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Influence of Railway Wagon Types for Intermodal Transport to Variable Costs

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Abstract- Presently variable cost has an irreplaceable role in process of choosing the wagons for intermodal transport in specifically transportation relation. The paper deals with comparing the cost of railway infrastructure and other variable costs such as costs for wagons, locomotives, locomotion drivers and energy. Here is described the system of charging for using the railway infrastructure in the EU and Slovak republic. The article gives the model of the quantification of the variable cost using normal costing system. The calculation has been made for the wagons with different technical parameters and different loading schemes.

Keywords**:** charging schemes, loading schemes**,** railway infrastructure**,** variable costs

1. Introduction

"Transport is fundament of our economy and society. Transport enables economic growth and job creation: it must be sustainable in the light of the new challenges we face. The future prosperity of our continent will depend on the ability of all of its regions to remain fully and competitively integrated in the world economy. Efficient transport is vital in making this happen." (Web-1)

One of the main objectives of the European transport policy is to increase the share of rail freight on the transport market. This objective can be achieved only by effective combination of road, rail and eventually water transport. Combined transport must provide quality and competitive price of services. Most carriers are decided on the basis of the price at the moment. Currently have many intermodal transport carriers demand for quality railroad wagons which allowing efficient transport of containers. One of the major item of transportation costs are charges for transport infrastructure. Therefore, it is important to reduce the proportion of the tare of the wagon to the weight of the transported container what simultaneously allow the transport of more containers per train.

2. Methods

"A railway services involves using a large number of factor services, many of these being highly specific and each with its own physical lifespan. When it comes to considering line closures, the essential questions revolve around deciding exactly which costs are fixed." (Button, 2010)

Variable cost can be calculated by using normal costing system. The main principle of this method is to calculate single cost element by multiplication appropriate norm and cost rate. There is necessary to calculate with comparable unit of the cost.

2. 1. Variable Costs

We will calculate variable costs of the train with predetermined technical parameters (norm of train load and norm of train length) using different loading schemes (Dolinayová, 2012).

Total variable costs to train can be following:

- Spending on wagons;
- Spending on locomotive;
- Costs of labour - driver;
- Energy costs;
- Costs of using railway infrastructure.
- Costs for wagons included:
- Capital costs;
- Maintenance costs;
- Insurance.

By using normal costing system we can write formula:

$$C_W = \sum wkm * R_{wkm} \qquad R_{wkm} = \frac{TC_w}{Tkm_W} \tag{1}$$

Where:
C_w – costs for wagons;
wkm – wagons kilometres;
R_{wkm} – rate for unit wagon kilometres;
TC_w – total costs of wagon per year;
Tkm_w – total kilometres of loaded wagon per year.

Costs for locomotive included:

- Capital costs;
- Maintenance costs;
- Insurance.

$$C_L = \sum Lkm * R_{Lkm} \qquad R_{Lkm} = \frac{TC_L}{Tkm_L} \tag{2}$$

Where:
C_L – costs for locomotive;
L_{km} – locomotive kilometres;
R_{Lkm} – rate for locomotive kilometres;
TC_L– total costs of locomotive per year;
Tkm_L – total kilometres of locomotive per year.

Costs for locomotion driver included:

- Direct total labour costs;
- Deductions for employee and employer;
- Statutory social costs;
- Indirect labour costs (staff training, uniform, travel costs…)

$$C_P = \sum th * R_P \qquad R_P = \frac{TC_P}{WT} \tag{3}$$

Where:
C_P – costs for driver;

R_P – rate for one working hour in a train;
TCP_L– total costs for driver per year;
WT – total working time per year.

Energy costs can write by formula:

$$C_E = E_C * R_E \quad (4)$$

Where:
C_E – energy consumption;
R_E – price for energy.

2. 2. System of Rail Infrastructure Charging

Railway infrastructure is a monopoly in most of the EU Member States. In order to render railway transport efficient and competitive with others transport modes of transport, manager of infrastructure have to provide infrastructure capacity and services related with transport operation for all railway operators in a way that excludes any extraordinary benefits for some railway companies. System of rail infrastructure charging in the EU has base in Directive 2012/34/EU of the European Parliament and of the Council. Basic charges are divided into two parts - charges for the use of railway infrastructure (minimum access package) and for use of service facilities.

The minimum access package have to contain:

- Processing applications for railway infrastructure capacity;
- The right to utilise capacity which is granted;
- Use of the railway infrastructure, including track points and junctions;
- Train management including signalling, safety system, dispatching and the communication system and provision of information on train movement;
- Use of electrical supply equipment for traction energy, where available;
- All other information required to implement or operate the service for which capacity has been granted. (web-2)

Access, including track access, have to be given to the following services facilities, when they exist and to the services supplied by these facilities: p

- Passenger stations, their buildings and other facilities, including travel information display and suitable location for ticketing services;
- Freight terminals;
- Marshalling yards and train formation facilities, including shunting facilities;
- Storage sidings;
- Maintenance facilities, with the exception of heavy maintenance facilities dedicated to high-speed trains or to other types of rolling stock requiring specific facilities;
- Other technical facilities, including cleaning and washing facilities;
- Maritime and inland port facilities which are linked to rail activities;
- Relief facilities;
- Refuelling facilities and supply of fuel in these facilities, charges for which shall be shown on the invoices separately. (web-2)

The manager of railway infrastructure in the Slovak Republic are Railways of Slovak Republic (ZSR). The charges for access to rail infrastructure are specified in the Decree No. 3/2010, issued by the Office of Rail Regulation (RRA). This regulation recently changed the maximum payment for access to

rail infrastructure into the minimum access package (U_{mp}), track access to service facilities (U_{tp}) and track access to service facilities with extra charges for extra services.

The total amount of payments for access to the railway infrastructure is calculated as:

$$U_c = U_{mp} + U_{tp} \quad (5)$$

Charging scheme for minimum access package have to contain charges for ordering and allocation of capacity, charges for managing and organizing of transport and charges for ensuring serviceability of railway infrastructure. Maximum charges for minimum access package for passenger transport and freight shall include economically eligible costs of railway infrastructure associated with the provision of management and organization of transport on railway infrastructure, railway infrastructure services and operation in accordance with Act on Railways.

Calculation of total reimbursement for the minimum access package for the relevant train is determined according to the following formula, which consists of fee for ordering and allocation of capacity, fee for managing and organizing transport and fee for ensuring the operability of the railway infrastructure:

$$U_{mp} = \sum_{i=1}^{6} U_{1i} * L_i + \sum_{i=1}^{6} U_{2i} * L_i + \frac{1}{1000} * \sum_{i=1}^{6} U_{3i} * Q_i * L_i * k_e \quad (6)$$

Where:

U_{mp} – total reimbursement for using of railway infrastructure;

U_{1i} – maximum reimbursement for ordering and allocation of capacity;

U_{2i} – maximum reimbursement for managing and organizing transport;

U_{3i} – maximum reimbursement for ensuring the operability of the railway infrastructure;

L_i – total length track of competent category between transport single points in kilometers;

Q_i – total gross train weight rounded to whole tonnes;

k_e – coefficient which takes into account the train which use the vehicle of diesel traction on electrified tracks, whose amount is 1,2, amount of the coefficient for the others train is 1,0.

The maximum reimbursement for the individual acts are determined according table 1 on basis relevant line category, which is processed according to Decree no. 3/2010 - about determining the charges for access to the railway infrastructure.

Table 1. Maximum price without VAT for individual acts - Slovak Republic

Track category	Maximum reimbursement for ordering and allocation of the capacity	Maximum reimbursement for managing and organizing the transport	Maximum reimbursement for ensuring the operability of the railway infrastructure
	U_{1i} in €/train kilometers without VAT	U_{2i} in €/train kilometers without VAT	U_{3i} in €/thousands of gross ton kilometers without VAT
1.	0.0207	0.958	1.311
2.	0.0190	0.881	1.261
3.	0.0188	0.871	1.243
4.	0.0160	0.742	1.064
5.	0.0141	0.651	0.934
6.	0.0096	0.445	0.649

Source: Web-3

Charges of access to service facilities shall be different for every category of service facilities based on type of provided services. Maximum charges for access to service facilities within passenger transport and freight shall comprise economically eligible costs connected with services as follows:

- Use of traction electrical supply equipment, or electrical equipment for preheat of the trains, if available
- Use of passenger stations, their buildings and facilities
- Use of marshalling yards and train formation facilities or freight terminals and siding tracks (web-4)

Calculation of total reimbursement for access to service facilities is determined according to following formula, which consists of fee for using an electrical supply and fee from train composition of freight transport.

$$U_{tp} = \frac{1}{1000} * Q * L_e * U_e + \sum_{j=A}^{D} P_{Pj} * U_{Nj} \quad (7)$$

Where:
Q – Total gross weight of train harnessed on electrified track, rounded to the whole ton;
L_e – Length of used electrified stretch in kilometers;
U_e – Maximum reimbursement in €/thousands of gross ton kilometers of used electrical supply;
P_{Pj} – The number of train access according to respective category of transport point for trains of freight;
U_{Nj} – Maximum reimbursement in € for access of trains of freight transport.
The table 2 shows the charges for access to service equipment.

Table 2. Maximum prices without VAT for individual acts – Slovak republic

Maximum reimbursement for using electric equipment for supply of traction	
U_E in €/thousands gross ton kilometers without VAT	
0.26	
Maximum reimbursement for access to the marshalling yard and equipment which are used for train formation and also for access to loading terminals which are owned or administered by regulatory subject.	
Category of transport points for trains freight transport	U_{Nj} in € without VAT
$A_{ND\ (ND = freight)}$	56.537
B_{ND}	23.907
C_{ND}	15.291
D_{ND}	0.000

Source: Web-3

The fee for minimum access package must be paid by each railway operator. Infrastructure manager provides the basic services, but supplementary and ancillary services are under unregulated prices for railway operators. The tariffs for services provided above the framework included in the charge for the use of infrastructure shall be determined by the service provider when signing the contract.

3. Application

We show practice comparison total variable costs for four types of container wagons with different technical characteristics of various train configuration. Table 3 shows technical parameters of these wagons.

Table 3. Intermodal container wagons – technical parameters

Type of wagon		Sggmrss 90'	Sgnss	Lgs	VEL wagon
Axles/wagon	*number*	6	4	2	4
Total length	*m*	29.6	19.74	14.02	25.8
Loading length	*m*	27.6	18.5	12.78	24.5
Tare weight/wagon	*tons*	29.0	19.8	10.8	24.0
Max gross weight/wagon	*tons*	106.0	70.2	29.2	90.0
Number of TEUs per wagon	*number*	4	3	2	4

Source: Processed by Catalogue of freight wagons, ZSSK Cargo and Materials of VEL-Wagon Project

3. 1. Comparison Total Variable Costs

Calculation variable costs was realized in the conditions of Slovakia. We calculated the cost per TEU in trains with equivalent capacity for different wagons (train norms: maximum length 600 m and maximum weight 1800 gross tonnes). Table 4 shows unit costs (per TEU) of railway infrastructure by types of wagons.

Table 4. Unit costs of railway infrastructure at distance 300 km

Type of wagon	Sggmrss 90'	Sgnss	Lgs	VEL wagon
Number of wagon/train (by norm of weight)	15	21	33	16
Number of wagon/train (by norm of length)	19	29	40	22
Number of wagon/train real	15	21	33	16
Number of TEU/train	60	63	66	64
U_{1i}	6.21	6.21	6.21	6.21
U_{2i}	287.4	287.4	287.4	287.4
U_{3i}	674.51	690.56	690.79	685.92
U_E	133.77	136.95	137.00	136.03
U_{Nj}	113.07	113.07	113.07	113.07
Total infrastructure costs	1214.96	1234.19	1234.48	1228.63
Unit infrastructure costs €/TEU	**20.25**	**19.59**	**18.70**	**19.20**

Fee for using the railway infrastructure is a significant item of direct costs of railway undertaking. Considering to dependence on train kilometers and gross ton kilometers is mainly in railway freight transport with using the modern wagons possible decrease the costs.

Figure 1 shows the comparison of unit variable cost per types of wagons according to distance.

As can be seen in Figure 1. VEL wagon is more efficient than other type wagons. The total variable costs/TEU VEL wagon is 9 % lower than Sggmrss 90' and 13 % lower than Lgs. Unit variable costs VEL wagon is comparable with Sgnss wagon because we use optimal loading scheme (one container ISO 1A and one container ISO 1C).

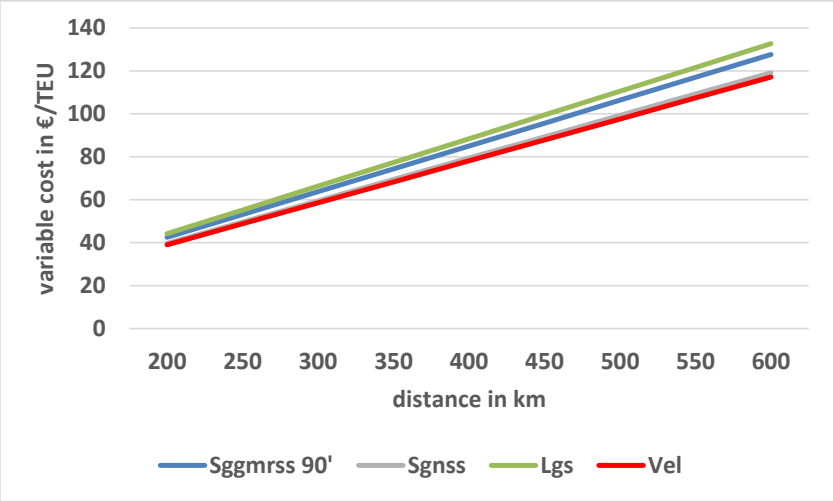

Fig. 1.Variable costs – different distance

3. 2. Variable Costs with Different Loading Schemes

The calculation have been done in the maximum number of wagons with respect to minimum of maximum train length (600 m incl. locomotive) and maximum train weight (1 800 gross tonnes excl. locomotive). Different loading schemes are mix of 20 ft and 40 ft containers in the train. The calculation have been done for a 400 km distance in Slovakia using five loading schemes. The result is shown in figure 2.

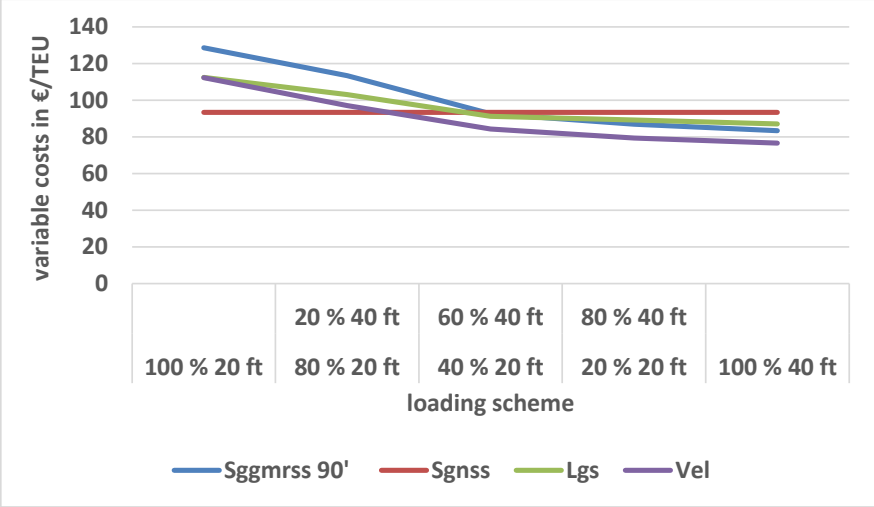

Fig. 2. Variable costs – different loading schemes

Comparison in figure 2 shows high cost differences between different loading schemes. Here is evident that unit variable cost is lower the more 40 ft containers expect Sgnss wagon. In this wagon is possible to load two 20 ft containers or one 20ft container with one 40 ft container or only one 40 ft container. The cost for Sggmrss 90' and VEL wagon decrease with rising volume of 40 ft containers, because on these wagons is possible to load two 40 ft containers or four 20 ft containers.The limiting factor was almost for all loading schemes maximum train length.

4. Conclusion

By using modern wagons for intermodal transport we can significantly reduce unit cost for transporting TEU. This could lead to increase market share of the intermodal and rail transport. The EU transport policy and many others documents which deal with the transport system indicates that it is necessary to ensure the sustainable development of rail freight. Increased use of intermodal and rail transport can bring many benefits to society that do not bring direct immediate financial return. Often there bring the multiplier effects, such as greater use of rail in intermodal transport, less traffic congestion, reducing the need for new high-speed communications, while increasing traffic safety, reduce the environmental impact of traffic and improve the health status of the population and so on.

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