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Social and Economic Efficiency of Operation Dependent and Independent Traction in Rail Freight

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Abstract

Continual increase of transport mobility has caused a lot of environmental and community problems. Although the railway transport is considered to be the most environmentally friendly type of transport, its share on the EU transport market was reduced. In comparison with 2000, the share of the rail freight transport within modes of transport used in EU decreased in 2012 by 1.3%. Using electric traction leads to the external costs in the freight rail transport 90% lower compared to the road transport. The contribution deals with social costs incurred in the course of operation of the freight rail transport. Social costs include costs borne by the manager of the infrastructure, costs borne by the operators of the freight rail transport and external costs that are passed on to the whole company. The contribution provides with the results of the survey focused on the comparison of social costs incurred by the use of dependent and independent traction.

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Keywords: economic benefits; internal costs; railway transport; social costs; sustainable mobility; traction.

1. Introduction

In general, transport is considered to be the industry with “derived” demand depending on number of social and economic factors. The supply and demand in the field of transport is influenced for example by the lifestyle, land planning, organization of the production, availability and quality of the transport infrastructure, integration and

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international specialization and the like. This demand should be met with respect of all of the principles of sustainable mobility.

In general, railway transport is considered to belong among the modes of transports with lowest negative impact on the environment and society. However, when researching the air pollution and climate change, there is a huge difference between electric and diesel traction. The examination of the profitability of electric and diesel traction must be carried out from the point of view of socioeconomic efficiency, i.e. it is necessary to consider all costs and benefits of the rail transport.

2. Economic and social benefits of railway transport

Railway transport can provide the society with various advantages which may not imply an immediate direct financial return. This often involves multiplication effects, for example higher use of railway transport means lower congestions, leading to decreased need for new highways and moreover, the safety of the transport augments and environmental impacts are reduced, health condition of the population is improved and the like. The construction of the new tracks or modernization of the old ones generate work opportunities similar to those relating to construction of speedways, the industry related to the railway is on the rise and the direct or indirect employment rate is growing.

The benefits generated by more frequent use of railway transport have impact not only on the very railway companies, but also on the population and government expenditures. They can be summarized as follows:

- energy savings,
- reduction of freight costs,
- reduction of the land occupied by transport communications,
- increasing the land value,
- reducing the congestions on road communications,
- time savings resulting from reduction of the congestions,
- increase of the industrial production linked to railway transport thus also leading to the augmented employment rate,
- reduction of water and soil pollution,
- abatement of public health nuisance caused by noise,
- reduction of greenhouse gas emissions and reduction of the emissions causing local air pollution,
- improving transport safety etc...

It is important that the railway companies themselves could identify their advantages over other modes of transportation and promote them in a trustworthy way. In order to do so, it is necessary to:

- *To know their own costs.* Assessing construction costs, or rather modernization of the railways is relatively simple, but it is quite demanding to figure out the total operating costs and to change them proportionally depending on increasing or decreasing performance. Therefore it is important to have very precise system of accounting considering the responsibility and relation between individual organizational units in the railway company.
- *Understand the competition.* To know what effects will ensue from any improvement of the services, perhaps even lowering the price for competition and to know the critical value. It requires a special knowledge of competitive modes of transport including infrastructure of their costs and pricing strategy.
- *To identify the impact on the environment.* Railway transport offers a number of advantages in the field of environment; however, it is necessary to evaluate their economic influence that should involve all aspects. This influence is very hard to quantify, as a matter of fact, there is a number of studies providing different results. It is important to choose at least those whose value is demonstrably proven and acceptable by the society.
- *To identify the business development.* It is necessary to know the potential of the industrial and business development that could be an outcome of a more effective railway transport. At the same time, it is important to consider all multiplication effects, as well as the fact, that the business activities could develop positively also for other modes of transport.

- *To elaborate and give reasons for financial and economic analysis.* It is necessary to elaborate financial and economic analysis in its complex form. When obtaining contributions from public funds it is important to maintain good communication between railway companies and relevant ministry.
- *To assign the personnel intended for communication with government.* Business development, political arguments and advertising require knowledge and a specialized team of employees including lobbyists who know they work for the government. The survey in some bigger railway companies who successfully argued for economic contribution shows that these companies have built up a team of at least 20 people for such activities. Staff costs can be negligible compared to the potential contributions (International Railway Gazette 2008).

An effective and prosperous railway can bring a number of advantages not only for the area it traverses, but also for other regions. These monetary benefits could be transferred to the railway and in the end they could augment the financial independence of the railways, improve offered services and eventually lower the tariffs. (Meško et al. 2013).

3. Social costs of railway transport

Social costs of rail transport can be divided into three basic groups:

- costs of the infrastructure manager,
- costs of the operators of railway transport,
- external costs.

3.1. Costs of the infrastructure manager

Costs of the infrastructure manager involve all costs related to providing the operation of railway infrastructure. As in most EU countries, this is the matter of so called natural monopoly, considerable part of these costs is being reimbursed from the state budget and only a small percentage (which is in Slovakia 20% for example) is reimbursed by the users of railway infrastructure.

If we want to compare the costs of the dependent and independent traction, it is sufficient to take to consideration costs of the infrastructure manager for complex provision of the operational efficiency of the traction equipment. These include the following:

- initial costs for the realization of electrification,
- costs for servicing and maintenance of the traction lines,
- costs of substations and posts,
- costs of heavy-current equipment.

3.2. Costs of the operators of railway transport

The operators of railway transport most often divide the costs into direct and indirect ones. Direct costs include in particular costs of traction fuel and energy, direct material costs, direct wages, total costs of the vehicles, fee for the use of railway infrastructure and all other costs directly related to the realization of the transport. Indirect costs include operating costs and administrative expenses.

Costs of the operators of railway transport changing depending on the type of traction include:

- The costs of the total consumption of the electricity (or diesel oil),
- The fees for using railway infrastructure,
- Write – offs,
- Periodic maintenance (either depending on the period of vehicle use or the lifetime mileage of the vehicle),
- Scheduled maintenance (regular technical inspections, defect controls, etc.),
- Emergency repair and maintenance (in the case of vehicle damage in accidents),
- Regular repair and maintenance (e.g. cleaning and disinfection of the vehicles).

3.3. External costs

Although railway transport is regarded as one of the ecological types of transport, it has a negative impact on the environment and society mainly in these areas:

- Noise – health nuisance caused by noise inflicting population in the areas close to the railroads and with increasing speed (if the speed of the train grows by 25%, the noise level rises by 3dB).
- Air pollution – external costs are caused above all by diesel traction and the process of production of the electric energy in individual countries is difficult as well.
- Vibrations – close to the railroads they can cause damages to buildings.
- Accidents – only the accidents caused by the users of railway transport should be listed here; the railway crossing accidents should be excluded (road user is almost always at fault).

All these costs occur during using of diesel as well as electric traction. In order to evaluate them, it is possible to make use of the study "Handbook on estimation of external costs in the transport sector". Quantification of the externalities for the freight transport according to this methodology is stated in Table 1.

Table 1. External costs of the rail freight transport using average loading factor (Maibach et al. 2008).

Externalities	Mode, time	Electric traction	Diesel traction
Noise	Urban, day	0.12	0.12
	Urban, night	0.49	0.49
	Interurban, day	0.11	0.11
	Interurban, night	0.19	0.19
Accident	Urban/Interurban	0.02	0.02
Air pollution	Urban	0.00	1.05
	Interurban	0.00	0.88
Climate change	Urban/Interurban	0.00	0.08
Up- and down-stream processes	Urban/Interurban	0.13	0.10
Nature and Landscape	Urban/Interurban	0.00	0.02
Soil & water poll.	Urban/Interurban	0.02	0.02

The stated specific external costs within given methodology were calculated by average occupancy of freight train – 348 tons.

4. Modeling of expediency of use of the dependent and independent traction from the point of view of the social costs based on situation in SR

When examining the efficiency of the use of dependent or independent traction from the point of view of the social costs, we applied the methods of the final and budget calculation. We used the final calculations by quantification of the costs of infrastructure manager; preliminary calculations were used by estimation of the costs of operator of the rail freight transport and external costs.

4.1. Quantification of the costs of infrastructure manager

The manager of the railway infrastructure in SR is represented by ŽSR (Railways of the Slovak Republic). The tracks of ŽSR are electrified by two electric traction systems, namely in DC traction system in the voltage range 3000 V, 1500 V and 600 V and AC traction system in the voltage range 25 000 V/50Hz, 15 000 V/16,7 Hz. In order to supply individual traction lines with electric current, it is necessary to have required transformation stations, substations and posts that are a part of the electrical equipment administered by ŽSR.

The overall length of the operated tracks in ŽSR administration is 3 595 km, where the overall length of electrified tracks is 1 589 km (762 km – AC traction network, 827 km – DC traction network).

Table 2 presents all costs relating to provision, administration, operation and maintenance of the electrical equipment for both voltage networks administered by ŽSR. Costs are stated in mn. €.

Table 2. Costs of electrical equipment in administration of ŽSR (Mitas 2014a).

Name of equipment	Write-offs	Administration, maintenance, operation	TOTAL
Traction mains JTPS	4.770	5.166	9.936
Substations and posts JTPS	2.075	4.053	6.128
Total JTPS	6.845	9.219	16.064
Traction mains STPS	4.413	3.747	8.16
Substations and posts STPS	1.163	1.018	2.181
Total STPS	5.576	4.765	10.341
Heavy-current equipments	0.850	1.319	2.169
Total for electrical. equipment	13.271	14.853	28.574

Quantification of individual costs requires the knowledge of dependence of the costs on transport performance and realized transport performance for the given period. The development of the traffic performances of the electric traction during 2010–2013 is stated in Table 3.

Table 3. Traffic performances of the electric traction (Mitas 2014b).

Year	Traffic performance in thousand train-km		Traffic performance in mn. GTK	
	Passenger transport	Freight transport	Passenger transport	Freight transport
2010	20 530.63	12 396.87	7 066.33	15 979.59
2011	18 854.56	10 153.09	6 959.05	14 884.01
2012	18 557.93	9 678.21	6 788.33	14 090.05
2013	18 766.09	10 155.61	6 819.09	14 430.23

In 2013 the costs of electrical equipment in administration of ŽSR amounted to 1.345 EUR per thousand GTK. Maximum reimbursement for the use of electric power supply for the supply of traction current is set based on Order no. 3/2010, Railway Regulatory Authority in amount of 0.260 €/1000 hrtkm. As follows from the above quoted facts, state grants are needed for the provision of operation of electrical equipments designed for supply of the traction current and they should reach 80, 67% share of the total costs of these equipments.

4.2. Costs of operator of freight transport

In case of the economic evaluation of dependent and independent traction, with regards to an extensive comparison and within all of the recorded performances on the ŽSR tracks, we chose model trains with parameters stated in Table 4. The use of road-rail vehicle with independent traction is supposed only for unelectrified tracks.

Table 4. Parameters of model trains.

Train	Train weight [gross tons]	Needed number of locomotive stated for individual versions based on traction characteristics			
		Series 131	Series 363	Series 756	Series 751
I. version	1600	1	2	3	3
II. version	800	1	1	2	2

By these model trains we assume maximum track grade 16‰, type of the traction resistance T, and length of the transport session 350 km. The quantification of total costs for individual versions is based on these assumptions:

- average costs of locomotives:
  - HDV 131 – 0.92 EUR per loco km;
  - HDV 363 – 0.65 EUR per loco km;
  - HDV 756 – 1.14 EUR per loco km;
  - HDV 751 – 2.15 EUR per loco km.
- average use of traction fuel and energy:
  - HDV 131 – 17.8 kWh/K. GTK;
  - HDV 363 – 19.2 kWh/K. GTK;
  - HDV 756 – 5.9 l/K. GTK;
  - HDV 751 – 6.7 l/K. GTK (Michalčíková 2014).
- average costs:
  - electric energy – 0.15 EUR per kWh without VAT;
  - diesel – 1.076 EUR per l without VAT.

Values of consumption, costs for reparation and maintenance costs stated in Table 7 are determined based on average values incurred in the course of operation of individual HDW rows on the train route, with the cargo carrier ZSSK CARGO. Price for the traction current is an average price charged by Railway Energetics Slovakia within tracks of ŽSR. Price for diesel fuel is stated as an average price for the whole area of Slovak republic.

Charges for the use of electric power supply for the supply of traction current can be determined based on formula: (Slovak Republic. Railway Regulatory Authority, 2010)

$$U_{tp1} = 1/1000 . Q . L_e . U_e ,$$

where: U_{tp1} – total reimbursement for the use of electric power supply for the supply of traction current for respective train; Q – overall gross weight of the train in tons; L_e – length of the utilized electrified track sections in kilometers rounded to three decimal places; U_e – maximum reimbursement in Euros for thousand GTK of utilized electric power supply equipment.

Quantification of the costs of the operator of freight transport for individual tractions and model trains was realized via method of budget (preliminary) calculation. Final values are stated in table 5. Within quantification, we considered only those cost items that are variable depending on the use of traction; these are the following:

- A – costs of energy,

Table 5. Budget (preliminary) calculation of the costs of individual tractions.

Cost Item	Version	Costs in EUR without VAT			
		Dependent traction		Independent traction	
		Loco 131	Loco 363	Loco 756	Loco 751
A	I.	1 495.2	1 612.8	3 555.10	4 037.15
	II.	747.6	806.4	1 777.55	2 018.58
B	I.	322	455	1197	2 257.5
	II.	322	227.5	798	1 505
C	I.	145.6	145.6	0	0
	II.	72.8	72.8	0	0
D	I.	0	0	5.25	5.25
	II.	0	0	3.5	3.5
∑	I.	1 962.8	2 213.4	4 757.35	6 299.9
	II.	1 142.4	1 106.7	2 579.05	3 527.08

- B – costs of locomotives,
- C – fee for the use of the electric power supply,
- D – costs for change and supply of motor oil.

Based on calculation of the costs of individual tractions for model trains, it is possible to quantify a significant saving of the costs borne by the carrier within the use of dependent traction. Cost saving is observed within energy consumption, as well as by the costs for locomotives. Lower costs for energy consumption by dependent traction are caused by higher efficiency of electric engines and lower costs of the traction current. Costs for the maintenance of the locomotives of independent traction are higher as the construction of this version of engines is more demanding; they require higher elaborateness and have higher consumption of spare parts – unlike locomotives of dependent traction. As regards to designed model trains, to overcome the grade by the independent traction, it is necessary to furnish more locomotives based on weight tables of the drawn vehicles, which also results in higher costs for locomotives.

4.3. Quantification of external costs

We performed the quantification of external costs based on evaluation of the externalities in the study "Handbook on estimation of external costs in the transport sector" stated in Table 1. As the external costs in this study relate to transport performance, we used the coefficient of the ratio of net ton km against gross ton km according to the data from ZSSK CARGO in the amount 53.99%. With regard to proportional distribution of the operation of freight transport in SR at night and also during the day, we employed average values. The final estimation of the external costs for the examined variants is presented in table 6 and stated in Euros.

A result of application of the values presented in table 6 on the dependent and independent traction we evaluated, we can observe a significant saving of the external costs related to utilization of dependent traction converted to transport performance, in comparison to independent traction.

Table 6. Quantification of external costs.

Externalities	Mode	Variant	Electric traction	Diesel traction
Noise	Urban	I.	263.47	263.47
		II.	131.74	131,7356
	Interurban	I.	129.58	129.58
		II.	64.79	64.79
Accident	Urban/Interurban	I.	17.28	17.28
		II.	8.64	8.64
Air pollution	Urban	I.	0.00	1 295.76
		II.	0.00	647.88
	Interurban	I.	0.00	760.18
		II.	0.00	380.09
Climate change	Urban/Interurban	I.	0.00	69.11
		II.	0.00	34.55
Up- and down-stream processes	Urban/Interurban	I.	112.30	86.38
		II.	56.15	43.19
Nature and Landscape	Urban/Interurban	I.	0.00	17.28
		II.	0.00	8.64
Soil & water poll.	Urban/Interurban	I.	17.28	17.28
		II.	8.64	8.64
Total	Urban/Interurban	I.	539.90	2 656.31
		II.	269.95	1 328.15

5. Results

Within comparison of social costs of dependent and independent traction in view of the conditions in Slovakia, we counted the costs of manager of infrastructure, operators of the transport and external costs. As for the costs of manager of the infrastructure, we considered only those costs that are not reimbursed by the operators of the transport within fee for the utilization of electric power supply equipment for the supply of traction current. The final values are presented in Table 7.

The study based on model examples proved the significance of the use of electric traction in the rail freight transport. Utilization of this traction leads not only to external costs saving, but also to saving internal costs of the transport operators, which leads to raising their competitiveness against road freight transport. The overall social costs are almost twice as big when using diesel traction in comparison to the use of electric traction.

Table 7. Quantification of social costs for model trains.

Costs	Variant	Dependent traction		Independent traction	
		HDV 131	HDV 363	HDV 756	HDV 751
Infrastructure manager	I.	489.7	489.7	0.0	0.0
	II.	244.9	244.9	0.0	0.0
Operator of the transport	I.	1 962.8	2 213.4	4 757.4	6 299.9
	II.	1 142.4	1 106.7	2 579.1	3 527.1
External costs	I.	539.9	539.9	2656.3	2 656.3
	II.	270.0	270.0	1 328.2	1 328.2
Total	I.	2 992.4	3 243.0	7 413.7	8 956.2
	II.	1 657.2	1 621.5	3 907.2	4 855.2

6. Conclusions

1. The share of transport performances of electric traction is almost 60% in passenger traffic and more than 70% in freight traffic on the network ŽSR. Despite the fact revenues of the use of electric power supply for the supply of traction cover only 20% of total costs of this equipment.
2. Rail freight transport realized via dependent traction results in significant saving of costs borne directly by the carrier, in comparison to independent traction. We calculated the cost for eight model trains with different loading schemes. Saving of cost by using electric traction was more than double compared to diesel traction. By realization of the transport via dependent traction, there is also significantly smaller impact on the environment, particularly in terms of
3. emissions of pollutants. Although operating the equipments serving for provision of traction current increases the costs for the infrastructure manager that are not covered by sales, it is necessary to increase the share of electrified tracks regarding their expediency from the point of view of total costs of the company.

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