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External costs of transport by rail on the example of the power plant

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Abstract: According to experts, passenger and goods transport is essential for the economic growth and prosperity of each society. Every transport system burdens the environment, using the dedicated infrastructure and its resources. The contemporary means of transport use the environment to generate propulsion energy (directly in combustion engines or indirectly in electric power plants). Rail transport is considered to be environment-friendly owing to its low external costs, which include the costs of the consequences of discharging gases and/or dusts into the atmosphere. In the paper the method of research, which is characterized by a different ratio than in the observation of the subject to the phenomenon under consideration. Observing the studied phenomenon has not been changed. The aim of this research was to identify the components of rail transport costs borne by the orderer of a transport service and by the electric power plant supplying the railway with electricity, on the basis of a case study of the transport of aggregate. Calculations showed the share of such costs in transport costs (in the considered case) to be marginal. In the light of this finding the definition of external costs is critically evaluated..

Introduction

Transport plays an unquestionably vital role in the socio-economic (civilizational) life of societies. But it has negative environmental impacts which need to be identified and limited. The fact that transport does not cover all the social costs of its functioning leads to distortions in transport market competition conditions.

One of the components of transport costs are external costs defined in economics as the difference between the social costs and the operating costs of a transport company (organization/system) [1, 5].

External costs in transport

An external cost is the cost or its part which is not borne by the entities creating this cost, but by the ones which have nothing to do with it, but suffer its negative consequences [1]. Before trying to determine the influence of transport system operational parameters on the level of external transport costs let us break them down. And so the external transport costs include:

- the costs of congestion and infrastructure deficiency (increased travel time, increased vehicle operating costs, an increase in the social costs of travel, increased fuel

consumption, lower reliability of transport operations, no slots (alternative services connected with the travel start/end), no positive external effects resulting from an improvement in the quality of services);

- the costs of accidents (the costs of material losses, administration costs, medical costs, costs connected with production losses, costs of suffering);
- air pollution costs connected with the emission of dust (solid particles) and gases: nitrogen oxides (NO_x), sulphur dioxide (SO₂), volatile organic compounds (VOC), generating: health loss costs, material losses, crop losses, ecosystem losses;
- noise pollution costs connected with the emission of acoustic waves the intensity and frequency of which causes a nuisance to people and to the environment (reduced satisfaction from free time activities, discomfort during resting, sleep disorders, hearing loss, stress, hormonal changes);
- costs of climate changes caused by the emission of transport greenhouse gases such as: carbon dioxide (CO₂), dinitrogen monoxide (N₂O), methane (CH₄);
- other costs (landscape transformations, water pollution, soil pollution), which are usually neglected since they are difficult to estimate.

In the case of the considered external costs of rail transport, the operational parameters having a bearing on the level of such costs generated by this branch of transport need to be identified and highlighted.

Determinants of external costs in rail transport

Prior to estimating the scale of external costs in rail transport the identifiable operational parameters should be enumerated. These are [3]:

- train traffic organization,
- the (average) commercial travelling speed,
- the maximum speed,
- the train acceleration and braking frequency,
- the length of the distances between stops,
- the type and load capacity of the rail cars,
- the length of the trains,
- the geographic location of the route (the size and number of high grounds and curves, the length of wooded route sections, the length of the route low ambient temperature and snowy period),
- the technical condition of the rail route,
- the length of the route in urban and non-urban areas,
- the distance of the route from settlements,
- the daily/nightly period in which the route urban distances are covered,
- the number of guarded/unguarded level crossings,
- the possibility of putting up noise absorbing barriers,
- the possibility of fencing off the route and building grade-separated wildlife crossings.

The main operational parameters in electric-traction freight rail transport are [3]:

- the type of electric traction vehicle,
- the travelling speed,
- the distance between stops,
- the size of downgrades and upgrades,
- the local traffic density (important for energy recuperation during braking),
- the ambient temperature,
- the parameters of the power plant/system from which electricity is drawn.

Rail transport electricity demand and generation

An energywise optimal trainset is considered to be such the weight of which is maximum (for a given route, timetable and locomotive) at a minimum number of axles (the maximum allowable axle set load).

Assuming the average values of the parameters (locomotive efficiency – 0.9, average vehicle resistance – 30 kN/t, flat track and 10% starting and braking losses), the average specific electric energy consumption for a freight train is assumed to be $E=10\text{Wh/tkm}$ [3].

The electricity generation problem for rail transport needs is limited here to the Lower Silesian Province and the Opole Province.

The Opole Power Plant is assumed as the electricity supplier. The Plant's power generation efficiency in 2010 amounted to 38.6% [7].

The electricity drawn by the receivers (taking into account

the auxiliaries and the transmission and transformation losses) amounts to 81.8% of the generated power [4].

The resultant electric locomotive power supply efficiency as the product of the power generation efficiency value of 38.6% and the transmission value of 81.8% amounts to 31.6%.

Taking into account specific electricity consumption $E=10\text{Wh/tkm}$ and an electricity generation and transmission efficiency of 31.6%, the specific power output (for the needs of rail transport) amounts to 31.7 Wh/tkm.

For comparison, the carriage work and energy and fuel consumption indices averaged for the European countries (in 2000) were at the level of 42,6% [2].

In trainset formation practice there are the following two cases in which freight movement optimization is possible:

- having a given series locomotive one should form such a trainset (for a specified route and timetable) which will consume a minimum amount of energy,
- for a formed trainset (the weight and types of cars are given) one should select such a locomotive which in the given (carriage work performance) conditions will consume the least amount of energy.

The level of energy consumption for carrying out transport tasks is connected with the levels of greenhouse gases emission and exhaust gas toxic components emission.

Environmental load resulting from electricity generation

The environmental load resulting from electricity generation is illustrated by the data provided by the Opole Power Plant, in the form of a power utility ecological balance [7], shown in table 1.

Table 1.

Unit emissions contributing to Opole Power Plant electricity generation environmental load in 2010.

No.	Pollution	Emission rate, kg/MWh
1.	CO ₂	875
2.	SO ₂	0.63
3.	NO _x	1.36
4.	CO	0.10
5.	Dust	0.05

SOURCES: PGE Elektrownia Opole SA; Environmental Declaration acc. to EMAS regulation [7].

Environmental charges

The regulations relating to environmental charges are contained in the Environmental Law.

Environmental charges are incurred for:

1. discharging gases or dusts into the air,
2. discharging sewage into waters or soil,
3. water abstraction,
4. waste storage.

The amounts of the charges, with regard to the aspect considered here, depend on the amount and kind of gases or dusts discharged into the air.

The unit charge rates for selected gases and dusts discharged into the air in 2014 were published in the Environment Minister Announcement of 13 August 2013 con-

cerning the environmental charge rates for 2014 [6]. The rates selected for calculations are shown in table 2.

Table 2.

Unit charge rates for selected gases or dusts discharged into air in 2014.

No. in tab. G	Kinds of gases or dusts	Unit rate
22	Sulphur dioxide	0.53 pln/kg
23	Carbon dioxide	0.29 pln/Mg
58	Carbon monoxide	0.11 pln/kg
59	Nitrogen oxides (in terms of NO ₂)	0.53 pln/kg
53	Coal-graphite dusts, soot	1.46 pln/kg

SOURCE: Environment Minister Announcement of 13 August 2013 concerning environmental charge rates for 2014 [6; Annex 2 tab. G].

The Environmental Law (art. 284.1) states that the entity which uses the environment determines on its own the amount of the charge due and pays it into the bank account of proper Province Marshal's Office. Therefore the air pollution cost element connected with dust and gas emission, defined under external costs, should be excluded from this category of costs.

The Act of 16.11. 2012 (Law Gazette item 1342) concerning the reduction of some administrative charges in the economy introduces amendments into the Environmental Law (Law Gazette, 2008, No. 25, item 150, with later amendments) relating to environment use reporting. Since 2013 environment using entities pay environmental charges and submit schedules containing the information and the data used to determine the amounts of the charges to the Province Marshal once a year. Also since 2013 no environmental charges the total annual amount of which payable into the account of Province Marshal's Office does not exceed 800 pln are paid.

Hence there is a need to estimate the above costs through a case study.

Case study

In order to estimate environment use costs a case study of aggregate transport by rail was carried out. The aggregate related parameters (obtained from an aggregate producer having the aggregate transported) were as follows:

- aggregate transported on the A-B line,
- distance – 420 km,
- the weight of the aggregate: 1624 t,
- railway charges: 72953 pln,
- carriage work: 682080 tkm.

On the basis of the above numerical data and the adopted energy indicator (31.7 Wh/tkm) the level of electricity production for the analyzed line was calculated to amount to 21.6 MWh.

The emissions burdening the Opole Power Plant electricity generation environment, connected with the fulfilment of the order for the transport of aggregate, are shown in table 3. The charges due for gas and dust emissions into the atmosphere of the Opole Power Plant electricity generation environment, being the product of the emission amount and the unit rates, in the considered case of aggregate transport are shown in table 4.

Table 3.

Emissions burdening Opole Power Plant electricity generation environment for considered aggregate transport line.

Kind of emission	Weight, kg
sulphur dioxide	13.61
carbon dioxide	18900
carbon monoxide	2.16
nitrogen oxides (in terms of NO ₂)	29.38
dusts	1.08

SOURCE: own study.

Table 4.

Charges due for gas and dust emissions into atmosphere of Opole Power Plant electricity generation environment in considered case.

Charges due for gas and dust emissions for analyzed aggregate transport line, pln	
for CO ₂ emission	5.48
for SO ₂ emission	7.21
for NO _x emission	14.98
for CO emission	0.24
for dust emission	1.58
TOTAL	29.49

SOURCE: own study based on [7].

The share of the emission costs in the transport costs (for the analyzed line) can be calculated by dividing the environmental charge by the transport cost:

$$29.49 / 72953 = 0.0004$$

which corresponds to 0.04%.

Conclusions

As shown above, the percentage of gas and dust emissions to the environment amounts to only a small fraction of the transport costs. It should be recognized that the external costs (connected with gas and dust emissions) are borne by the transport company. This means that the definition of external costs (within the analyzed scope) as costs caused by the means of transport, but not covered by the carrier is imprecise.

The matters relating to environmental charges are regulated by the Environmental Law.

The Environment Minister annually fixes environmental charge rates. ■

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