economic congestion costs), vehicle provisioning and operating costs (including depreciation, driving personnel and increased wear and tear under congested travel patterns), disamenities in crowded systems, additional fuel costs and more reliability. The best estimation of congestion costs, based on speed-flow relations, value of time and demand elasticity have been proposed in IMPACT. The assessment also takes into account the average level of GDP in Poland in relation to GDP in the European Union in 2010.
3. RESULTS

The research showed that the average fuel consumption in the performed inland waterway work is dependent upon the size of the pushed set only in case of the lower classes of the waterways. With the increase in capacity of the barge fuel consumption increases significantly. Thus, in case of upper classes of waterways (from class III onwards) fuel consumption per unit of transport work is the same. It should be noted that in Poland out of 3659 km of inland navigable waterways, only 610 km has a class III and higher. Nearly 2 thousand kilometers of roads has class Ia and Ib. On these roads fuel consumption per unit of transport work is only about 30% higher than in road transport. It should also be noted that a large part of the navigable routes included in the European navigable waterways AGN does not meet even the shipping class III (Table 2).

| - 367 km of the 739 km of the Oder waterway |
| - 778 km of the 938 km of the Vistula waterway |
| - the whole length of the Oder-Vistula waterway |

Although on the III-V shipping class waterways fuel consumption is almost twice lower than in road transport, it does not mean that the emissions generated by inland waterway are also half the size. The analysis shows that the level of emissions of certain pollutants such as sulphur dioxide, particulates and non-methane volatile organic compounds in inland waterway (Table 3) is lower than in road transport.

In case of sulphur, the higher emissions of its compounds are due to differences in standards of pollution of fuel oil used in inland shipping and road transport. Maximum allowable sulphur content in diesel is 10 ppm, while for the fuel used by inland waterway it is 1000 ppm, which makes road transport emissions of sulphur dioxide tens times smaller than in the waterways in spite of

Table 2. Average fuel consumption in road transport and inland shipping including the load capacity of means of transport

<table>
<thead>
<tr>
<th>Parameters of inland waterway unit</th>
<th>IWW ship – I Class</th>
<th>IWW ship – II Class</th>
<th>IWW ship – III Class</th>
<th>IWW ship – IV Class</th>
<th>IWW ship – V Class</th>
<th>Truck</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average speed – upstream (km/h)</td>
<td>7</td>
<td>7</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>n.a.</td>
</tr>
<tr>
<td>Average speed – downstream (km/h)</td>
<td>12</td>
<td>12</td>
<td>11</td>
<td>11</td>
<td>11</td>
<td>n.a.</td>
</tr>
<tr>
<td>Fuel consumption – upstream (dm³/h)</td>
<td>17</td>
<td>30</td>
<td>34</td>
<td>60</td>
<td>140</td>
<td>n.a.</td>
</tr>
<tr>
<td>Fuel consumption – downstream (dm³/h)</td>
<td>10</td>
<td>20</td>
<td>26</td>
<td>32</td>
<td>50</td>
<td>n.a.</td>
</tr>
<tr>
<td>Average fuel consumption (dm³/km)</td>
<td>1,6</td>
<td>3,0</td>
<td>3,3</td>
<td>5,2</td>
<td>11,0</td>
<td>0,32</td>
</tr>
<tr>
<td>Average fuel consumption (kg/vkm)</td>
<td>1,39</td>
<td>2,53</td>
<td>2,81</td>
<td>4,42</td>
<td>9,37</td>
<td>0,27</td>
</tr>
<tr>
<td>Deadweight (t)</td>
<td>180</td>
<td>500</td>
<td>730</td>
<td>1200</td>
<td>2500</td>
<td>24</td>
</tr>
<tr>
<td>Average fuel consumption (kg/tkm)</td>
<td>0,008</td>
<td>0,005</td>
<td>0,004</td>
<td>0,004</td>
<td>0,004</td>
<td>0,011</td>
</tr>
</tbody>
</table>

Source: Own calculations achieved on the basis of conducted research

Table 3. Emission of pollutants in waterway and road transport (g/1000tkm)

<table>
<thead>
<tr>
<th>Pollutants</th>
<th>IWW ship – I Class</th>
<th>IWW ship – II Class</th>
<th>IWW ship – III Class</th>
<th>IWW ship – IV Class</th>
<th>IWW ship – V Class</th>
<th>Truck</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO₂</td>
<td>15.4</td>
<td>10.1</td>
<td>7.7</td>
<td>7.4</td>
<td>7.5</td>
<td>0.2</td>
</tr>
<tr>
<td>NOₓ</td>
<td>327.3</td>
<td>215.0</td>
<td>163.6</td>
<td>156.7</td>
<td>159.3</td>
<td>373.9</td>
</tr>
<tr>
<td>CO</td>
<td>83.9</td>
<td>55.1</td>
<td>42.0</td>
<td>40.2</td>
<td>40.9</td>
<td>76.3</td>
</tr>
<tr>
<td>nm-VOC</td>
<td>36.4</td>
<td>23.9</td>
<td>18.2</td>
<td>17.4</td>
<td>17.7</td>
<td>11.4</td>
</tr>
<tr>
<td>PM</td>
<td>31.7</td>
<td>20.8</td>
<td>15.9</td>
<td>15.2</td>
<td>15.4</td>
<td>9.7</td>
</tr>
<tr>
<td>CH₄</td>
<td>1.4</td>
<td>0.9</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
<td>1.1</td>
</tr>
<tr>
<td>CO₂</td>
<td>23</td>
<td>105</td>
<td>15</td>
<td>178</td>
<td>11</td>
<td>551</td>
</tr>
</tbody>
</table>

Source: Own study based on: [25, 26]
the fact that in road transport fuel consumption appears much greater. Moreover, harmful emissions from road transport consistently decrease. Since 1987 when the regulations of Euro 0 standards were published, the restrictions of pollution generated by road vehicles have been constantly raising. For instance in Euro V norm the allowed level of emission of particular matters is 30 times lower than in Euro I. In new Euro VI norm the allowable emissions of nitrogen oxides is 400 mg / kWh - 80% less than in the standard Euro V. Limits of particulate matters are reduced by 66% (to 10 mg / kWh). \[32\]

The analysis carried out on the basis of a study of traffic flows proves that daily on country roads is performed transport work of over 170 million vehicle-kilometers (about 63 billion per year), of which nearly 20% is done by trucks and 10% by supplying vans. The vast majority of transport work - almost 70% is performed by cars. In 2010 on national roads happened more than eight thousand accidents, with 1416 people killed out of which only 28 on the highways. Road accidents affected 11 263 people. According to the Blue Paper on road infrastructure recommended by the Jaspers, the likelihood of fatalities in road transport is dependent upon the type of road and is between 0.2-0.4 people per 10 million vehicle-kilometers. The analysis carried out on the basis of the stream of traffic showed that the Jaspers guidelines are greatly overstated. In case of a probability of an accident on the highway - up to six times for other roads - twice (Table 4).

Analysis of fuel consumption for inland waterways and road transport as well as the verified probability of an accident allow for the assessment of external costs generated by inland waterway and road transport. In accordance with the commonly accepted opinion, the results of the analysis showed that the costs generated by road transport are the highest, with the dominance mainly due to the high costs of congestion and costs connected with traffic accidents (figure 1). External costs resulting from pollution from road transport are much higher than in the inland waterway traffic class III-V and smaller on class I waterways.

<table>
<thead>
<tr>
<th>Road Categories</th>
<th>Number of Fatalities</th>
<th>Number of Serious Injuries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highway and express way (2x2 lanes, multilevel intersections)</td>
<td>0.247</td>
<td>0.04</td>
</tr>
<tr>
<td>Main road (2x2 lanes, crossroads, separated lanes)</td>
<td>0.432</td>
<td>0.22</td>
</tr>
<tr>
<td>Main road (2x2 lanes, crossroads, physically un-separated lanes)</td>
<td>0.581</td>
<td>2.614</td>
</tr>
<tr>
<td>Main road (2x1 lanes, crossroads)</td>
<td>0.491</td>
<td>2.208</td>
</tr>
</tbody>
</table>
| Source: Calculations and development based on: \[18, 28\]

Fig. 1 External costs generated by inland waterway and road transport

Source: Own study
Moreover, the costs are 2-3 times lower than the proposed, e.g. for Marco Polo, which is mainly due to a much lower level of development of Poland than the European Union average.

4. CONCLUSIONS

The analysis shows that in practice the external costs generated by transport are much smaller than in the number of guidelines for estimating external costs. Although there is a noticeable advantage of inland waterway transport in relation to the road transport, but it results mainly from the lack of external costs generated as a result of fatal and serious accidents and congestion, which on waterways does not occur. The costs of pollution are comparable. Over the last few decades the quality of the engines used in road vehicles has significantly improved, which greatly decreased the amount of harmful substances emitted by them. Such technical progress has not taken place in the inland waterway. Improving the performance of inland waterways can contribute to the reduction of the total external costs of transport not only due to the expected modal shift, but also thanks to the possibility of increasing the capacity of waterway sets. It is worth noting that improving the technical parameters of waterway infrastructure entails other social benefits such as: the development of river tourism (passenger ships, sailing, river ports and marinas), the development of inland ports. This results in extending service offers of economic centers and their growing importance in the region. As a consequence, it may lead to reduction of unemployment and increase of investment attractiveness of the regions.

ACKNOWLEDGEMENTS

The project was funded by the National Science Centre allocated on the basis of the decision DEC-2012/05/B/HS4/00617.

REFERENCES

Method of Assessing Social Benefits of the Development...

Logistics and Transport № 4(20)/2013


[27] Results of Transport Operations; 2010; GUS: Warsaw, 2012. [In Polish]


[30] Program of the development of inland water transport infrastructure in Poland; Part 1 Analysis of the functioning of inland water transport and water tourism in Poland; study commissioned by the Ministry of Infrastructure; Ecorys: Rotterdam, Warsaw, 2011 [in Polish]


Izabela Kotowska
Maritime University of Szczecin, Poland
i.kotowska@am.szczecin.pl