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Cost that is directly incurred as a result of operating the train service on the 1520 mm rail with primarily freight transportation

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Abstract

Under the Directive 2012/34/EU (21 November 2012) "the charges for … [rail] infrastructure … shall be set at the cost that is directly incurred as a result of operating the train service". This charging rule is new for Baltic States' railways, where due to the favorable geographic position a full cost application without detalization was possible. Although, a big number of relevant studies on the issue was made in EU, all of them covered only 1435 mm railways with primarily passenger transportation. This study has been made in order to understand the impact of train operating on 1520 mm rail infrastructure with primarily freight transportation.
A gradual model of infrastructure charging process in the Baltic States rail networks has been introduced as a result of this study.

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Keywords: railway costs; charging model; 1520 mm railway

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1. Introduction

Under the Directive 2012/34/EU (21 November 2012) "the charges for … [rail] infrastructure … shall be set at the cost that is directly incurred as a result of operating the train service" (hereinafter – direct costs). According to the Directive's delegation, the European Commission (hereinafter – EC) provided common regulation 2015/909 on the modalities for the calculation of the cost that is directly incurred as a result of operating the train service on 12 June 2015 based on judicial decisions made in Europe in last decade and a number of relevant scientific studies. All of them cover 1435 mm railways with primarily passenger transportation only. However, according to the deliverable D3.8 of *NEAR*[2] international project (2013) and other studies there are sufficient distinctions between maintenance of 1435 mm and 1520 mm railways. For instance, increased maximum axle load on 1520 reduces the intervals between the maintenance works; allowance of longer trains requires longer tracks and platforms in stations, signal spacing. The mechanical signalling of 1520 mm uses signs located on the side of the tracks and staff on a daily basis operate trains. Freight rolling stock spend in stations and hubs 50–60% of total Baltic state crossing time in order to compensate irregularity (Cislov & Khan, 2013) that is not typical for 1435 mm rail network. On the other hand, higher exploitation speed demanded by mostly passenger transportation needs of 1435 mm, requires longer axial distance between tracks, higher track cant and different length of transition curves in the horizontal alignment. The electrified traction system, used on most part by 1435 mm, substantially reduces maintenance cost and service time. The operating of passenger trains is provided mostly on yearly schedule basis. The automatic signalling is implemented with colour-light signals and its messages are directly displayed in the driver's cab. These distinctions ask more for capital and less for exploitation costs. So the calculation of direct costs for 1520 mm rail can be based on the results of 1435 mm studies only to some extent, due to a significant difference in the causation of costs.

This was the reason for the study with the aim "to understand the impact of train operating on 1520 mm rail infrastructure with primarily freight transportation". The conclusion made during the previous study (Hudenko & Ribakova, 2015) was that the construction and exploitation differences noted above should affect the calculation of direct costs on all steps required by EC's implementation act. Unpredictable traffic volume in 1520 affect the result of infrastructure operation, and not necessarily in the same year. If the traffic volume was more than assessed, the operational costs can be equilibrated in longer time (three and more years); otherwise, increasing traffic troubles infrastructure operation and dramatically raises maintenance and renewal works in the future. Therefore rail infrastructure construction, renewal and maintenance requirements and costs are related to forecasted environment circumstances and operating volume and could not be changed in a short run. The simple dividing of costs into eligible and non-eligible costs is not sufficient in 1520 area. It is more preferable to divide costs using Vuuren's (2002) model: sunk costs, fixed costs and variable costs. The impact of trains is clearly not coherent in the different networks and throughout the network too.

This study summarizes conclusions of the previous study and results in introducing of the model of measurement of the costs that are incurred by train operation. The conclusions of the study should be interpreted only in strong connection with charging needs.

2. Methods used

When studying rail data with mathematical methods, it is essential to look into processes substantially. That is the reason of a preliminary analysis of more than 100 Latvian and international (mainly European and Russian) scientific and practical sources. After it was concluded that none of the existing charging systems could be directly transposed to the Baltic State case due to non-analogous circumstances of the Baltic States', the main insights were generalized into propositions given to 15 experts in different rail infrastructure operational fields. The experts were asked to evaluate these propositions in 6-point system, and to provide short explanation of position as well as the recommendations. The questioning was made orally. The results of in-depth examinations were summarized using content analysis.

Based on prior examination results, data for empirical verification was required from Latvian infrastructure manager. The infrastructure manager was able to provide information only for the period 2008.-2014., due to significant changes in accounting principles until this time. Data that describe the technical condition of the railway infrastructure was collected partly from infrastructure manager and partly from network statements. All the above information was grouped in dynamic tables and analysed using a combination of methods. Firstly, data was normalized in order to exclude financial impact – staff and staff related costs by using *Consumer price index*; energy and fuel costs by using average price index; and other costs by using *Production price index*.

There are too many parameters that experts consider needed to be taken into account when modeling unit direct costs. Some of them are interrelated (for instance train km vs vehicle km); therefore, additional econometric expertise (using regression analysis) was made to choose the most appropriate. The data was analyzed for each infrastructure operational field separately due to different causation noted by experts. The strong correlations between costs and performance indicators was not found. However, there was no intention of finding any mathematical optimization models in order to exclude the activities of infrastructure manager. The introduced model is based on hypothetical deductive analysis of existing information and graphical interpretation of data.

3. Results

The implementing regulation allows the usage of bottom-up concepts (modeling of unit direct cost), but explores top-down concept in more detail. That means primary collecting all relevant cost, then excluding non-eligible costs and then charging the remaining part of costs using a cost driver to a concrete train category. This concept is relevant to the methodology structure now used in the Baltic States. Nevertheless, each charging step raises questions due to different charging philosophy in 1520 mm area, peculiarities in definition of maintenance and renewal processes, place of rail infrastructure services, charging accuracy and so on.

Vlasov and Gundarev (2013) generalized four costing principles for charging needs: absorption costing; activity based costing; variable costing; marginal costing. The EC is more favorable to marginal costing due to conclusions of the working groups *UNITE* (2003) and *CATRIN* (2009). However, other researchers' (Verhoef, 2001) recommendations to EC were to use not "social marginal costing", but "social marginal cost based charging". *CER* (2013) is more favorable to average variable costing where the base is a financing amount that is needed for infrastructure manager for providing infrastructure capacity to some predictable traffic volume. European Court adjudgement C-512/10 (81., 82. un 83.p.), when the question of direct cost was examined, stated that "the costs connected with signaling, traffic management, maintenance and repairs may vary, at least partially, depending on traffic and, accordingly, may be considered to be directly incurred as a result of operating the train service".

The choice among cost allocation models more depends on rail infrastructure financing policy than on objectivity. Calvo & d'Ona (2012) have noted such differences in charging policies objectives (for instance – full cost max obtaining in Germany and Great Britain versus lower social costs in Sweden). Absorption methodology, used in Latvia and Russia, is very good for examining internal process, but it does not reflect the quality of rail infrastructure service as well as demand criteria (Khusainov, 2013) which is very handy in rail network that is not supported by state and is working on a commercial base. However, absorption methodology works well only in case if successful business – consumers are able to cover full cost base. In reality, the demand of rail infrastructure service in Latvia has cyclical fluctuations with decreasing trend. That means that a charging body has to modulate the costs base to unpredictable smaller traffic unit number. That arithmetically cause increasing of charges. Therefore, the existing methodology needs changes.

The first step of the direct cost calculation is to assign relevant historical costs. Last tendencies (Marschnig, 2015) in researching rail infrastructure costs show more and more focus on life cycle costs (see. Fig. 2). Many researches and practices (Garnham & Davis, 2008; SERSA, 2011; Czili et al, 2012) have shown that long-term thinking leads to cost reduction in life cycle terms. This costing methodology refrain from *use it or lose it* phenomena (Illie, 2012; Makovšek, 2014), which means that short time planning pushes infrastructure manager to invest all available financing in infrastructure otherwise in the next planning period these recourses would be reduced. Moreover, Lucaci (2013) stressed the dependence of rail infrastructure costs on the coherency of the whole rail system – vehicles, traffic control, constructions and environment. The degradation of one of the elements leads to accelerated degradation of other system parts. Survey of experts accepted all this propositions, except *use it or lose it* for Latvian network. Fig. 1 demonstrates that simple adoption of historical data of previous periods is not correct, due to incoherent distribution of life cycle costs and therefore that should be simulated for future period.

The basis of the simulated data resulted from the measurements of the infrastructure damage and calculation of possible expenses in order to recover target condition (Link & Nilsson, 2005; Newbery, 1988). There is a risk, that infrastructure manager would affect calculations and real level of works done. Works that are not done due to one of or both reasons negatively affect the volume of works in the next period and, therefore, raise life cycle costs (IHHA, 2015; Herrmann, 2014; ACEM, 2011). Even if the infrastructure manager deals fairly, then the unpredictable increase of traffic intensification can simultaneously decrease the volume of work due to shorter possession slots and accumulate additional defects. These factors should be taken into account.

There are also some other factors that should be recognized when simulating direct cost base. Firstly, it is a problem of infrastructure quality, raised in many cases (Sand, 2012; MSŽD, 2015; Macharis & Bernardini, 2015; Tournay, 2008; Link, 2012) and accepted by experts for Latvian case. The requirements of quality differ in European (CENELEC, 1999) and CIS (Zamisljajev et al, 2012) countries and have different philosophy as well. European *RAMS* (van den Breemer et al, 2009) methodology defines qualitative and quantitative indicators for optimization. CIS countries, where infrastructure financing is very limited, explore infrastructure marginal state concept (Andrejev et al, 2014) – the volume of infrastructure maintenance and renewal is estimated by the control of technical parameters. When these parameters are near to critical limit, the maintenance activities are performed without any delay, and if possible in other cases. Requirements to rail *RAMS* become stricter over time (Mahutov, 2014) and those should influence the cost base. It is essential, at least for Latvian case, that quality level have strong connection to safety, whereas safety level has strong connection to traffic volume. For example, signalling operating costs depend on the chosen technology: the minimum (drawn signs and telephone management) for minor lines and sophisticated (automatic locking and computerized management) for intensive lines. Therefore, Latvian experts recommend using of a mixed approach: stated qualitative long-term (life cycle time) planning parameters revised from time to time according to the actual situation.

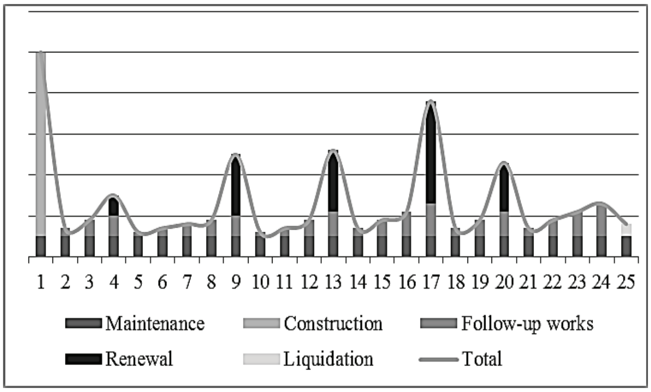

Fig. 1. The distribution of life cycle costs (based on Beltjukov et al (2014)).

Secondly, due to the proposition that wear and tear is not uniform both in different networks and throughout one network, it is essential to make corrections in maintenance and renewal works taking into account concrete places of network where these works are scheduled. For example, places where track changes parameters (track-bridge points, crossing points and so on) static load is three times higher (IHHA, 2015). The outside environment also plays a part in the decision on the level of maintenance: track wrinkles, junctions, clinches and curves cause vibrations and noise and need preventions in inhabited places (Cui et al, 2015).

The second step of the implementation act provides that the non-eligible costs should be excluded from the cost base. EC bases the considerations on the idea that trains impact rail infrastructure. But the common position of experts in Latvia is that rail is an open system where result of train-infrastructure contact depends both on train and infrastructure as well as on other factors like environment, construction quality and traffic control, therefore only very few maintenance and renewal cost positions are considered as not directly incurred due to operating the train service.

IHHA (2015) agree that deformations in infrastructure are related to deviations from ideal wheel-track exploration; consequently, maintaining and renewal are activities that are necessary for returning the system to geometry that is more appropriate. Andrade & Teixeira 2012 well established that wear and tear is proportional to accumulated tonnage, but the concrete proportion is related to wheel-track friction coefficient (IHHA, 2015; Andrade & Teixeira, 2012; Alwahdi et al, 2005). Trainload pressure incurs third part of in-track cables damages (Konevic & Bolonkin, 2012) and provokes electric corrosion and further construction damages (IHHA, 2015; Altinbajev, 2014). Trains generate cyclical fluctuations of ground and therefore affect civil engineering objects (IHHA, 2015; Dowding, 2000) this is particularly dangerous for bridges with a big arch (Podwornaja, 2014).

Only few reasons were extracted as not linked to the train service (Mahutov, 2014): temperature; defects (mostly hidden) of material used, natural corrosion, destruction of construction materials, gravity degradation; natural processes (earthquakes, landslides, water ingress, geological fractures, radiation), human factors (errors of constructors, vandalism), wind. However, late maintenance of non-train invasion cause accelerated degradation incurred by operation of the train service (Lyu et al, 2015; Franklin et al, 2013; Abma, 2010). Latvian experts also confirmed the latter.

It was considered, that exploitation of Vuuren's (2002) model dividing costs into three parts (sunk, fixed and variable costs) is more preferable. Sunk costs cannot be excluded even at zero traffic volume. Fixed costs are costs that ensure the movement of traffic, but they do not vary with the volume of traffic, therefore they need to be optimized to a forecasted traffic volume in given operational circumstances (both required quality and life cycle position). Variable costs are costs that depend on traffic and changes in environmental circumstances and can be described by production function. The results of Beltjukov (2014) study demonstrate (Fig. 2.) that infrastructure defects (and therefore cost base) differ with the intensity of traffic. In case of high intensity the number of defects grows exponentially, that means that the function of variable cost has to have at least three possible scenarios: forecasted traffic, lower traffic and high traffic.

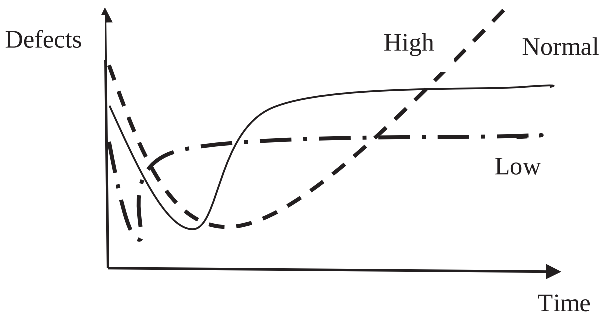

Fig. 2. The dynamics of accumulation of defects in different traffic conditions (based on Beltjukov et al (2014)).

The third step of the implementation act establishes a mechanism of calculation of direct unit cost. The main problem when modulating unit cost are multi-collinearity of the allowed performance indicators (Herry & Sedlacek, 2002; Himanen et al, 2002); lack and invalidity of data (Link, 2004); and choice from short-run and long-run costs (Jansson & Lang 2013; Beltjukov et al, 2014). According to *UIC* (2012) study, most of European countries use simple charging (a charge for train km or tonn km) or cumulative charging (where single component supplied with some compositions of other component for usage of parts of specific infrastructure) and less countries use simple charging with differentiation. Latvian experts choosing parameters for modulation of direct unit costs from the list of those allowed by the implementation act, selected the same parameters that are used at the existing cost allocation system – train category (freight/passenger and traction power), tonn km for track maintenance and renewal and train km for other fields of maintenance and renewal. Most of experts agreed that a range of speed and quality of the contact place are also factors that incur additional costs. Introduction of those parameters may have wide discussions, due to execution of common pool of wagons on the 1520 network.

The fourth step of the calculation of the direct cost is to check the level of control. The implementation act provides thresholds where if charges are equivalent to either less than, the regulatory body may carry out the control in a simplified manner. However, existing studies on direct costs show that even in 1435 networks the level of the costs can significantly vary. For instance UNITE (2002) project has shown 30–38% for maintenance and 10–95% of renewal results for different asset types. Link & Nilsson (2005) report research results that 30% to 60% of rail maintenance and renewal costs vary with track usage volumes. ACEM (2013) project concluded that maintenance costs vary in 30 000–100 000 euro km per year diapason. ProRail study (Zoeteman, 2007) concludes that primary reasons cause more than 50% of costs. Calvo & De Ona (2012) state that cost base depends on network peculiarities and traffic distinctions. It was calculated 10.24 €/train km for freight, 6.06 €/train km for high-speed trains, and 2.20 €/train km for similar passenger traffic. The only relevant study (Teresina et al, 2010) for 1520 networks assess 70–76% as semi-fixed costs. Currently LICB (2008) develops normalization cost bases in order to compare level of costs in different countries. After using normalization LICB has found that the average cost may be equal to 70 000 EUR/km on average, where about the half is the maintenance and the half is the renewal. The cost varies 20–60 euro/km for maintenance and 10–80 euro km for renewal. All above facts speak about non-coherency of infrastructure charging.

After explanation of all steps of the calculation of the direct costs, the time series analysis of traffic and cost base data was executed for the period 2008–2014. The cost base was transformed in time series by grouping it in several dimensions: by maintenance and renewal fields and the cost elements. It was assumed that infrastructure is coherent throughout the network. The time series was normalized: staff related costs by consumer price indices (2010 = 100), fuel and electricity by average price indexes and other cost categories by producer price indexes (2010 = 100). All known non-eligible costs (financial costs, overall costs and depreciation) were excluded from the analysis.

It was found that regression between known traffic volumes and cost base is not sufficient, but after representing data in scatter chart, it maybe notices that infrastructure costs gradually vary however, the ranges of stages overlap (Fig. 3) but after threshold about 40thous.tkm the level of costs grows exponentially. In the context of previous literature review and expert survey this means that infrastructure manager can provide different maintenance regimes (with different cost base), thus adjusting to different ranges of transportation volumes. However, this does not happen with every additional train.

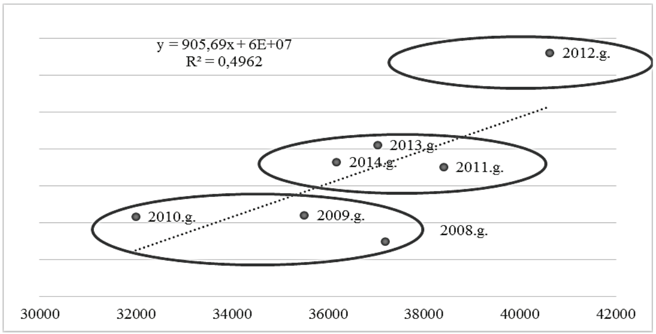

Fig. 3. Comparison of the dynamics of traffic volume (x) and normalized cost base (y) in 2008–2014.Source: authors' construction.

4. Discussions and conclusions

Based on results of literature review, survey of experts and time series analysis the adopted model of the calculation of direct costs on European 1520 rail network was introduced (the graphical interpretation is represented on Fig. 4.):

1. In order to provide more accuracy, the network may be divided in different parts if there are sufficient differences in terms of maintenance conditions;

2. The non-eligible costs mentioned in the implementation act without precondition "unless incurred by operation of the train service" shall be excluded from network-wide direct costs;
3. The infrastructure manager based on the range of traffic forecast shall modulate a level of costs for the defined traffic range, and traffic range below and above of forecasted, using engineer technical procedures and ensuring the following planning conditions:
   - the forecasted performance and its seasonal, technological and cyclical fluctuations;
   - set of quality parameters will remain unchanged both in the reporting period and in further period;
   - costs which are not related to the operation of the train services (external temperature changes over the projected normal exploitation values, defects in materials, natural corrosion, degradation due to gravity or to natural processes over the projected normal exploitation values, human factors) are excluded;
   - the volume of maintenance and renewal work has not lead to additional costs for railway undertakers and its consumers or caused any externalities;
   - a stage of life cycle of railway infrastructure elements will be considered;
4. For calculation of the direct unit the following train categories should be used (1) freight trains (2) passenger electric (subject of electrical supply equipment costs) (3) passenger diesel trains (4) international passenger trains (5) narrow-gauge trains. Query for the speed is a subject of reallocation of costs that are incured by additional technical requirements.
5. Track maintenance and renewal costs shall be allocated to train category using forecasted tonn km driver, all other costs by using forected train km driver. The direct unit cost measurement shall be stated as a combination of train km and gross tonn km.
6. It is essential that achieving of forecasted traffic level should be promoted using charging instruments. If the traffic level goes down the discounts for new service encouragement shall be introduced, and in case that traffic level grows above higher threshold, the network performance scheme shall be executed in order to limit scarcity.

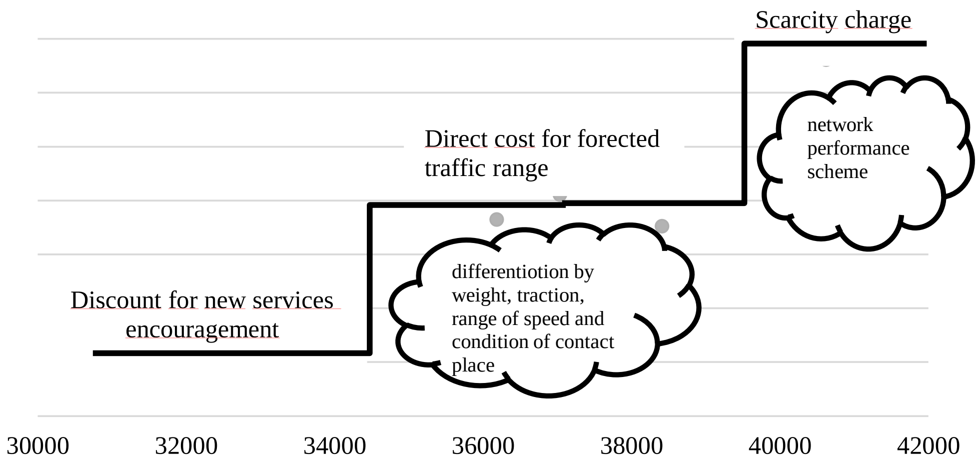

Fig. 4. Gradual model of direct cost allocation.Source: authors' construction.

There are questions that are the subject for further research: traffic forecast and provision of modeling parameters; point of scarcity and "encouragement", assessment of contact places of common vehicle park of 1520; clear demonstration of charging process to funding institutions.

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