Railway infrastructure pricing systems for freight in Europe: Analysis and evolution in the last decade

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Declaração

Declaro que o presente documento é um trabalho original da minha autoria e que cumpre todos os requisitos do Código de Conduta e Boas Práticas da Universidade de Lisboa.

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Resumo

O estudo visa avaliar os diferentes princípios e níveis de tarifação em algumas das rotas europeias nacionais e internacionais mais relevantes e compará-las com os resultados de 10 anos atrás. Outro objetivo é comparar o transporte rodoviário e ferroviário de mercadorias.

Na análise Qualitativa foram descritos e comparados os sistemas de tarifação para o transporte ferroviário de mercadorias. Observou-se que nos últimos dez anos muitos sistemas foram simplificados.

A análise Quantitativa contém: variação de intervalo dos níveis das taxas, níveis das taxas dos pares OD Nacional e EFC e o impacto do peso do trem nos níveis das taxas.

Apenas os sistemas de tarifação italiano e alemão cobram por quilómetro para um trem de 500 toneladas superior a 2 €. Uma enorme parte de suas taxas é tomada pelo mark-up. Em outros países, o mark-up é muito baixo ou mesmo 0. Isso resulta em heterogeneidade dentro dos Corredores Ferroviários Europeus.

Verificou-se que em 10 anos, na maioria dos sistemas de tarifação, o nível de taxa diminuiu. A maior variação relativa de preço foi observada na Itália – cerca de 61%. Por outro lado, a maior queda relativa de taxa foi observada na Holanda, França e Polônia – de 44% para 47%. As tarifas de EFC para trens de 500 toneladas diminuíram.

Na comparação da tarifação para mercadorias no transporte rodoviário e ferroviário, verificou-se que em muitos países e corredores o transporte ferroviário de taxa passou a ser competitivo apenas para trens com peso mínimo de 960 toneladas.

Palavras-chave

Sistemas de tarifação; taxa de uso da infraestrutura; Transporte ferroviário de mercadorias; pacotes ferroviários; Mercado internacional; custo marginal

Abstract

The study aims to assess the different charging principles and levels in some of the most relevant European national and international routes and compare them with the results from 10 years ago. Another goal is to compare road and rail freight transport.

In the Qualitative analysis the infrastructure pricing systems for rail freight transport were described and compared. It was observed that within the last ten years many systems were simplified.

The Quantitative analysis contains: interval variation of charge levels, charges levels of the National and EFC OD pairs and the train weight impact on the charge levels.

Only Italian and German pricing systems charge per km for a 500-tonne train is bigger than 2 €. An enormous part of their charges is taken by the mark-up. In other countries the mark-up is very low or even 0. That results in heterogeneity within the European Freight Corridors.

It was found that in 10 years in most of the pricing systems the level of charges decreased. The biggest relative change in price was observed for Italy – about 61%. On the other hand, the biggest relative decrease of charge was observed for the Netherlands, France and Poland – from 44 to 47%. The charges for EFC for 500 tonnes trains decreased.

In comparison of freight pricing in road and rail transport it was found that in many countries and corridors the rail freight transport started to be competitive just for trains weighing at least 960 tonnes.

Key-words

Infrastructure pricing system; Rail freight transport; Railway packages; International market; Marginal cost

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Acronyms and Definitions

EC	European Commission
EFC	European Freight Corridor:
EU	European Union
FC	Full Cost
FC-	Full Cost minus governmental mark-ups
HGV	Heavy goods vehicle
HSL	High-speed line
IM	Infrastructure Manager
ITF	International Transport Forum
MC	Marginal cost
MC+	Marginal cost + mark-up
NS	Network Statement
OD Pair	Origin-Destination Pair
OECD	Organization for Economic Co-operation and Development
RU	Railway Undertaking
tkm	Tonne-kilometre
UIC	International Railways Union

1. Introduction

1.1. Background

Since the European Economic Community creation (later renamed as the European Community), one of its objectives was to establish common transport policy in the European space. One of today's concerns is a modal shift in freight transport. The target set from the EU Sustainable and Smart Mobility Strategy, released in 2011, is to shift away 30% of freight traffic from the road by 2030 and 50% by 2050 [1]. The aforementioned objective is driven by factors related to accessibility, sustainability, climate change, safety, resilience and economic development. Road freight transport mainly has advantages over other modes in terms of reliability, flexibility, accessibility and shipment size. It is said to be the cheapest mode over short distances [1]. In long distance transport, rail transport is the biggest competition for road transport.

One of the most important factors for shippers choosing transport mode is its price, which involve, inter alia, infrastructure usage charge. The determination of infrastructure prices is a complex process.

The railway pricing system is related to multiple subjects. It is found by infrastructure managers (IM). Each of them establishes the rules for its infrastructure and describes them in the Network Statement (NS). They are to comply with regulations set by the Member State, which is influenced by European Commissions' (EC) legislations. Moreover, they are influenced by other Member States and the third countries, depending on their trade relationship, involving transport connections. On the other hand, there are railway undertakings (RU) who are to decide to allocate their trains on the infrastructure. Their decision is affected inter alia by level of prices, regulations, complexity of the system, incentives and penalties. They establish their availability and prices for freight transport, which is observed by representatives of freight market demand – shippers and logistic service providers, who are to choose the most attractive mode of freight transport. The national regulatory bodies should prevent discrimination within group of infrastructure manager, services facilities operators and railway undertakings and improve relations between them.

Moreover, member states' railway pricing systems differ significantly in complexity and price level. The prices often depend on multitude of variables, which may be discriminatory, that is, they tend to protect old operators. For example, it may be constructed in such way that the charges are low only for some specific trains. The heterogeneity of the pricing systems manifests itself also in divergent political guidelines and priorities, the physical characteristics of the networks and difficulty in public funding.

To oust discrimination from the pricing systems, increase the efficiency and competitiveness of the rail transport and its share in transport modes, European Union Commission published directives and regulations. It required the account separation of the infrastructure manager and operators (Directive 1991/440/EC). The infrastructure usage fee should be based on marginal cost (MC), that is the cost that is directly incurred as a result of operating the train (Directive 2001/14/EC).

The regulations and directives, however, left some space for interpretation, which resulted in various ways of usage fee implementation, thus retention of the heterogeneity. That complexity and difference of the systems impede changes in traffic mode share.

The competition in transport modes is also hindered due to differences in charging of the road and rail infrastructure usage. Whereas there are regulations making railway undertakings cover the costs of rail deterioration, there is no such thing for road transport. The truck toll payments often do not cover the damage caused [1]. Moreover, there are many roads with free access, whose deterioration is to be paid for by public entities.

1.2. Objectives and methodology

The main objective of this study is to analyse and discuss the current state of the practice and existing problems related to railway freight pricing systems in Europe.

The second main objective is to evaluate the evolution of railway freight pricing systems in the last decade.

Another goal, reinforcing the main objectives, is to review the current legislation and the State of the Art, which will help understanding the matter of study and it will be used as a reference in further analyses.

Two main objectives involve subordinate objectives which are:

- to assess the current different charging principles and levels,
- to analyse the alignment of Network Statement with the current EC legislations,
- to evaluate the impact of directives and regulation on the evolution of pricing systems,
- comparison of the road and rail transport modes in order to find out about the competitiveness of the rail mode in regards to other modes.

This study concerns the pricing systems in 10 selected European countries, taking part in some of the most relevant European Freight Corridors (EFC).

The methodology involves:

- Analysis of the legislation,
- Review and discussion on the state of the art on pricing methods,
- Detailed analyses of existing system structure based on current Network Statements,
- Calculations of current tariff levels, based on the methodology that was already defined in UIC report [2], concerning 2013 pricing systems;
  - Calculation of possible ranges of charge for selected countries and their comparison,
  - Calculation of tariff levels for selected ODs (origin – destination pairs) and comparison among them for both national and international pairs,
  - Sensitivity analysis on the weight impact on tariff levels,
- Calculation of road tolls for the routes corresponding with the selected before ODs,
- Assessment of the systems as they were in 2013, based on the Network Statements of that time,
- Comparison of systems structure and tariffs levels (2013 vs 2023).

1.3. Structure

This work is divided into 5 chapters. The first one introduces the framework of the theme, the objectives and methodology of the study.

The chapter 2 involves State of Art. Firstly it introduces the background focusing on transport mode competition. Then the legal point of view is presented. Next part involves review of the papers on infrastructure pricing systems. At the end of the chapter a discussion is raised that confronts the studies and legislation.

The chapter 3 presents the current state of practice on railway infrastructure pricing systems. It involves methodology description, qualitative and quantitative analyses, comparison of freight pricing in road and rail transport modes and critical analysis of network statements.

In chapter 4 the evolution of the infrastructure pricing systems is analysed. It involves methodology, system structure, tariff levels and discussion on best practices and recommendations. As each chapter before raises some question, they are gathered together in this chapter in order to evaluate the evolution and to observe if and how the questions and problems were solved within the last decade.

In chapter 5 some of the final thoughts and conclusions emerged from the carried out analyses are presented.

2. State of Art on railway infrastructure pricing

2.1. Background

There are a multitude of important issues relevant to the subject of pricing systems. Nevertheless, so as to emphasize the importance of traffic mode change from road to rail, at the beginning the reports and papers explaining traffic mode choice are examined.

From the start of 21st century road mode of transport has dominated in the European Union in both passenger and freight transport. Between the years 2000 and 2019 passenger car transport share increased from 82% to 82,5%, train transport share increased from 7,5% to 8,5%, whereas motor coaches and busses and trolley busses decreased from 10,5% to 9,5% [3]. For freight transport between years 2005 and 2019 road transport share increased from 74,4% to 77,4%, rail share decreased from 18,5% to 16,8% and inland waters transport share decreased from 7,1% to 5,8% [4]. The modal split didn´t change greatly. The road transport increased its dominance.

The International Transport Forum (ITF) analysed the current situation of modal split and explained what are the factors for mode choice in freight transport. Each mode of transport has its specific characteristics. Transportation price for freight is one of the most important factors [1].

In many papers in 21st century rail traffic is said to be more susceptible to price change than road one. Vierth et al. [5] notice that the demand for rail is relatively responsive to changes in the price associated with road transport, whereas the contrary is not the case. They explain that with the fact that advantage of trucks in service quality is high enough to compensate any price reductions of other modes.

The road freight transport is said to be the cheapest mode over short distances [1]. The relatively low cost of road transport mode may be the result of low rate of internalization of the negative external costs (for instance costs related with: air pollution, greenhouse gas emissions and accidents) [1]. The non-road modes have a great advantage over road mode in terms of environmental sustainability. The railway transport emits the least greenhouse gases - including both emissions from transport operation and those associated with fuel extraction. Another advantage of rail transport is safety. The road freight transport is the most dangerous and it causes the highest costs related to traffic accidents.

It is important to point out that the preference of the mode of transport depends on type of transported goods. The non-road modes usually transport heavy bulky goods (as oil products, metal ores), however in European countries those types of goods excluding energy raw materials and refined products are still significantly more frequently transported by road transport. The low-weight goods are almost exclusively transported with road mode. As the rail and inland water transport are generally safer than the road transport they are preferred for dangerous goods [1].

The road freight transport is a competitive market, which seldom can be told about rail freight transport. The market competition for rail transport is imperfect and characterised by oligopolies and monopolies, in spite of decades of liberalisation policy efforts [6].

Bearing in mind the environmental sustainability, transport safety and lack of competitiveness of the rail transport sector in relation to other existing transport modes, there was interest on the part of the

European Commission to boost the rail. In order to achieve it they aimed to introduce market competition to liberate the rail sector. It started with the Directive 91/440/EEC, which led to the financial separation of infrastructure management and operations. In order to liberate rail services, firstly freight, then passenger on both international and national levels, the European single market was created. That induced the introduction of infrastructure charges. However, that brought some problems. The costs that were passed on the operator in railway transport, did not exist in other modes.

2.2. Relevant EU Legislation

2.2.1. Framework

In order to deal with the problems of the rail transport sector, the European Commission publishes directives, which serve as recommendations and as a base for further regulations set by both the European Commission and government of each European Union member.

In 1991 arose Directive 91/440/EEC. It focused on the independence between Infrastructure Manager and Railway Undertaking and on separation of their accounts. It was noticed that infrastructure use charging is needed but it is not specified how it should be done.

After that, the Directive 95/19/EC arose the first rules for infrastructure usage, charging and capacity allocation. It clarified the role of the IM in these matters.

In the White paper the European Commission set a strategy to revitalise the Community's railways. They proposed, inter alia, extending access rights to railway infrastructure for all freight and international passenger services and promoting the creation of trans-European rail freeways for freight.

The Directives 91/440/EEC and 95/19/EC were amended by the first railway package, published in 2001. It was constituted by the Directives 2001/12/EC, 2001/13/EC and 2001/14/EC.

The first two directives focused on development of railway transport and licensing of railway undertakings.

The directive 2001/14/EC imposed on IM to publish Network Statement. It described its structure and what it should contain. The charges had to be based on direct cost, however the Directive provided the possibility to implement a cost mark-up for markets that could bear it. Nevertheless, charges couldn’t exceed full cost. The directive also specified other possible charges and encouraged IM to adopt a performance scheme which would include incentives and penalties.

The second railway package, constituted by the Directives 2004/49/EC, 2004/50/EC and 2004/51/EC and Regulation 881/2004, aimed at improved safety, interoperability. It fully opened the rail freight market to competition as from 1 January 2007.

The third railway package contains Directives 2007/58/EC, 2007/59/EC, and 2007/60/EC and Regulations 1370/2007, 1371/2007 and 1372/2007. It introduced the open access rights for international rail passenger services and created a universal in entire European network driver licence. It allowed to the train operators to pick up and set down passengers at any station on an international route. Moreover, the third railway package strengthened the rail passengers' rights.

The Directive 2012/34/EU is a current legislation for establishing the pricing system. It will be discussed in depth in the next chapter.

2.2.2. Directive 2012/34/EU 14.12.2012 – initial legal act

The Directive 2012/34/EU was published in December 2012 in order to reformulate the directive 2001/12/CE. The directive aims at increasing the competition in railway transport. To achieve that aim railway infrastructure should be constantly developed. The Railway undertakings should not be discriminated, inter alia, in terms of access to service facilities, rules providing them to pay for the use and traction current supply.

The directive highlights that the economic equilibrium of the public service contract should be retained in terms of: profitability, passenger demand, ticket pricing, ticketing arrangements, location and number of stops on both sides of the border and timing frequency of the proposed new service.

To provide the competition in railway freight market, the railway undertakings should be independent of the infrastructure managers. For this reason, the infrastructure management and transport operations should have separate profit and loss accounts and be independent of essential functions that is decision-making on train path allocation and on infrastructure charging. The independency and lack of discrimination should be controlled by a regulatory body established by a member state.

The directive also sets the requirements for infrastructure charging. It is required that the charge for the minimum access package and for the access to infrastructure connecting service facilities should result from direct cost. The directive assumes the possibility of inclusion to charge the environment effects or scarcity of capacity aspect. There are also provided reservation charges, which means a levy of charge for allocated capacity that is not used.

There are provided discounts granted to the railway undertakings. They should be non-discriminatory and limited to the actual saving of the administrative cost to the infrastructure manager. However, they may be applied in order to promote the efficient use of infrastructure, encourage development of new services or to use of underutilised lines. On the other hand, penalties for disruptions of network operations or delays there are provided.

Even though the full cost (FC) is not permitted as a charging base, the IM may aim to recover full costs using mark-ups. The member states may levy mark-ups in cases when the market can bear this. The mark-ups levy should be based on efficient, transparent and non-discriminatory principles, while retaining optimal competitiveness of rail market segments. On the other hand, if a country is able to fully subsidize the infrastructure costs, an IM may set mark-ups zero for all market segments.

Before setting the mark-ups, the infrastructure managers should evaluate their relevance for specific market segments, considering at least following pairs:

- passenger versus freight services;
- trains carrying dangerous goods versus other freight trains;
- domestic versus international services;
- combined transport versus direct trains;
- urban or regional versus interurban passenger services;
- block trains versus single wagon load trains;
- regular versus occasional train services.

Within each market segment, further sub-segmentation may be established.

The directive also points out environment and noise issues. It recommends the introduction of charge for a rolling noise caused by brake blocks with cast iron technology and setting limits of noise produced by railway vehicles, noise mapping and action plans to reduce noise exposure. The noise-reduction measures applied for the rail sector should be also considered for the other sectors of transport. One establishing noise charge should take into consideration the duration of the noise, the sensitivity of the area affected.

From the infrastructure managers it should be required to examine the available infrastructure capacity and develop a clear understanding of the factors which determine direct cost. They should be incentivized to reduce the level of access charges and costs of providing infrastructure.

The directive points out the importance of coordination of allocation schemes, especially for international traffic. Moreover, the infrastructure managers should cooperate to enable efficient capacity allocation for transport crossing more than one network of the rail system within the Union. The directive marks the importance of the open market for international traffic, especially for the freight sector.

The railway undertaking should be provided with clear and consistent economic signals from capacity-allocation and charging schemes that would make them making rational decisions. In order to take part in the capacity-allocation process they should meet certain requirements due to reputation, financial fitness etc.

Both railway undertakings and the infrastructure manager should be provided with incentives to minimise disruption and improve performance of the network.

The directive signals the need for a control system for trains. Thus recommends for infrastructure managers to incentive, with an appropriate construction of charging system, railway undertakings to equip trains with ETCS.

Optimal use of the railway infrastructure shall result in reduction in the cost of transport to society. The directive set a deadline on 16 June 2015 for the Commission to adopt measures setting out the modalities for direct cost calculation, that is cost that is directly incurred as a result of operating the train. After the entry into force of these modalities the infrastructure manager was to be given a possibility to gradually adapt to them in a period no longer than four years.

Since it is necessary to invest in railway pricing, systems should include incentives for infrastructure managers to such actions. Charging in rail infrastructure can internalize external costs in a way that is coherent and balanced with other modes of transport. It should result in optimal balance of different transport modes.

2.2.3. Regulation 2015/909 Method for estimating direct costs

The Regulation 2015/909 sets out the modalities for the direct cost calculation in order to set a minimum access package. It indicates two methods of direct unit cost determination.

First one is based on difference between full cost, which includes providing the services of the minimum access package[1] and access to infrastructure, and non-eligible costs, that is, costs that are not directly incurred by operation of the train service (for instance fixed cost related to provision of line section which the infrastructure manager have to exercise even in absence of train movements).

In this method to calculate direct costs, asset values should be based on historic values and in case of lack of those or where current values are lower, it should be based on current values. Thus costs should be based on payments effected or forecast by the infrastructure manager.

The direct unit cost is an average direct unit cost for the entire network, obtained by dividing the direct costs on entire network by the total number of train kilometres or gross tonne-kilometres (tkm).

The regulation also provides possibility for infrastructure manager to apply different direct unit cost for sections of network that differ in terms of levels of wear and tear caused by parameters as: train mass, type of vehicle (in particular its unsprang mass), train speed, traction power, axle weight and/or axle numbers, train length, track parameters, actions that impact on the track, and other cost related parameters. In that case infrastructure managers may use a combination of vehicle kilometres, train kilometres or gross tonne-kilometres.

The second method is a determination of direct unit cost by means of econometric or engineering cost modelling. The Infrastructure Manager should prove that the direct unit cost includes only the cost incurred by the operation of the train service and does not include any non-eligible costs.

The pricing systems established by infrastructure managers are controlled by a regulatory body. If direct cost on the entire network is significantly smaller than full costs of maintenance and renewal, the regulatory body is allowed to carry out the control over the calculation of direct costs in a simplified manner.

Independently from before mentioned control, the regulatory body may accept the calculation of direct unit cost, if a direct cost per train kilometre for 1 000 tonnes train is not higher than 2 € (at 2005 prices and exchange rates, which for 2013 year with inflation between 2005 and 2013 at level 22,0% gives 2,44 € and for 2021[2] year with inflation at level 33,5% gives 2,67 €).

The infrastructure managers should update the methods of calculation of its direct costs due to the best international practice.

2.2.4. Further amendments of the Directive 2012/34

The Directive (EU) 2016/2370 amends directive 2012/34/EU on independence between IM and RU, focusing on impartiality of the infrastructure manager in respect of traffic management and maintenance planning, outsourcing and sharing the infrastructure manager's functions and on financial transparency.

The COMMISSION DELEGATED DECISION (EU) 2017/2075 amends directive 2012/34/EU on the allocation process. It allows Infrastructure Manager to reschedule an allocated train path to obtain the

[1] minimum access package contains, inter alia, the right to use the previously granted capacity; use of the railway infrastructure, including track points and junctions; train control (signaling, regulation, dispatching and the communication and provision of information on train movement); use of electrical supply equipment for traction current, where available;

[2] Data from Eurostat on average index and rate of change only available up to 2021 year

best possible matching of all path requests. Moreover, it describes procedures of scheduling due to capacity restrictions.

In 2019 a new version of Directive 2012/34/EU was published. It amended the article on access to railway infrastructure including information on relations of member states with the third countries. In case of distortion of competition in cross-border railway transport, the Member State may limit the right of access to services operated from and to the third countries.

Due to development of high speed railways, it prepares the member states to introduce it without compromising the already existing passenger transport market.

The Directive also determined that the member states may require from railway undertakings to cooperate with each other using for instance through-tickets schemes, in order to provide to passengers the possibility to journey on more than one operators' services. The created scheme should not create market distortion nor discrimination between railway undertakings.

2.2.5. Regulations concerning noise, capacity allocation and other temporary rules

The Regulation 2015/428 imposes on infrastructure managers to give bonuses to railway undertakings using retrofitted wagons, as well as charge infrastructure managers for running noisy trains. The bonuses should be based on axle-km. They may be limited to the value of retrofitting costs. The charge for noisy trains shouldn't be higher than the bonuses, unless there is such a charge applied in the road freight transport.

The Regulation 2016/545 sets procedures and criteria concerning framework agreements for allocation of rail infrastructure capacity. It imposes on Infrastructure Managers to present framework capacity allocated on the lines and indicate the volume and nature of the available capacity. While concluding or extending a new framework agreement, Infrastructure Manager should bear in mind, inter alia, optimum use of infrastructure capacity, passenger and commercial needs, freight sector.

The Regulation 2017/2177 describes procedures and criteria for access to service facilities. It imposes on Operators of service facilities to prepare and publish service facility descriptions. The regulation also describes procedures of cooperation between the operators and railway undertakings applying for their service facilities.

As a response to the negative economic effects of the COVID-19 outbreak, the European Commission published a set of Regulations (2020/698; 2020/1429; 2021/1061) setting temporary rules supporting railway undertakings. Member States might have authorised infrastructure managers to reduce, waive or defer the payment of minimum access package charges and to review the economic ability of market segments and re-establish mark-ups values.

2.2.6. Legislation criticism and objections

Crozet [6] observed that 4th Railway Package came with objections of several member states, which led to corrections made in February 2014 by the European Parliament.

France and Germany, with the support of Italy and Luxemburg opposed the mandatory separation of ownership between infrastructure and operations.

The regulator’s role became more crucial and complex. Existence of a holding company instead of full separation makes the relation between IM and RU less transparent, thus the eventual privileged relationship between the IM and the holding company’s other subsidiaries is more difficult to find and to prevent.

As the EC directives left much room for IMs to reform their railway systems a complete separation of infrastructure and operations on all countries was not yet imposed. That passes more work to the rail regulator in the form of regular and thorough assessments of the inner workings of the IM [6].

2.3. Studies and Researches on railway infrastructure pricing

The importance and complexity of infrastructure pricing systems provoked the emergence of many studies. In this chapter chosen papers are examined in order to better understand the problem and to set up a base for further analyses. As the main objective of this dissertation focuses on the freight pricing system, studies on passenger transport will be rather overviewed briefly. However, their importance cannot be neglected as both freight and passenger pricing systems have many common limits and often work analogically.

2.3.1. Studies on the calculation of cost directly incurred

A very important part of the pricing system is the direct cost (also referred as marginal cost), as the minimum access package and for access to infrastructure connecting service facilities should result from it. The direct cost should include only the costs incurred by the operation of the train service. The studies, concerning that issue, are important because they provide knowledge about the scale of the damage incurred by certain types of trains. Wheat et al. [7] noticed that comparisons across models in their study, helped to understand the underlying cost variation. With that knowledge Infrastructure Managers set the direct cost adequate to type of train and type of section. As a result, transport becomes more sustainable.

Yet it is very difficult to correctly and precisely assess the marginal cost (MC). One of the existing problems is lack of data. In its overview of transport infrastructures expenditures and costs [8], The European Commission points out that their study is based on a lot of data obtained from different sources. Moreover, the methods used often require assumptions, which decrease the reliability of results.

The complexity of the issue led to the emergence of multitude papers and studies on marginal cost evaluation. The calculations were exercised with various methods. The two most popular of them are engineering and economic methods. The engineering method (bottom-up approach) uses models to estimate the extra damage caused by additional traffic. Then by using the unit cost of repair costs, the marginal cost is determined. On the other hand the econometric method (top-down approach) is used to assess a direct relationship between costs and traffic, using statistical or judgemental techniques [7].

One of the most important and an often cited study, CATRIN [7], used a top-down approach. Afterwards it reviewed the study that used an engineering model in order to discuss the relationship between those approaches. In the study Wheat et al. compare the marginal cost in selected European countries: France, Sweden, Switzerland, Great Britain, Austria. To obtain the variable cost function they use double log functional form and the Box-Cox functional form. The formulas used include the possibility that the cost is not-constant due to traffic change. Then using one of those functions average cost (which in this study is equal maintenance cost) and cost elasticity is determined. The average cost is calculated by dividing the cost by traffic volume.

Finally, the marginal cost is determined by multiplying the average cost and the cost elasticity. Wheat et al. highlight that the usage elasticity is increasing with traffic density. The table 1 presents the marginal costs calculated using different methods.

Table 1 Summary measures for marginal cost, € per 1000 gross tkm, for selected countries and Pooled International[3] [7].

			Whole Sample Averages		
Study	**Preferred functional form**	**Mean Tonnage density (Tonne-km / Track-km)**	**Unweighted Mean**	**Weighted Mean**	**Median of sample**
France	Box-Cox	7,300,000	2.70	1.39	1.80
Sweden	Box-Cox	7,650,000	11.52	0.46	0.86
Switzerland	Box-Cox	13,100,000	0.84	0.32	0.50
Austria	Box-Cox	10,600,000	2.60	1.20	1.50
Great Britain	Double-log	4,810,000	2.51	1.73	1.56
Pooled International	Double-log	8,135,000	4.36	2.17	2.53
Study	**Evaluated at sample mean of data**	**Evaluated at average infrastructure quality and 3,650,000 tonne-km per track-km**		**Evaluated at average infrastructure quality and 12,775,000 tonne-km per track-km**	
France	2.01		2.25		2.00
Sweden	0.54		0.52		0.24
Switzerland	0.39		0.92		0.39
Austria	0.88		1.46		0.79
Great Britain	1.07		3.16		1.78
Pooled International	3.55		5.98		1.18

It was observed that marginal costs decrease with traffic density increase and with track quality decrease, despite increase of usage elasticity. While for high density traffic usage elasticity is higher, the average cost is lower, thus their product – marginal cost may also be lower.

For the European countries the marginal costs that used the weighted (by gross tonne-km) mean fluctuate from 0,32 to 1,73 € per thousand gross tone-km. However, the authors emphasize that the whole sample unweighted mean can differ significantly from other measures, because all studies estimated a very high marginal cost for sections with low occupancy. The number of these types of sections then impacted on the results.

They point out evaluating marginal costs at average infrastructure quality and at the same tonnage level as possibly most useful for comparison purposes.

On table 2 the marginal cost for passenger and freight traffic are presented.

[3] Pooled International contains data from six infrastructure managers, namely Network Rail (Great Britain), OBB (Austria), Prorail (Netherlands), Amtrak (US), Irish Rail (Ireland) and Infrabel (Belgium).

Table 2 Marginal cost estimates by passenger and freight traffic using the whole sample average weighted by tkm measure, € per 1000 gross tkm [7].

Country	Marginal Cost			Ratio of Passenger to Freight
	Passenger	Freight	Total (for comparison)	
Sweden	1.058	0.140	0.461	7.559
Switzerland (Maintenance)	0.265	0.184	0.321	1.438
France	2.103	0.692	1.390	3.036

For all the studies compared in the table the passenger traffic marginal costs are greater than freight traffic costs. The relative difference between those is high. It oscillates from 1,4 to 7,6. The authors interpret it as exaggeration, referring to the engineering approach. It was explained that the passenger traffic causes only slightly more damage per gross tonne-km than freight traffic [7], which is debatable.

Wheat et al. [7] recommend to charge all the sections using average cost at the network wide level. As alternative they suggest charging with different marginal costs routes that differ with traffic density and infrastructure quality characteristics.

Importantly, they note that there are strong differences in damage between different vehicle types even per gross tonne-km. They point that the best practice should consider the infrastructure characteristics and quality as well as the vehicle characteristics.

However, the approach used in this study raises some questions and conclusions:

- Different charges due to quality of infrastructure is reasonable as the high quality of infrastructure makes it less prone to damage, thus implying less maintenance costs.
- The lower charge for sections with high traffic does not make any sense from the engineering point of view. The damage caused by one particular train should be the same regardless of the traffic. Allocating another train on the section does not decrease the damage caused. That shows flaws of the econometric approach. Perhaps the obtained marginal cost contains a part of fixed costs, which is later divided by traffic, which could explain the different results for the sections with different traffic density.
- Should a passenger train incur more damage per gross tonne-km than a freight train? On the one hand passenger trains drive with higher velocity. On the other hand freight trains usually have higher axle load.

Other work concerning, inter alia, the marginal costs is the report made by EUROPEAN COMMISSION [8], in which the transport infrastructure expenditures and costs for the European countries were overviewed. Interestingly, the report contains total infrastructure costs and marginal costs for different transport modes. The approach exercised in this work is presented in figure 1. It shows how the total infrastructure and marginal costs are estimated.

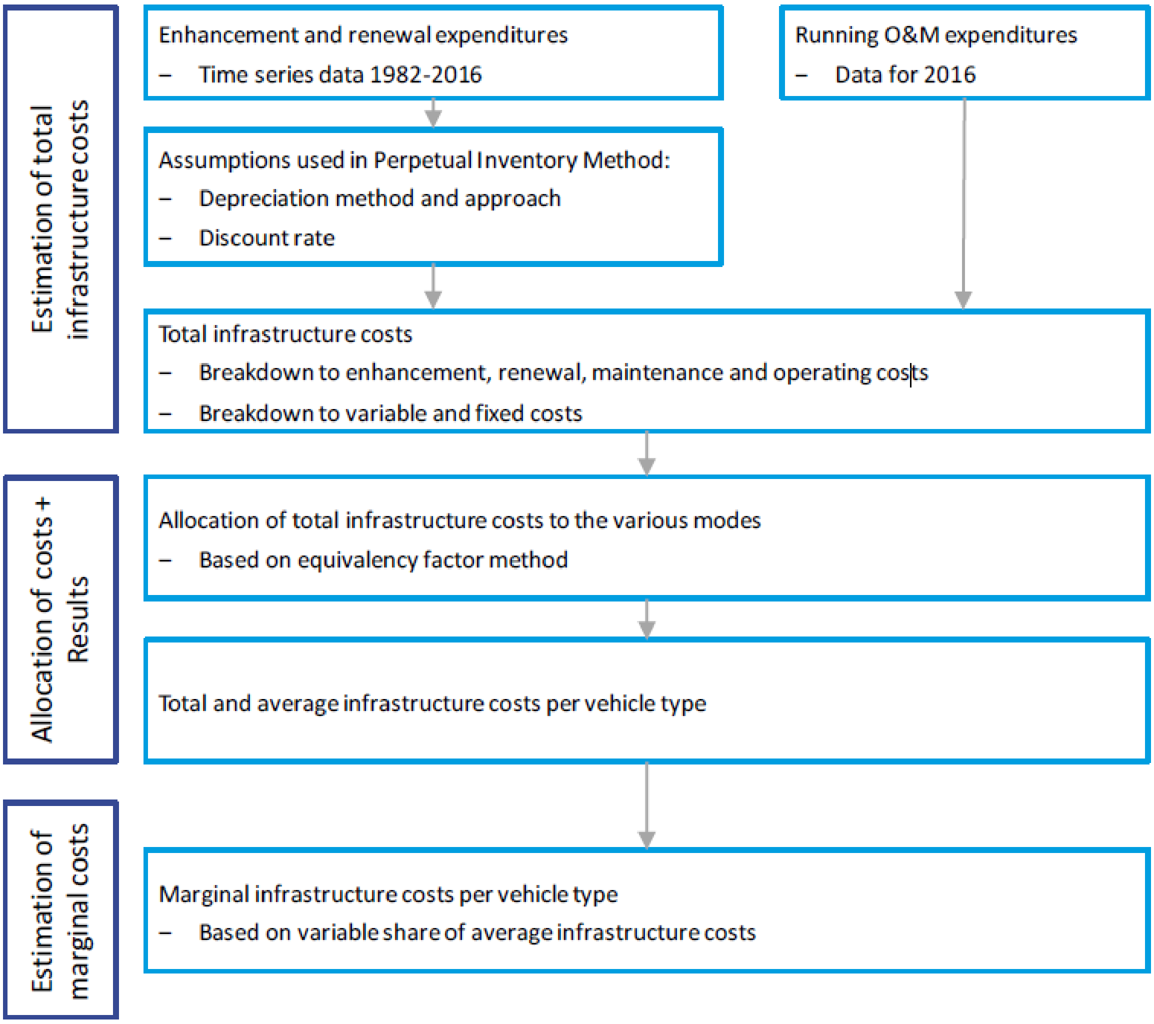


Figure 1 General approach to estimate infrastructure costs [8].

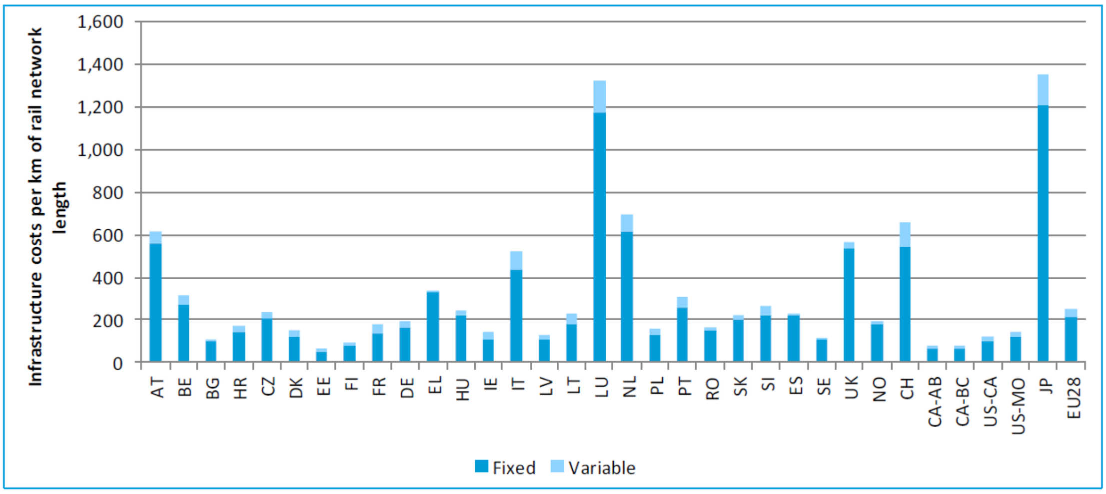
Firstly, they calculate the total infrastructure cost using Perpetual Inventory Method, which accumulate and revalue the acquisitions over their lifetime, bearing in mind depreciation. The total infrastructure cost contains investment (further broken down into enhancement and renewal costs) and operational and maintenance (O&M) costs. The investment costs are calculated based on expenditures data from 1982-2016 period and O&M costs calculation is based on expenditures data from 2016. The data was collected from international sources as OECD and Eurostat and from national sources, that is, infrastructure managers.

The marginal costs are calculated with a cost allocation approach. It is assumed to be equal to the share of the average infrastructure costs that is variable (not fixed). The authors define the variable costs as costs that vary with transport volumes while the functionality of the infrastructure remains the same. The variable costs are constituted by shares of maintenance and renewal costs. On the other hand, fixed costs consist of full enhancement and operation costs and shares of renewal and maintenance costs. Since the data on shares of fixed and variable rail infrastructure costs was available only for the Netherlands and UK, for the other countries, the report use the values recommended by the CATRIN study [7], thus the 35% of the renewal costs are assumed as variable and share of variable costs in total maintenance cost is dependent on the traffic density. For traffic density below 3 million tonne-kilometres per track-km per annum, share of variable costs were assumed 20%, between 3 and 10 million tonne-kilometres – 30%, and for above 10 million tonne-kilometres – 45%.

Subsequently, the total rail infrastructure costs, based on selected proportionality factors, are allocated to 6 various train categories. The proportionality factors for marginal costs are tonne-km for the variable share of renewal costs and for the variable share of maintenance costs they are 50% based on train kilometres and 50% based on tonne-kilometres. It reflects that part of the cost is fully dependent on train movements and another part is dependent on the train mass.

The European Commission noticed that the proportionality factors (drivers) significantly affect the final infrastructure costs per vehicle category, therefore their choice of the factors was based on a literature review. The final source they used was the study of CE Delft and ITS from 2015. Unfortunately, the work of these authors, published in a given year are not included in the references, thus it impedes understanding of the selected method. [8]

The figure 2 presents the infrastructure costs per track-km with division on fixed and variable costs for selected countries.



Note: There are no railways in Cyprus and Malta.

Figure 2 Infrastructure costs per track-km of rail network length (x 1000 € per km, PPS adjusted) [4] [8].

According to EC [8], fixed costs constitute about 87% of the total cost for European Union countries. The highest costs emerge for countries with complex geographic formations as for Austria, Italy and Switzerland and for countries with small operated networks, modernizing its lines (Luxemburg and Netherlands) or developing high speed services (Japan).

The figure 3 shows the average infrastructure costs calculation results for different modes of transport.

[4] These figures refer to rail track-kilometers (and not rail line kilometers)

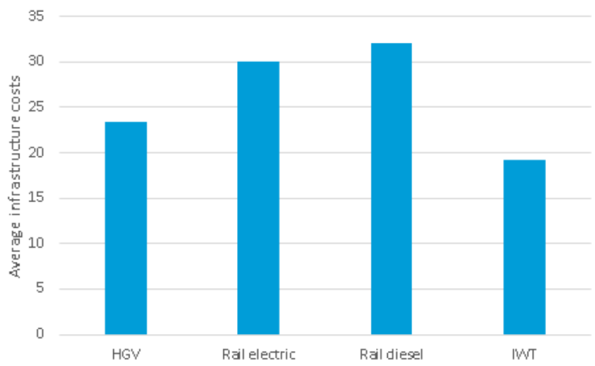


Figure 3 Average infrastructure costs in 2016 for road, rail and IWT freight transport in the EU28 (€ per 1000 tkm, PPS adjusted) [8].

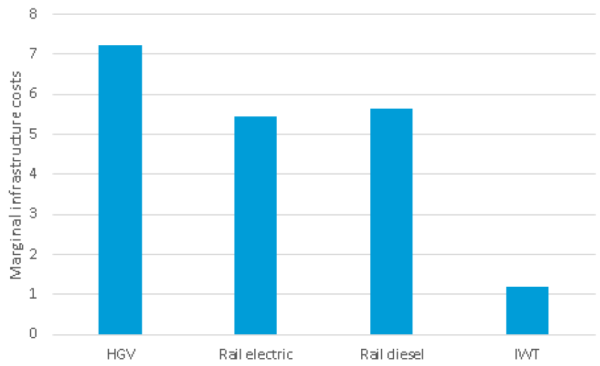


Figure 4 Marginal infrastructure costs in 2016 for road, rail and IWT freight transport in the EU28 (€ per 1000 tkm, PPS adjusted) [8].

The highest average infrastructure cost was observed for rail transport. The authors explain it with higher fixed costs of railway infrastructure compared to road infrastructure (respectively 200 000 € and 30 000 € per track/road-kilometre).

Interestingly, the cost of diesel trains is higher than for electric trains. It is explained with difference in average load - 512 and 494 tonnes per train, electric and diesel trains respectively. Another possible cause they point out is a probability of the lower intensity of use of diesel rail infrastructure[5] (compared to electric rail infrastructure). Therefore, the high average fixed costs are divided by less diesel trains. Analogically, the difference between HGV (Heavy goods vehicle) and railway freight transport may be explained.

On the figure 4 the marginal infrastructure costs are shown. The marginal cost (usage-dependent renewal and maintenance costs) for road freight transport is the highest– 7,2 € per 1000 tkm. For electrical and diesel trains it was equal 5,5 and 5,6 € per 1000 tkm, respectively. The change of the order in relation to average costs, shows that the effect of fixed costs diminished for modes comparison.

On figure 5 marginal infrastructure costs for all the countries included in analysis are presented.

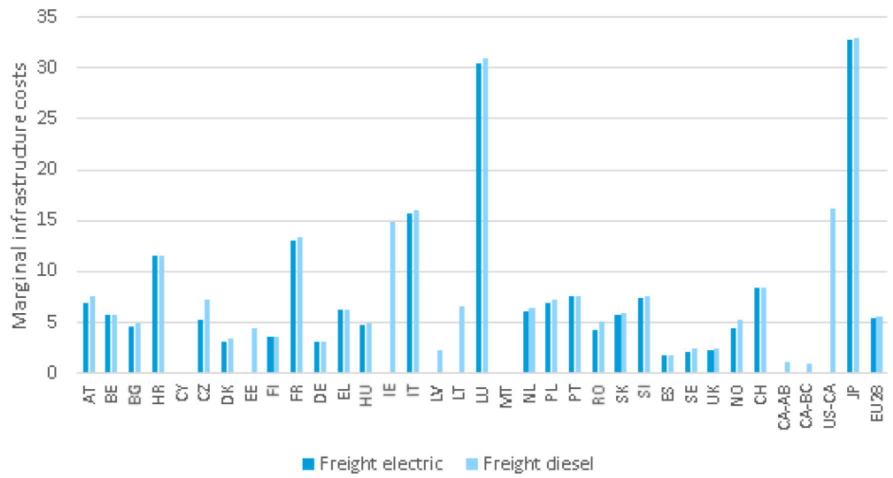


Figure 5 Marginal infrastructure costs rail freight transport in 2016 (€ per 1000 tkm, PPS adjusted) [8].

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[5] In this methodology the cost incurred by diesel trains are only the infrastructure costs on non-electric lines.

The marginal costs should be lower and the differences between the countries should not be that huge. An enormous deviation from average marginal cost was observed. In the European Union the marginal cost oscillates from about 2 € to over 15 € per 1000 tkm (or over 30 € per 1000 tkm for Luxemburg which was assumed as outlier).

The results of that study do not align with the study described before, even though it is based on its recommendations. Moreover, the differences of the marginal costs between the countries are enormous. That raises the question if the approach used was appropriate.

In a more recent study by Smith et al [9], different methodology was used. The figure 6 presents its procedures.

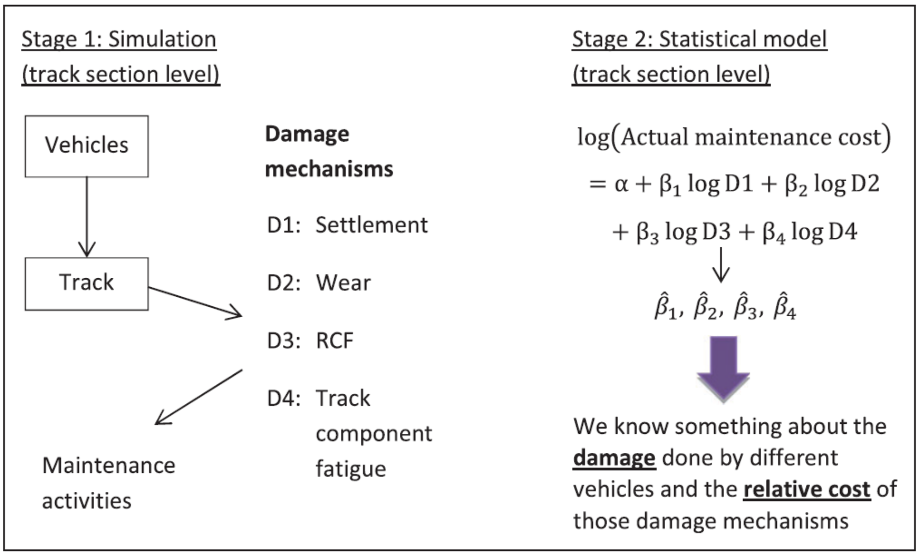


Figure 6 Overview of the methodology [9]

The approach involves two stages. The first one base on a bottom-up method and is used to find the measures of the different damage types per ton-km for each vehicle type.

Smith et al. pointed out that the damage measures also depend on infrastructure characteristics such as track geometry and curvature. Therefore, they divided the track sections on 10 different subsections categories depending on its radii length: 0–400 m, 400–600 m, 600–800 m, 800–1000 m, 1000–1500 m, 1500–2000 m, 2000–3000 m, 3000–5000 m, 5000–10000 m and above 10000 m. They used data provided by the Swedish Transport Administration (Trafikverket) from 2014. It involved infrastructure and traffic characteristics of 143 track sections in Sweden (whose total length comprise about 11000 km). The data also included information on vehicle types and their ton-km values. In the study the vehicles were categorized due to type of the running gear, vehicle category (freight/passenger), axle load and maximum speed. However, the speed of vehicles was assumed to be the permissible speed on each line.

The damage was divided into four categories due to its mechanism: wear, rolling contact fatigue (RCF), track settlement and track component fatigue[6]. The damage values were calculated for all of the subsection categories listed before for every vehicle operating on that specific section. They were

[6] The components affected by the repeated loading are rails, rail pads, rail fasteners, and sleepers.

expressed in damage index per track-km. For all types of damage, the maximum values were considered. Then the damage values were summed for all axles.

The simulation was exercised using Swedish multibody simulation software GENSYS.

The damages values calculation was based on models developed by various academics. The settlement damage was calculated using Technical University of Munich model:

$$Settlement = A \cdot Q^{1.21} \log N \quad (1)$$

where N is a number of axle passes, Q is the dynamic vertical force at the wheelset (in this case the values of 99,85th percentiles were taken from the simulations), and A is a constant (A=1).

To calculate track component fatigue, UIC/ORE10 calculation method was used:

$$Track\ component\ fatigue = \frac{1}{n_v} \cdot \sum_{i=1}^{n_v} \left[\sqrt{{Q_{tot_i}}^2 + {Y_{qst_i}}^2} \right]^3 \quad (2)$$

where n_v is the number of axles, Q_{toti} is the sum of static, quasistatic and dynamic vertical force (from the simulations - 99,85th percentiles), and Y_{qsti} is quasistatic lateral force.

The wear damage is expressed as the dissipated energy in the wheel-rail contact patch.

$$\bar{E} = F_x \nu_x + F_y \nu_y + M\varphi \quad (3)$$

where, F_x and F_y are longitudinal and lateral creep forces, v_x and v_y are longitudinal and lateral creepages, and M is the moment and φ is the spin in the contact patch.

The RCF calculation is also based on the energy dissipation. Firstly the energy dissipation is calculated and then the RCF index is taken from the diagram (figure 7).

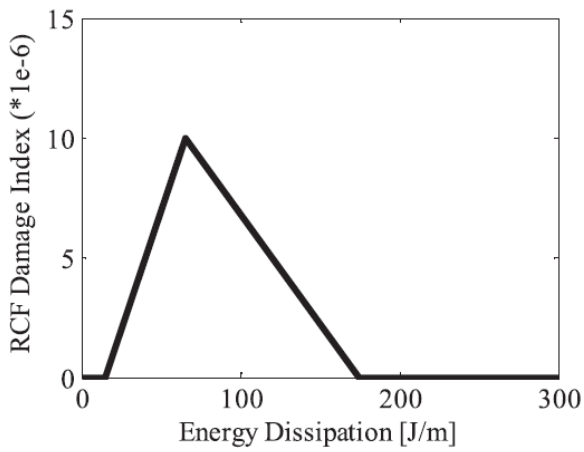


Figure 7 Rail RCF damage function [9], [10]

In the second stage cost elasticities for damage types are derived with econometric methods. Due to the lumpy nature of renewals and data for just one year, the marginal cost is constituted only by maintenance cost.

The maintenance cost (C_i) is expressed as a function of damage types (D_{1i} – D_{4i}) and infrastructure characteristics such as track length and the average age of rails (X_i) (formula below).

$$C_i = f(D_{1i},\ D_{2i},\ D_{3i},\ D_{4i},\ \boldsymbol{X}_i) \quad (4)$$

where i = 1; 2; ...; N are track sections.

Thus the maintenance cost is not only dependent on damage caused by trains but also on the infrastructure characteristics.

The model is a second order approximation of a cost (production) function. In this model marginal cost is a dependent variable and damages and infrastructure characteristics are independent variables. Both were subjected to logarithmic transformation, which reduces skewness and heteroscedasticity, thus it helps to avoid an invalid statistical inference.

Finally, marginal cost per damage unit is evaluated and next it is connected with vehicle types due to the amount of damage per ton-km they incur according to the first stage of the study approach.

Table 3 presents a weighted marginal cost per ton-km for each vehicle type. It contains wear and settlement damages caused by a particular vehicle, marginal costs of those damages and total marginal cost.

Table 3 Damages and marginal costs SEK[7] per ton-km and vehicle type [9].

Vehicle type	Wear per ton-km[a]	Settlement per ton-km[a]	MC wear[b] (equation (10))	MC settlement[b] (equation (10))	Total MC[b]
Motor coach 4×21 t, V_{max} 200 km/h[c,d]	209.76	995 468	0.0295	0.0093	0.0389
Three-piece bogie 4×30 t, V_{max} 60 km/h, laden	97.56	867 067	0.0137	0.0081	0.0219
Passenger car 4×14 t, V_{max} 160 km/h	57.34	741 423	0.0081	0.0069	0.0150
Freight loco 6×30 t, V_{max} 70 km/h	36.85	1 001 992	0.0052	0.0094	0.0146
Freight loco 6×20 t, V_{max} 120 km/h	36.90	945 300	0.0052	0.0089	0.0141
Motor coach 4×16 t, V_{max} 200 km/h[d]	41.46	852 697	0.0058	0.0080	0.0138
Passenger Loco 4×19 t, V_{max} 175 km/h	40.69	740 151	0.0058	0.0070	0.0128
Three-piece bogie 4×6.5 t, V_{max} 60 km/h, tare	50.22	602 992	0.0071	0.0056	0.0127
Passenger Loco 4×19 t, V_{max} 140 km/h	40.85	748 934	0.0057	0.0069	0.0127
Motor coach, Jacob bogie 3×16.5 t, V_{max} 160 km/h[d]	53.58	476 803	0.0075	0.0045	0.0120
Y25 bogie 4×22 t, V_{max} 100 km/h, laden	30.32	795 901	0.0043	0.0075	0.0117
Freight wagon 2×6.5, V_{max} 100 km/h, tare	49.75	383 151	0.0070	0.0036	0.0106
Motor coach, Jacob bogie 3×12.5 t, V_{max} 200 km/h[e]	33.73	571 887	0.0048	0.0054	0.0101
Freight loco 4×20 t, V_{max} 120 km/h	**21.75**	**743 656**	**0.0031**	**0.0070**	**0.0100**
Motor coach 4×12 t, V_{max} 140 km/h[e]	21.12	668 032	0.0030	0.0063	0.0092
Freight wagon 2×22 t, V_{max} 100 km/h, laden	26.48	464 017	0.0037	0.0043	0.0081
Motor coach 4×16 t, V_{max} 200 km/h[e]	12.03	676 894	0.0017	0.0063	0.0080
All vehicles, weighted averages	44.10	751 142	0.0062	0.0070	0.0132

[a] $\sum_i \frac{D_{ijv}}{GTkm_{iv}} \cdot \frac{GTkm_{iv}}{(\sum_i GTkm_{iv})}$ (the last part of equation (10)).
[b] SEK in 2014 prices.
[c] High centre of gravity.
[d] Stiff wheelset guidance.
[e] Flexible wheelset guidance.

The charges for the vehicle types listed in the table oscillate from 0,88 to 4,28 € per 1000 tkm. For all the vehicles the weighted average charge is equal 1,45 € per 1000 tkm.

Regarding the results presented on table it was observed that generally the marginal cost increase with:

- Number and mass of axles,
- Maximum speed,
- Stiffness of wheelset guidance.

Interestingly, a tare freight wagon (2 x 6,5 t, V_{max} 100 km/h) obtained higher marginal cost than corresponding laden train (2 x 22 t, V_{max} 100 km/h). The costs were respectively equal SEK 0,0106 and

[7] Average exchange rate in 2014: 1 € = 9,1021 SEK, 1 SEK = 0,1099 €

SEK 0,0081 € per ton-km. Although laden wagons induce bigger settlement, the tare wagons cause higher wear. It is explained with the fact that a lighter vehicle "moves around" on the track. [9]

What also draws attention is the big relative difference between the marginal cost of passenger car 4 x 14 t, V_{max} 160 km/h and freight loco 4 x 20 t, V_{max} 120 km/h. Even though the axle load of the freight train is 6 tonnes bigger the settlement damage caused is almost the same as for the passenger car. However, the dynamic vertical force not only depends on axle load but also on velocity. On the other hand, the passenger car causes almost 3 times higher wear damage.

2.3.2. Research on pricing systems and its impact

In regards to pricing systems analysis and evaluation, many reports and papers have been published in last ten years. This section reviews some of them.

Prodan et al. [11] evaluated an impact of legislations on tariff systems of Europe. They examined the evolution of tariff levels and how did the complexity of the systems change between 2005, 2007 and 2012.

Those time periods are related to directives from years 2001, 2004, 2007 and 2012. An important time mark is 1 January 2007 as Directive 2004/49/EC fully opened the rail freight market to competition since that date. The Directive 2007/58/EC introduced open access rights for international rail passenger services, whereas Directive 2012/34/EC mainly concerned separation of infrastructure management from operations.

In regards to complexity of the charging systems, it was observed that the number of variables has increased definitely between 2005 and 2012, whereas it remained similar in the period between 2005 and 2007 [11]. The changes are presented on the figure 8.

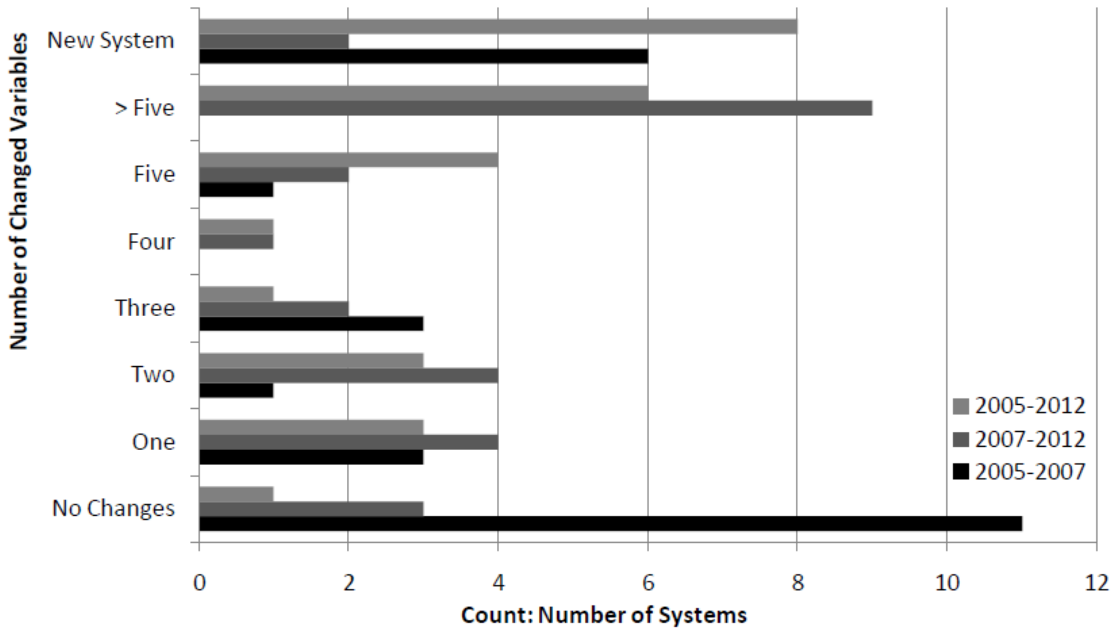
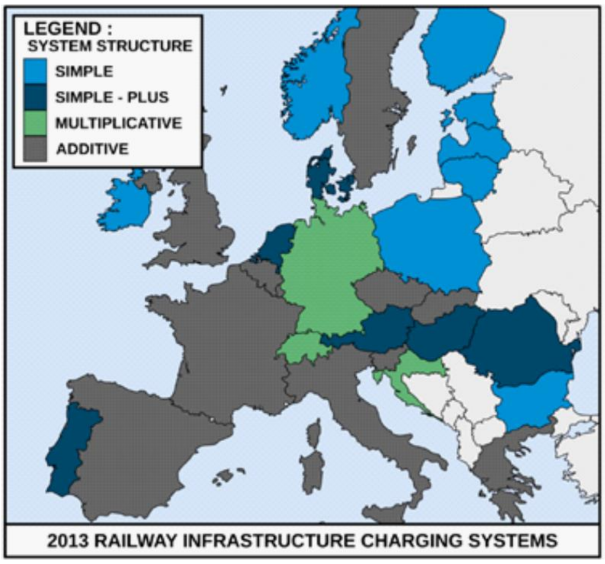


Figure 8 Summary of Tariff Structure Changes 2005-2012 [11].

In quantitative analysis the level of charges for selected Origin-Destination (OD) pairs were examined for 2007 – 2012 period. An increase of dispersion in tariff system has been observed. The charges generally increased for high-speed lines (HSL), while they rather remained the same or decreased for regular lines [11].

The work that has the most influence on my thesis is the UIC report [2]. It is used as a reference point to which the present situation is compared. The report presents existing conditions in rail freight market for 2013 year. It refers to objectives of European directives 2001/14/EC and 2012/34/EC (mainly regarding the separation of infrastructure management from operations) and assess the impact of these legislations on pricing systems of each member state.

The report describes the structure of the systems along the Europe. The classification used consist of 4 categories: simple, simple plus, multiplicative and additive. A simple charging system contain only one price per-train-kilometre or per-tonne-kilometre, whereas a simple plus one may include additional parameters. A multiplicative one uses multiplicative factors, which modify base price due to certain parameters. On the other hand, an additive system is constituted by multiple charges, which may be structured as a simple, multiplicative or other formula. Those systems consider only fees included in the minimum access package. It was noted that the system structure varies significantly from country to country and often even neighbouring countries have different structures. The geographical distribution of the system is presented on the figure 9.



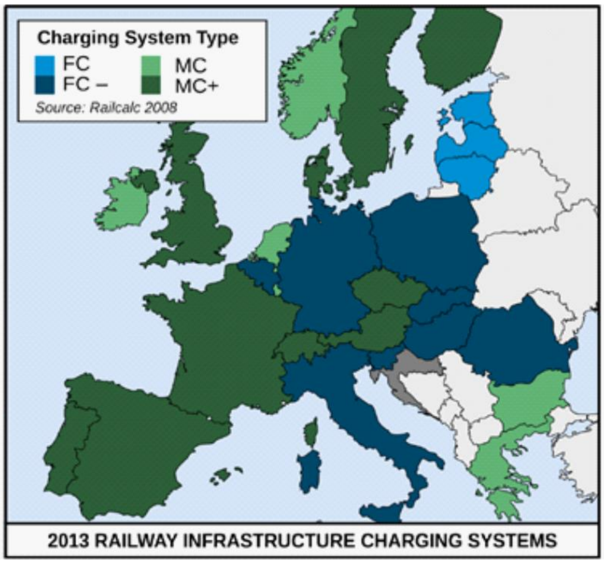


Figure 9 System structure Types [2]. **Figure 10 Charging System Philosophy [2].**

In other part of the qualitative analysis the charging system philosophy is examined. It describes the cost-recovery goals set by IM. Marginal cost systems recover only direct costs. In case of marginal cost plus system it contains also a mark-up. In full cost systems, the full operation costs are passed on to the RUs as charges. If a government set a subsidy to help recover the costs, the system is classified as full cost-minus [2]. Although the directive 2012/34/EC require to base the charging systems on marginal costs, it is not a legal act. It takes time to incorporate it as a law in each member state and the IM need some time to adjust its system. It came to law only in 2015 with Regulation 2015/909 and the infrastructure manager could gradually adapt to it at most in four years. The results presented on figure 10 were derived from RailCalc study from 2008, because at that time it was not required from IMs to state the charging philosophies. It was pointed out, that the systems classified as marginal cost-based not always demonstrate the calculation methodology and it may not be rigorous. It was noted that the charging philosophy had been evenly split along Europe.

In the quantitative analysis it was observed that the charges vary substantially for selected National OD pairs. Only half of the examined countries' charges were between 1,5 € and 3,5 € per train-km, while the highest charges reached about 10 € per train-km. The complexity of charging systems was not found to be correlated with charging levels. The levels of the charges are presented on figure 11.

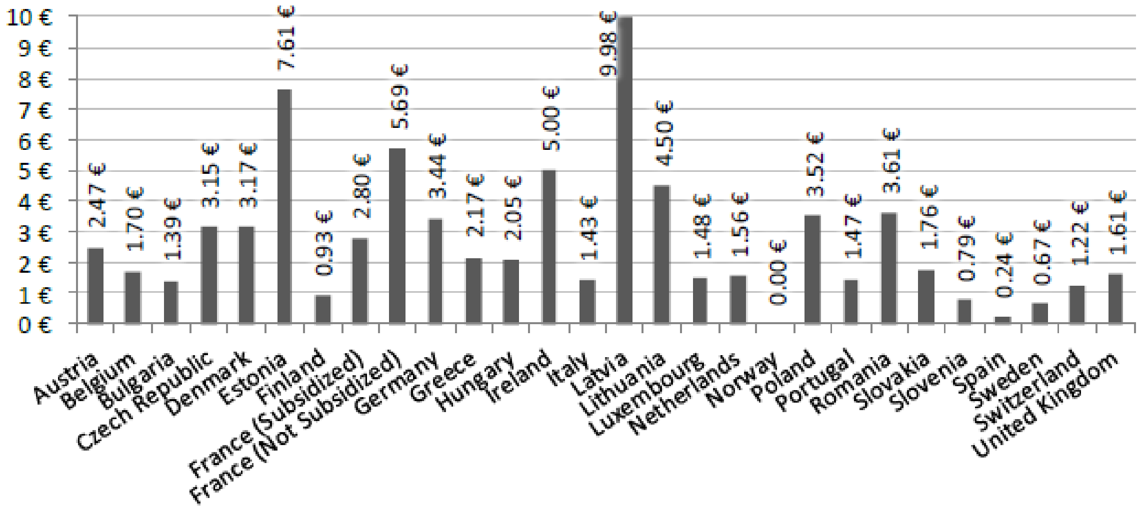


Figure 11 National OD Pairs (500-tonne train) - € per km [2].

It was observed that, the pricing systems along the Europe also differed significantly in regards to weight change. The charges per train-km for 500 t, 1000 t, 2000 t and 3000 t were compared. France, Spain, Latvia, Norway, Portugal and Spain did not condition their charges on weight, whereas in Finland and Ireland charges increase proportionally with weight growth. It was pointed out that most countries do not depend on axle load increase, however some of them set a maximum axle load limit on their lines.

In regards to international corridors naturally the charges vary less between, as the charges are the average of the fees in countries that are included in the corridor. The median charge was around 2,5 € per train-km and half of the charges were between 2,3 € per train-km and 3,2 € per train-km. Nonetheless, the charges kept to vary substantially within the corridors. For instance in Corridor 4 they varied from 0,27 to 5,10 € per train-km (figure 12). The authors of the report raised the question if it was fair to recover more costs from one train with particular willingness to pay by one country than its neighbours.

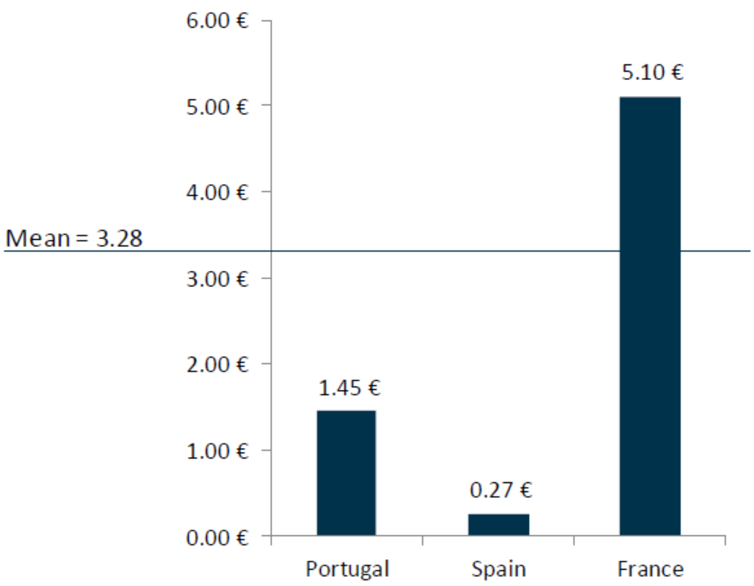


Figure 12 Cross-border Comparison: Charges (€ per train-km) for European Freight Corridor 4, 500-tonne train (the mean value is an average charge for entire corridor) [2].

Moreover, it was pointed out, that the RUs using the corridors, have to deal with from 2 to 7 infrastructure charging systems, in spite of one-stop-shop for the corridor. The variables with greatest impact on charges turned out to be: train type, time of day, train speed and line type/importance. Adjusting to them for RUs operating on international corridors is impeded as they differ throughout the countries.

Another existing problem pointed out by UIC [2] is Network Statements complexity in regards to charging system description. The authors recommend to construct it in concise, clear and understandable manner. The Network Statement should prevent all the necessary information to calculate the infrastructure charge. Very convenient would be also if the IMs did not refer to number of annexes. Other necessary features that allow charges calculation is well-translated English and information on all line segments, including any eventual categorization.

The freight transport tariff systems were also evaluated by Lopes [12]. Lopes pointed existence of heterogeneity in terms of design of systems and usage fees values. In addition, it was noted that in period between 2012 and 2013 IMs attempted to optimize their systems, which resulted in instability in the choice of parameters. The systems along the Europe differ also in terms of unit per which the charge is levied. It influences then the decisions of train operators. While charge levied in € per train-km works as incentive to use fewer and longer trains, unit € per tkm encourage to usage for lighter trains. Selection of parameters to be charged may eventually be the base of competition bias. The discrimination was pointed on both national and international levels. As an example Lopes [12] pointed annual fee for access to the infrastructure depending on the operator's estimated total volume of traffic in Spain. It can be considered discriminatory as new operators may not have the liquidity to pay this amount at the outset [12]. These issues provide an “invisible barrier” to international freight transport in Europe, which in effect decrease of the competitiveness of the rail mode [12]. Meanwhile Spanish system has evolved removing this barrier, as further shown in the next chapter.

Lopes [12] recommended definition of criteria and objectives jointly by the IMs and simplification of the tariff systems, retaining only the most basic variables related to the characteristics of rolling stock, infrastructure and operation.

Another study of UIC [13] examine railway infrastructure pricing systems for 2017 exclusively for passenger services. This thesis focuses on freight transport, hence in this work overview just the parts that concern general analysis of the systems, notwithstanding issues related strictly to the passenger segments.

Teixeira et al. [13] examined the IMs alignment with legislation focusing on market segmentation and marginal costs. Due to Directive 2012/34/EU, the rail transport market should be divided on minimum six segments including distinction between:

- Domestic and International traffics,
- Passenger and Freight services,
- Urban and Regional and Long-Distance services,
- Regular and Occasional (ad-hoc) services,
- High-Speed and Conventional traffic.

The figure 13 shows the state of market segmentation in 2017.

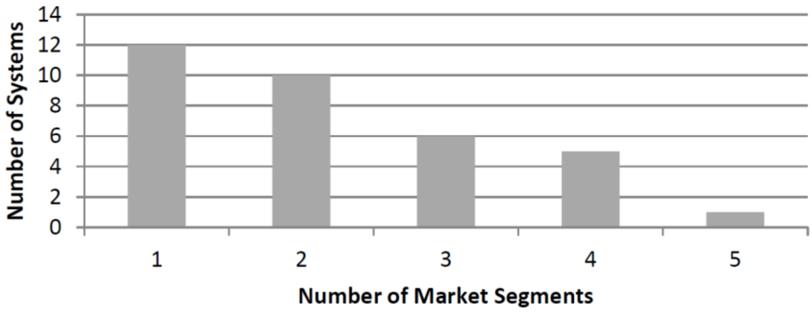


Figure 13 Number of charging Systems vs. Number of Market Segments [13].

The idea of market segmentation is related with different willingness to pay for the market segments, which is supposed to be a base for IM to establish a mark-up level. Although IMs subjected to European directives cannot use full costs charging system type, they can aim recovering full costs using mark-ups. On the other hand, country may fully subsidize an infrastructure manager so as to promote mobility and set mark-ups zero.

Teixeira et al. [13] points out that high-speed services have a high willingness to pay, whereas commuter and regional trains, which normally are unprofitable, have a low willingness to pay. Therefore, high-speed services segment may be levied with high mark-up and commuter and regional trains may require subsidies. However, the IM should bear in mind that higher mark-ups may result in reducing frequency by RUs.

The report [13] also mention misalignment with legislation that concerns marginal costs. Regulation 2015/909 impose on IMs justification of charging marginal costs in case if they exceed the given threshold of 2 € per train-km for a 1000-tonne train. For the charging systems based on marginal costs, the component considered as marginal cost was compared with the mentioned limit. To align with the legislation, IM have to declare that the system is based on marginal cost and to publish marginal cost calculation methodology. However, if marginal cost is less than 2 € per train-km for a 1000-tonne train, the regulatory body may accept the calculation, desisting strict control. In result it was shown that the great majority of IMs didn't align with the legislation. Teixeira et al. [13] comments on the state of existing competition in the market for passenger services by then. It was noted that for most countries domestic markets are still closed. Generally, opened markets contain numerous operators, however sometimes markets are opened only officially, while detaining competition by not clear means.

The report [13] also leaves remarks on industry structure in regards to vertical separation. Two models were pointed out: financial separation of the legacy railway company into infrastructure manager and operations and full separation. The first one maintains institutional links which may result in hindered competition. The latter is more transparent. Along the Europe both models are applied with a similar frequency. Less popular, additional measure is separate capacity allocation body. It usually does not favour any incumbents nor other industry subjects.

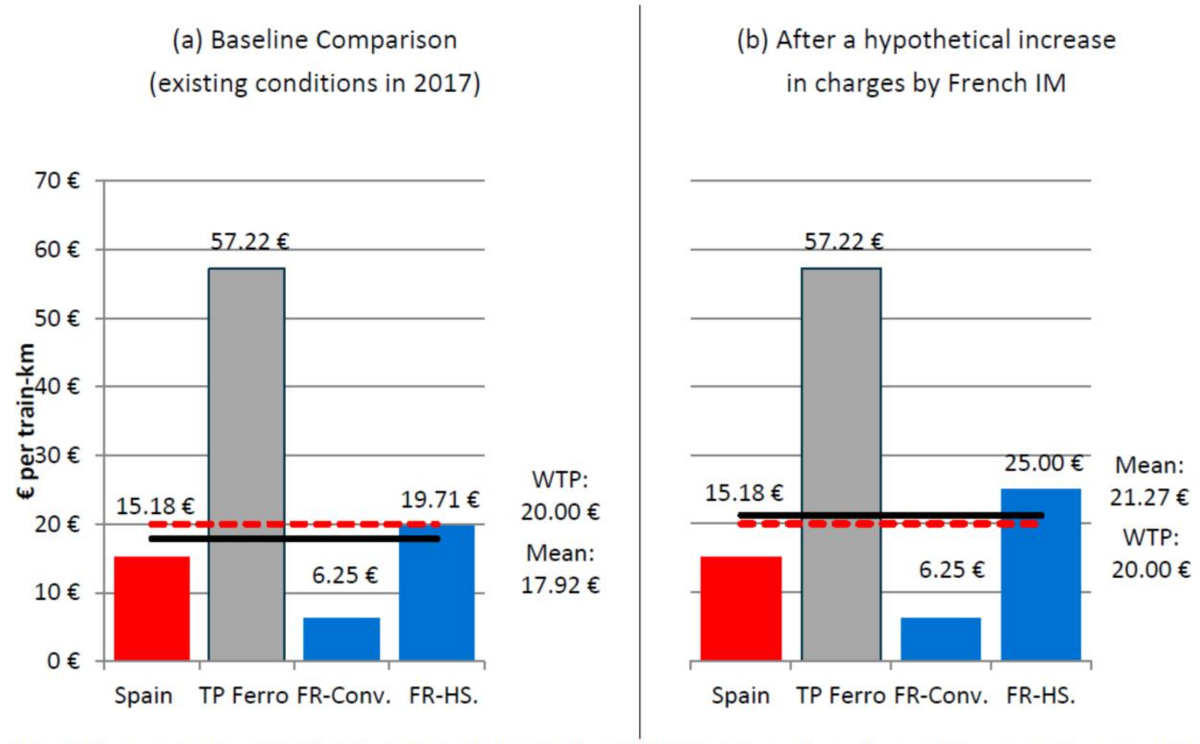
Teixeira et al. [13] explains why the pricing systems change over time and differ so remarkably, referring to legal situation in early 2000s. Then the infrastructure charging systems was open to interpretation. Each country could use different charging methodology and levels. Adoption of European directive 2015/909 was to mitigate the heterogeneity, by requiring from the pricing systems to be based on direct costs. It resulted to many significant changes in the systems along the Europe. The study provides an overview of evolution of some charging systems in period between 2007 and 2017. The Italian system was highlighted as it remained complex. It contained a fixed and variable components and it was strict in capturing the impact of train on the network. It included charges that considered number of pantographs, nodes, train speed and traffic density of a line. The charging system was presented in unfriendly way. It referred laws and regulation without providing access to them. Only some of parameters changed over time, however it was stated that for the year 2018 system would go through substantial changes, due to 2012/34/EU regulation [13].

The French system remained relatively stable. It was pointed out, that a number of lines were reclassified and new line class were added to better reflect the willingness to pay of trains on those lines [13]. Besides that, coefficients were slightly adjusted. In spite of small changes, the system was said to changed enough for a RU to be affected [13], which could even result in loss of relevance of already purchased rolling stock fitting to then existing charging system.

Enormous changes were found in the Swiss infrastructure charging system. Firstly, until 2013, Switzerland stopped charging for nodes, divided its network into lines due to traffic density, introduced a peak hour coefficient, removed charges for special infrastructure (for instance tunnels) and included charge for train path quality [13]. Then, in 2016, Switzerland introduced a new charging system, which used a bottom-up approach. It required testing and certification of all train types. The direct cost was calculated using variables as track radius, train speed and train type. It represented well a train influence on the infrastructure, but it was difficult to comprehend for RU.

The difference within the international corridors may come from the charge levels. That divergence may result in injustice between IMs. As an example in the UIC report [13] was brought the line between Barcelona and Paris. It consists of sections with four different charge levels: Spanish section between

Barcelona and TP Ferro, TP Ferro – the HSL connecting Spain and France, a French conventional line section, and a French HSL. The charges for those sections are presented on figure 14.



*Note: willingness to pay of 20.00 € per train-km is **assumed** and should not be used or referenced for any purpose except to show the problem described in this section.*

Figure 14 Power of a Single IM over an international Corridor - an example of hypothetical increase in charges [13].

The baseline charge level comparison presented in part (a) was juxtaposed with hypothetical increase in charges by French IM to 25 € per train-km. That said, the mean charge would increase from 17,92 to 21,27 € per train-km. To exemplify the eventual problem, amount of 20,00 € per train-km was assumed as willingness to pay of the RU on that line. In that case the train would no longer be profitable, thus the RU would decide not to operate it.

The report set out recommendations and guidelines how to construct the infrastructure charging system in particular cases. For example, in case when IM wants to increase frequency, the system should involve a component that reflects direct costs and a mark-up lower than the willingness to pay. Additionally, IM should encourage to use 2 shorter trains rather than one longer by charging per seat-km or number of seats in a way that charge would increase more than linearly [13].

In case of saturated lines it is recommended to apply high mark-up, to encourage to longer trains, by charging per train-km, to surcharge during peak periods or even applying other concepts that influence the capacity utilization (for instance penalty for deviating from a target speed) [13].

Teixeira et al. [13] list 6 general recommendations:

1. Move towards a common implementation of EU policies in each Member State.
2. Simplify charging system structure.
3. Make charging systems stable over time.
4. Standardize incentives, variables related to rolling stock, and calculation methodology for direct costs.
5. Resolve the problem of international corridors by making international charges consistent for the entire corridor, and by establishing an EU regulator.
6. Increase equity in infrastructure charges between modes, giving priority to modes with fewer externalities, increasing environmental and societal benefits.

Other issue mentioned by Prodan et al. [14] and in UIC study [13] is relation between cost and revenues. Prodan et al. [14] analysed the impact of infrastructure charge systems on RU revenues in period between 2007 and 2012. They estimated revenue per-train and compared to the train's infrastructure charge levied by the IM, keeping the assumptions consistent with ones made in previous UIC studies. It was found that infrastructure charges made significant part of RU revenues. For instance, for French high-speed lines made up above 25%, for Italian HSL between 6% and 15% and for Spanish HSL – between 15% and 40%. It was noted that the revenue for high-speed charges played an even bigger role than for most conventional lines [14].

Similar conclusion were withdrawn in UIC study [13] from 2017, where it was observed that that from 15% to 30% of the RUs revenues goes to pay infrastructure charges.

On the other hand from the IM perspective both studies [14], [13] also agree on fact that on that most of lines manage to recover required maintenance costs and even a significant portion of initial investment cost for high-speed lines [14]. In 2017 the net revenue for analysed lines was assessed to be between zero and 0,25 M € per year, which makes between 1,0% and 2,5% per year of construction costs [13], however French lines recovered between 1,0 M € and 1,5 M € per year, which makes between 8% and 35% of initial construction costs, depending on the line [13].

Many sources recommend various means that lead to opening the rail market. Crozet [6] analysed the liberalization and competition in the European railway sector. He points out that the first and second "Railway Packages" brought significant changes. Markets got more open and competition introduced [6]. It was highlighted that liberalisation led to a great transformation of the sector, although no obvious direct causality relation had been noted between opening to competition and rail freight market share [6].

What´s important Crozet emphasize that liberalization itself is not the main goal, but a mean to achieve higher efficiency and affordable prices and in result – an increase of traffic [6]. Relation between the liberalisation (Rail Liberalization index - RLI[8]) and traffic growth between years 2003 – 2012 is presented on the figure 15.

[8] Rail Liberalization index (RLI) tracks in details degrees of liberalisation. It considers, inter alia, information, administrative and operational barriers, the regulation of market access and the power of market authorities. The bigger index the more liberalized market.

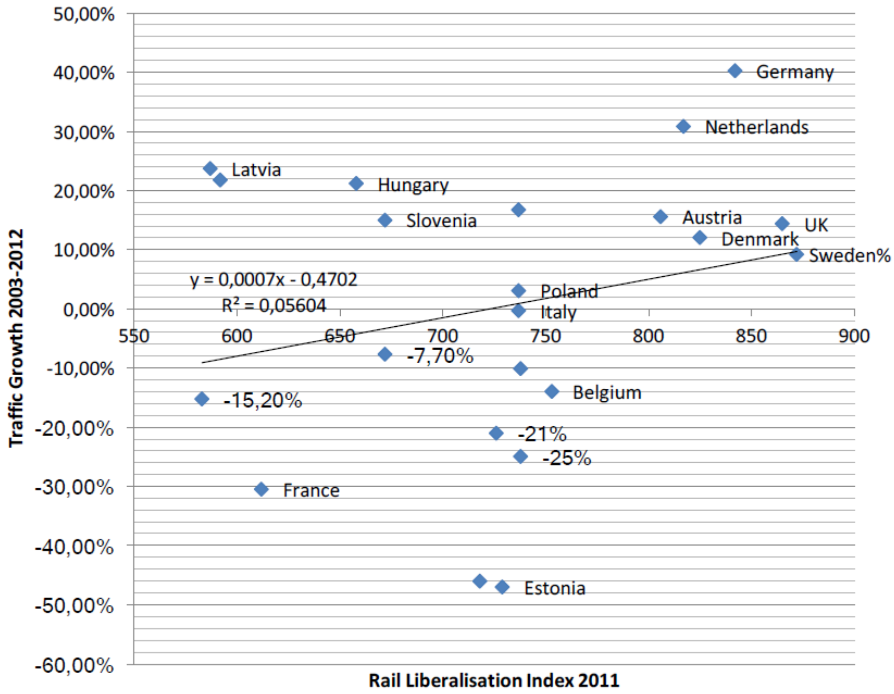


Figure 15 RLI and rail freight traffic growth (2003 - 2012) [6]

Crozet claims that relation between liberalisation (RLI) and traffic growth "is not easy to establish" [6]. He points out that "countries with a RLI higher than 750 have all encountered increases in traffic" [6], which in fact, looking on the diagram, is not true due to fact that Belgium had higher RLI than 750 and encountered decrease in traffic about 14%. Crozet attempt to find application of the relation between RLI and traffic growth, suggesting that possibly a threshold of liberalisation have to be reached to inject dynamism into the sector [6].

Crozet leaves accurate observations on rail transport sector nature. It deals with numerous entry barriers and market power that manifest itself in many areas of rail freight (for instance freight terminals are often owned by incumbent operator) [6]. Regarding network access rail and road differ greatly. Rail traffic has to be planned, often even several months in advance [6], whereas road infrastructure is always ready to use.

The analysis of Crozet is highly valuable. It gives a notion how to understand liberalisation and competition. Nevertheless, his approach raises some questions and perhaps it could be refined to be more accurate.

Firstly, traffic growth between years 2003 and 2012 and RLI in year 2011 could be not necessary the best parameters for attempting to find relation. There is no information included what happened with liberalisation in period 2003 – 2011. Did RLI increase or was it the same all the time? For instance, if the RLI changed just in 2011 and traffic grew between 2003 and 2010 and then started to drop, the growth of traffic between 2003 and 2012 would have nothing to do with RLI. The same can be noticed for the contrary: if the RLI changed just in 2011 and traffic decreased between 2003 and 2010 and then started to grow, the traffic drop between 2003 and 2012 would have nothing to do with RLI. The negligible correlation obtained in the analysis, should be expected. Comparison that would have more value is traffic growth with constant RLI in particular time period, or comparison traffic growth with RLI growth in same time period.

Besides selecting not representative parameters, traffic growth could be not the best indicator of the rail freight transport development. At the same time traffic growth of road freight transport could have increase much more than rail freight transport. In result rail traffic would become even less relevant. The traffic growth is convergent with economy growth. Crozet claimed that “countries with a RLI higher than 750 have all encountered increases in traffic […]”. All of those countries belong to group of the most developed European countries, therefore it is expected to observe economic growth, thus traffic growth. How did rail freight transport share change in that time?

Other question is what unit of the traffic should be compared. Perhaps more relevant way to present freight transport than tonne-km could be mass of transported goods. Increase of tonne-km could mean increase of distance, which could happen because of changing the route from optimal to less optimal.

The UIC [15] report perceived future challenges for railways**.** One of them is opening of the domestic railway markets leading to increase of competition and more efficient operations. The other one is related with competition between the modes. The development of automation may increase attractiveness of road transport as automated cars will be able to provide a solution to the last mile problem in the short term. They will be able to travel in platoons at high speeds while providing door-to-door service. Railways should also take benefit of the automation development. It could be used in operations in order to increase capacity and reduce operating costs [15].

2.3.3. Discussion

This chapter provided knowledge on many subjects related with rail infrastructure pricing systems. The reviewed analyses came from various sources. They did not always have the same conclusions. Those divergences raise some questions and discussion.

The legislations were met with objections and the member states not always fully aligned with them. Complete separation of infrastructure management and operations was opposed by some member states, what postponed its full introduction. Most of IMs didn´t divide rail services on demanded amount of segments [13]. The marginal cost calculation was not provided by great majority of IMs [13]. It would be of interest to assess if that still applies today.

The impact of directives has been also analysed. In the 2007 – 2012 period an increase of dispersion in tariff system has been observed.

The studies, concerning calculation of cost directly incurred, applied various approaches, which resulted in different marginal costs.

- In CATRIN study [7] the marginal cost fluctuates from 0,32 to 1,73 € per 1000 gross tkm, while charges for freight trains are quite lower (from 1,4 to 7,6 times) than charges for passenger transport.
- In the report of EC [8] the average marginal cost for freight trains in the European countries is equal about 5,5 € per 1000 gross tkm.
- In the study of Smith et al. [9] the average marginal cost is equal 1,45 € per 1000 tkm, whereas the charges of freight and passenger vehicles are similar.

The results from report of EC [8] stands out significantly from the other studies. The other studies obtained similar results, however they differ in terms of distinction between freight and passenger transport costs. The first and last mentioned studies are done by same authors. In the first one they put an accent on relation between marginal cost and traffic density and track quality. It was also noted that it is beneficial to favour less damaging vehicles. In the last one no more traffic density had relevance. It showed that the marginal cost is driven by infrastructure characteristics and vehicle features such as: number and mass of axles, maximum speed, stiffness of wheelset guidance.

The studies that use econometric approach are sensitive to traffic density. The marginal cost on track sections with low occupancy was higher than the track sections with high traffic density. That may mean that the marginal cost in this method may include the maintenance works that are undertaken regularly notwithstanding the damages occurring on the track.

On the contrary, in the studies that use engineering approach the marginal cost results from the damage caused by the train with regards to characteristics of infrastructure and of train.

In terms of marginal cost comparison due to traffic mode, the road freight transport turned out to be more expensive than rail freight transport. However, the results from the report of EC [8] seem to be inflated, thus the level of the differences should not be highlighted.

The issues as heterogeneity and disparity of pricing system structure and charge levels and system complexity are related with problems existing in international corridors. Train operators (TO) have to deal with totally different systems even in neighbouring countries. They differ with number of variables, charge levels, charge types which provide an “invisible barrier” for TO. Moreover, in the Network Statements charging systems were often described in complex and unfriendly way. Many studies agreed on tariff systems simplification and stabilization over time.

On the other hand, the study on calculation of cost directly incurred showed that it depends of multitude of variables regarding infrastructure and rolling stock characteristics. Maybe the resolution to that problem is not system simplification but rather improving its description. Stabilization of the systems not always is possible when the directive imposes new limits and rules.

The shift from road to rail is supposed to be achieved by increasing of competition by mean of lines liberalization. However, the impact of liberalization has been noticed and the competition has introduced, the shift from road to rail is negligible. Interestingly, in the Crozet’s [6] word choice: “[…] the relation between liberalisation (RLI) and traffic growth is not easy to establish” can be found a shadow of prejudice, as instead of finding the relation, it is tried to establish it.

This chapter showed that there is a number of issues of interest to be worked on. This thesis will focus on pricing systems for freight rail transport. It will involve analyses of charging systems structure, evolution of charge levels and alignment with directives. At the end the modes of rail and road freight transports will be compared.

3. State of the practice on railway infrastructure pricing

3.1. Methodology

The methodology applied in this study corresponds with one in the study UIC STUDY of European Railway Infrastructure Charges for Freight [2], as its results are used in the chapter 4 to observe evolution of railway infrastructure pricing systems.

This study concerns the current state of practice on pricing systems in 10 selected European countries, taking part in one of most relevant European Freight Corridors (EFC). It is based on Network Statements for 2023 provided by each IM.

Chapter 3. involve analysis of the current state of practice divided on four subsections. The first one concerns charging systems qualities, the second one focuses on charge levels using various assumptions, the third one compares rail freight transport with road freight transport pricing and the fourth one focuses on Network Statements (mainly on chapter on services and tariffs). The methodology briefly described above is applied to all the analyses, however it is developed further for each of them.

3.2. Qualitative Analysis of Charging Systems

In this section infrastructure pricing systems for rail freight transport of selected countries are described. For each Member State the Infrastructure Manager is introduced. Then the components of the charge for the minimum access package are described. Due to Directive 2012/34/EU it should result from the direct cost. At the end, the performance scheme, penalties and incentives are presented.

Austria:

The Austrian Railway Infrastructure Manager, ÖBB Infrastruktur is a company responsible for planning, constructing, maintaining, providing and operating a safe railway infrastructure. They are in charge of allocation, charging and providing service facilities. [16]

The minimum access charge is constituted by components: market segment charge and reductions/supplements. For freight traffic there are 2 market segments: manipulated and non-manipulated (block train). The non-manipulated traffic means that it transports the goods only between one sender and recipient and is not marked as combined transport[9]. As this segment is intended for block trains it involves rather national traffic. The manipulated traffic involves freight traffic not included in non-manipulated one. This segment captures foreign traffic and some national traffic. Each segment charge is divided on 2 charges with different units. The first is charged per train-km and the second one is charged per gross-tonne-km. A charge for non-manipulated traffic includes mark-up. [16]

The reduction/supplements involve Traction Unit Categories, Congestion charge (only on Hetzendorf – Mödling section) that are charged per tonne-km and Performance regime which is charged per minute of delay duration. [16]

The financial penalties and incentives involve reservation fees and compensation fees for framework agreements [16]. The Austrian charging system is very simple and clear.

[9] Combined transport is a transport in which the transport unit (for instance containers, semi-trailers, road vehicles, etc.) is transshipped instead of the freight itself.

Belgium:

In Belgium Infrabel performs as both infrastructure manager and operator of service facilities. [17]

The minimum access charge consists of direct line cost, mark-up, direct catenary cost and charge for specific cases. The direct line cost and direct catenary cost are expressed by fixed values charged representatively per train-km and per MWh of energy consumed for use of the electrical supply system for traction. The consumption of energy for freight trains involve 2 components which are fixed values per: 4 kWh per km and 12 Wh per tonne-km. Both of these components are the same for every market segment. The mark-up is charged due to market segment (transport type), density of the line and time period during which the train is running. By now only passenger segments are charged with mark-up. [17]

The Belgian infrastructure manager penalizes for path modification, alteration, non-usage and cancellation. No financial incentives are provided. [17]

Performance scheme is assessed due to minutes of delay during the year, and a target Performance Scheme ratio set for each RU due to the sector it belongs to. [17]

The Belgian charging system is very simple and clear as well.

France:

The French IM, SNCF Réseau divided minimum access charge into: running charge (traffic charge), electric traction charge, covering the losses in electrical systems, market charge, access charge, special charges and congestion charge. All the charges depend on the type of services. These consist of services for passenger activities under contract, for passenger activities not under contract and for freight activities. Of this study interest are charges only related to freight activities. [18]

The running charge (traffic charge) depends on line group and tonnage class. It is expressed in € per train-km. The charge that is levied from RU is diminished by the State subsidy for all trains whose tonnage is lower than 350 tonnes. [18]

The electric traction charge is levied for the use of electric traction installations, per electric train-km. The covering the losses in electrical systems involves the costs of providing the electrical energy so as to compensate for losses in electrical systems from substations up to train detection points. It is charged per electric train-km. [18]

The market charge depends on the market segment of the train path. It differs depending on line, day and time of departure. However, it does not apply to freight transport. [18]

The access charge is a fixed price per Transport Organising Authority. It also does not apply to freight transport. [18]

The special charge is levied for the use of the special infrastructures. It is to recover the investment costs incurred by SNCF Réseau on these infrastructures or its maintenance, operation costs incurred by SNCF in relation to these projects. Those charges are levied only on a particular section. The fee is expressed in € per train path-kilometre or just per train path. [18]

The congestion charge is not applicable for any service. [18]

The French IM provides also set of penalties and incentives including: penalties for changes to train paths by the candidate, penalties for changes to train paths by SNCF Réseau, penalties for non-use, train path cancellation penalty, incentive to develop new traffic, incentive mechanism regarding the declaration of the real train consist (railway undertakings that declares the actual composition of trains before their operation). [18]

Performance scheme contains a malus scale for SNCF Réseau depending on the segment of activity of the RU concerned and malus scale for RUs expressed as rate per minute lost over and above the target [18].

The scales of French charges were given for 2022, hence in calculations (which are presented in next section), they were increased by predicted inflation level presented in the Network Statement.

Germany:

The German Infrastructure Manager, DB Netz AG split the minimum access charge per market segment and further in direct costs and a surcharge to cover the full costs in regards to viability of the market segment and possible additional elements. [19]

The freight market segments are divided due to the nature of transport, flexibility and prioritisation. [19]

In regards to nature of transport the freight services the market is segmented on following categories: Very Heavy for (train weight over 3000 tonnes), Dangerous Goods, Local freight trains (with paths at most 75 km, and no longer than 370 metres), Local freight train for dangerous goods, Locomotive Runs and Standard (all trains that are not included in before mentioned other categories). [19]

Concerning flexibility (planning characteristics) services are divided on z-flex (temporal design-tolerance flexibility), r-flex (as z-flex: temporal design-tolerance flexibility and geographical flexibility – path changing retaining its origin and destination) and standard. [19]

Due to prioritisation the segments are divided into express and speed and standard, where the first one has the most priority and last one the least. [19]

The mark-up is surcharged for standard freight trains making up over 50% of total charge. [19]

The penalties and incentives involve; Penalties for Path Modification, Penalties for Path Alteration, Penalties for Non-usage, Penalties for Path Cancellation, Reduced Charges for Non-Contractual Condition, Charging Arrangements for Rail Replacement Services, Charging Arrangements for Emergency Bus Services in Passenger Traffic. [19]

Performance scheme is indicated with threshold values of the final punctualities differ including classification of a train run as sensitive to punctuality (with 30:59 minutes’ threshold) or not sensitive to punctuality (with 120:59 minutes’ threshold). [19]

Italy:

Rete Ferroviaria Italiana S.p.A. (RFI) is the Italian Infrastructure Manager. Their infrastructure charging system split the minimum access charge on two components. The component A concerns wear and tear of the infrastructure (track and overhead contact lines). It is divided into three sub-components: A1 (depending on weight classes of the train), A2 (depending on operating speed classes), A3 (depending on type of traction). The component B depends on the market segment´s ability to pay. The freight segment is further divided on: Night, International Freight Services, 2 National Freight segments (first for distance travelled between 100 km and 800 km and second for other distance travelled), and Promo (with mark-up equal 0 € for the new commercial services, defined in the catalogue by the IM). Both components are expressed in € per train-km. [20]

RFI also levies for traction current supply. The electricity consumption (kWh) is charged with use of Real Meter compliant with standard and connected to RFI's Digital Command System, or using value estimated with Davis formula. [20]

The financial penalties and incentives involve: Penalties for path changes requested by the RU, Penalties for non-compliance with disclosure requirements/ IM responsibilities, Penalties for delays caused by the Infrastructure Manager, Penalties for the Applicant in the event of non-designation of the RU by the Applicant (non-RU) and/or failure to contract the designated RU, Penalties for the RU in the event of failure to contract (partial or total) paths, Penalties in the case of failure to utilise the allocated train paths, Incentives and discounts on tolls and Penalties for the RU for exceeding layover times at foreign network connection stations. [20]

The performance scheme is exercised for penalty determination purposes. Each minute of delay is charged 1,00 € per minute, and then multiplied by factors based on type of service, type of network, punctuality performances, delay measured at the commercial stops, train class and cancellations. [20]

Netherlands:

ProRail is the manager of the main railway network in the Netherlands. It is a private company under Dutch law. [21]

The minimum access charge for freight services contains two components, Train path levy and Extra levy. Both of them depend on weight class, however Extra levy is additionally divided on market segments. The freight segment is not further divided. ProRail provides the Zero rate exemption scheme, which means that when the traffic runs in the performance of instructions provided by the IM, the rate of Extra levy is equal to zero. [21]

The Dutch IM does not provide financial penalties for changing of train paths by titleholders nor by the IM, neither for non-use of train paths by titleholders, nor for cancellation of train paths by titleholders. A financial compensation other than user charges may be provided to RUs in case of "capacity restrictions for works". [21]

ProRail applies a performance scheme to minimise disruption and improve the performance on the network. The components of the performance scheme are not available in NS. They are included in the Access Agreement. [21]

Poland:

PKP Polskie Linie Kolejowe Spółka Akcyjna (S.A.) is an IM (infrastructure manager) on the railway network it manages in compliance with the PLK Bylaw. [22]

The minimum access charge (Basic fee) is constituted by a direct cost ("Portion of the fee depending on the direct costs") and a mark-up ("Portion of the fee related to the type of the transports carried out"). [22]

The direct cost fee is a product of “average rate depending on the mass and the category of railways” is corrected with coefficients depending on train weight and line category. [22]

The PKP explained how the sizes of charges were calculated. The Coefficient concerning line category is a product of degradation factor (dependent on average permitted speed on given section) and axle load factor. [22]

That means that the IM is charging for maximum possible degradation on sections for all trains.

The Coefficient concerning train weight is based on the traffic volume coefficient describing the dependence of pavement degradation on traffic volume (with quadratic equation of traffic volume expressed in million tonnes per year). The average weight of one train is 632, therefore the coefficient for interval $600 \leq M < 660$ tonnes is equal 1. [22]

Traction-dependent part is a ratio of planned direct costs and planned operation work. [22]

Portion of the fee related to the type of the transports carried out is carried out on the basis of the market analysis. The trains exempted from that charge are intermodal trains and trains lighter than 660 tonnes (“in order to promote dispersed transport and attract new loads for the railways”). Nevertheless, as noticed in chapter Sensitivity Analysis, it is much cheaper to allocate one 1000 t train, than two 500 t trains, thus this promotion does not seem to be very attractive. [22]

The reservation charge is collected from the applicants for non-usage of allocated capacity. It is equal to 100% of the basic charge for the planned train run or at least 1000 PLN, whichever is higher, or 25% or even less if notice of cancellation is submitted early enough. [22]

Performance scheme includes: the train run delay tolerance within which a train is deemed to run on schedule; the expected percentage share of the RU trains which will not be delayed due to the RU’s fault; delay compensation; sanctions for disruption of the railway network operations; the scheme of incentives for the RUs which achieve the mean annual performance above the threshold level specified in the Performance Scheme. [22]

The freight trains are considered to be “on schedule”, when their maximum delay does not exceed 15 minutes. [22]

Portugal:

The Portuguese IM, Infrastructure Portugal, S.A. (IP) is a public company that arose from merging EP - Estradas de Portugal, SA and REFER - National Railway Network, EPE. [23]

The minimum access charge (base charge) is a product of: Direct Unit Cost (DUC), Utilisation of Overhead Line Infrastructure and Platforms Component (P_1), Line Demand Component (C_2), Train Schedule component (C_3), Market Segment Component (C_4). The DUC is a fixed value for all the trains, the P_1 depends on traction type, the C_2 on line type, C_3 on time of day and C_4 on market segment (there is only one segment for freight transport). [23]

The Portuguese IM penalize for unused capacity with a fee equal from 5% up to 50% of basic charge depending on how early was cancellation requested. [23]

The Performance scheme sets a threshold of 30 minutes for the freight trains up to which the train is not accounted for performance regime purposes. Whether the RU receives incentive in form of malus or bonus depends on a set objective which is a limit value derived from the year with a lesser global financial impact (minutes of delay multiplied by the cost of each minute for each market segment). [23]

Spain:

The Spanish IM, Adif is a state-owned company. In its charging system the minimum access charge was divided on tariffs: for capacity allocation, for use of railway lines and for using traction electric power conversion and distribution facilities. [24]

All of the charges depend on line type and type of service (market segment). They are expressed in € per train-km. In case of excessive run, IM provides an additional charge in order to increase efficient use of the network. [24]

No penalties for path cancellation nor for path modification, because there is a charge for excessive runs, and allocation charge. [24]

The performance scheme encourages rail undertakings and the infrastructure manager to minimize disturbances and improve the operation of the network. It includes incentives in the form of bonus and malus. [24]

Switzerland:

The Swiss Network Statement was published by jointly by infrastructure managers: SBB Infrastructure (SBBI), BLS Netz AG (BLSN), SOB Infrastructure (SOB), Sensetalbahn AG (STB) and Hafenbahnschweiz AG (HBS). [25]

The minimum access charge consists of Variable minimum train-path price, Stop surcharge, Basic prices by wear and weight and Surcharges and discounts. [25]

The Variable minimum train-path price depends on network category (based on operating, maintenance, alarm and rescue facilities). Minimum train-path price is a base expressed in € per train-km. It is multiplied by Peak-hour demand coefficient and Train-path quality. The Peak-hour demand coefficient applies only to particular sections and only during peak hours (Monday to Friday from 6:00 to 8:59 and from 16:00 to 18:59). Train-path quality is directly connected with type of services. [25]

The Stop surcharge is levied due to the fact that every stop reduces train-path capacity. The fee also applies to stops at departure and destination stations. It is a flat fee per stop. [25]

The Basic prices by wear and weight are charged alternately. Only one higher charge is levied. The wear charge depends on drive type (locomotive), operational speed, and section geometry (radius size). It is expressed in € per train-km. The basic weight charge is a fixed value and it is levied using a unit of CHF per gross tonne-km. [25]

Surcharges and discounts include: Surcharge for trains hauled by combustion-based motive power, Dangerous goods surcharge, Low-noise bonus, Discount for the ETCS train control system, Discount for transalpine freight trains and Discount for long trains. [25]

The Combustion surcharge is levied per gross tonne-km on electrified lines. [25] The Dangerous goods surcharge and Low-noise bonus are charged/ compensated per number of axles – km. [25] The ETCS discount applies for ETCS fitting to rolling stock. The discount is equal to 25 000 CHF per year. [25] The Discount for transalpine freight trains applies for particular sections and are given per powered axle and train-path km. [25] The Discount for long trains is given per meter towing load over 500 meters towing load. It is expressed in CHF per train-km. [25]

The Swiss charging system also provides a cancellation charge, that is calculated in regards to the variable train-path basic price and the stop surcharge. [25]

Moreover, the energy consumption is charged. The base charge is expressed in CHF per kWh and increased by coefficients depending on the time of the day. The consumption in kWh may be measured by the system or calculated by the method provided by IM due to train category, and type of vehicle braking. [25]

The penalties and incentives are all already included in the minimum access charge. In case of path modification, the RU is charged for the new path without any penalty. [25]

Due to the performance scheme no bonus/malus system is applied. [25]

General observations

Generally, the pricing systems for all the selected countries are more complex for passenger services than for freight services.

Besides minimum access charge, there are other categories of charge, namely charges for additional services and ancillary charges. They involve charges for services as for example: train tracking information, information processing, GSM-R services, technical inspection of rolling stock, services for exceptional consignments and dangerous goods, electricity supply and distribution, specialized heavy maintenance services, shunting services and other supplementary personnel services.

The responsibility of levying the charges for electricity supply and distribution is often burdened on the electricity suppliers. Therefore, its charging methods are often not presented in the network statements.

The figure 16 shows the variables and charge categories used in selected countries. Exactly the same analysis has been done for 2013 in the UIC report [2]. In the annex the original figure and one with explanation of the variables is attached.

	Austria	Belgium	France	Germany	Italy	Netherlands	Poland	Portugal	Spain	Switzerland
What Is Charged (only for freight trains)										
Time-of-day pricing	-	-	-	-	+	-	-	+	-	+
Train Frequency	-	-	-	-	-	-	-	-	-	-
Train speed	-	-	-	-	+	-	-	-	-	+
Train Type (Physical Characteristics)	-	-	+	+	+	+	+	-	-	+
Axle load	-	-	-	-	-	-	-	-	-	-
Loco/Traction Type (characteristics)	+	+	+	-	+	-	+	+	+	+
Service Type (Service Pattern, distance)	+	-	-	+	+	-	+	-	-	-
Train-path quality	-	-	-	+	-	-	-	-	-	+
Line Type (importance categorization)	-	-	+	-	-	-	+	-	-	+
Line Type (capacity)	-	-	-	-	-	-	-	+	+	+
Capacity maximization Charge	+	-	-	-	-	-	-	-	-	-
Scarcity Surcharge	-	-	-	-	-	-	-	-	-	+
Low-speed penalty	-	-	-	-	-	-	-	-	-	-
How is Usage Charged										
Flat Fee	-	-	+	-	-	-	-	-	-	-
Fee per train-km	+	+	+	+	+	+	+	+	+	+
Fee per tonne-km	+	+	-	-	-	-	-	-	-	+
Fee per min	-	-	-	-	-	-	-	-	-	-
Node fee	-	-	-	-	-	-	-	-	-	-
Axle-km	-	-	-	-	-	-	-	-	-	+
Axle load	-	-	-	-	-	-	-	-	-	-
Charge Categories										
Reservation Fee	+	-	-	-	-	-	+	+	+	-
Cancellation Fee	-	+	+	+	+	-	+	-	-	+
Running Charge	+	+	+	+	+	+	+	+	+	+
Admin Fee	-	-	-	-	-	-	-	-	+	-
Access Fee	-	-	-	-	+	-	-	-	-	-
Security Fee	+	-	-	-	-	-	-	-	-	-
Accident Insurance Charge	-	-	-	-	-	-	-	-	-	-
Environmental Surcharge	-	-	-	-	-	-	-	-	-	+
Special Infrastructure Fees	+	-	+	-	+	-	-	-	-	+
Dangerous goods transport	+	-	-	+	+	-	-	-	-	+
Noise fee/discount	-	-	-	-	-	-	-	-	-	+
ETCS fee/discount	-	-	-	-	-	-	-	-	-	+
Performance Scheme	+	+	+	+	+	+	+	+	-	-
Freight Subsidy / Discount	-	-	+	-	-	-	-	-	-	-
Traction Current and Fuel										
Traction Current - access	+	+	+	-	+	+	+	+	+	-
Traction Current - management	-	-	-	-	-	+	-	+	-	-
Traction Current - use fee	-	+	+	-	+	+	-	+	-	+
Fuel - management	-	-	-	-	-	-	-	-	+	-
Fuel - dispensing	-	-	-	-	+	-	-	+	+	-
Fuel - access	-	-	+	-	+	-	-	-	+	-
Varying rates for Diesel/Electric	+	+	+	-	+	-	+	+	+	+

Figure 16 Variables and Categories of Charges

It was observed that the Swiss Pricing System is the most complex one, whereas Belgian, Dutch and Spanish are the simplest.

All the analysed systems involve running charge and at least one of reservation and cancellation fee. The exception is the Netherlands, which does not penalize for neither path cancellation nor alteration.

All of the selected countries express the charge (or at least a part of it) in € per train-km. Three countries additionally introduced a component of charge per tonne-km. French IM use a flat fee for special infrastructure. Switzerland is the only country that considered axle-km in its pricing system.

Almost all selected countries depend their infrastructure charges on traction type. About half involve train type (physical characteristics). A little less popular variables are Line type, Service type and Time-of-day.

Train speed, train type (physical characteristics), number and mass of axles and infrastructure characteristics are the variables pointed out in the previous chapter as the ones with the impact on direct cost. Switzerland in its pricing system included all of them but mass of axles.

Although the Swiss system is the most complex, it complies with directives' and experts' recommendations.

3.3. Quantitative Analysis of Charging Systems

3.3.1. Interval variation

The first part of the quantitative analysis concerns ranges of charges for each country's charging system. The minima and maxima were obtained by manipulating variables on which the pricing systems were dependent. Only train mass remains constant, as ranges are presented for 3 weight categories 500 tonnes, 960 tonnes and 2000 tonnes. As analysis is made for regular freight services, the variables: dangerous goods and exceptional transport were excluded from scope. Moreover, in each train speed was assumed as 80 km/h (therefore LISEA Tours-Bordeaux high speed line was excluded from analysis as only high-speed freight transport services are allowed on this line). The assumptions were chosen in such a way in order to allow comparison with UIC STUDY [2] in the next chapter.

The results of calculations are presented on figures 17-19. Comparing the content of the set of diagrams it was observed that in the Netherlands, Belgium and Spanish Lines the values of charges are fixed.

In Switzerland and Germany, the differences between minimum and maximum charge are the biggest. For 500 tonnes the difference is about 3,5 € per km. For other weights for Germany prices stay the same and for Switzerland ranges increase – the higher weight the higher variation of prices. The top limit for Switzerland changes much more due to weight than the bottom limit. For other countries ranges stay the same or change just slightly. For Germany, Portugal and Spain charges don't change due to weight change.

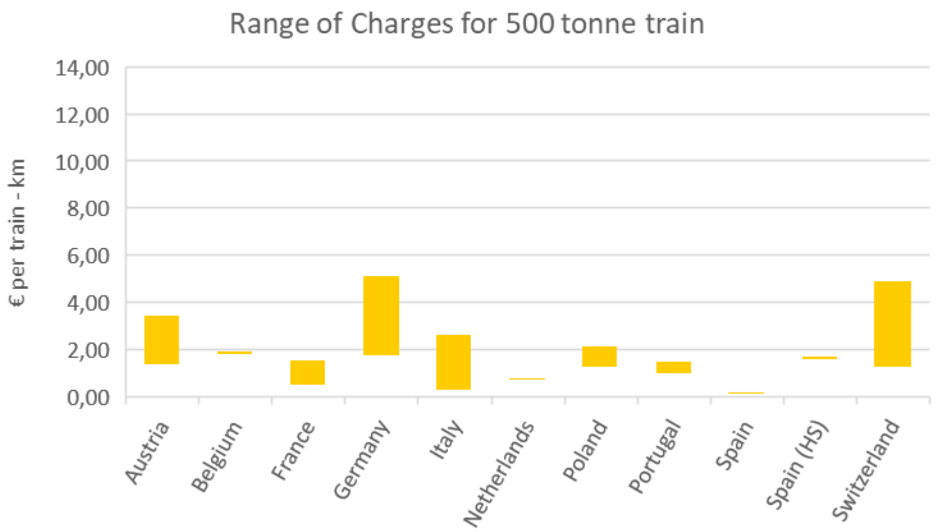


Figure 17 Range of charges for 500 tonne train

On the figure 17, presenting weight ranges for 500 tonnes train, it was observed that beside Germany and Switzerland mentioned before, Italy, France and Austria pricing systems contain pretty wide intervals.

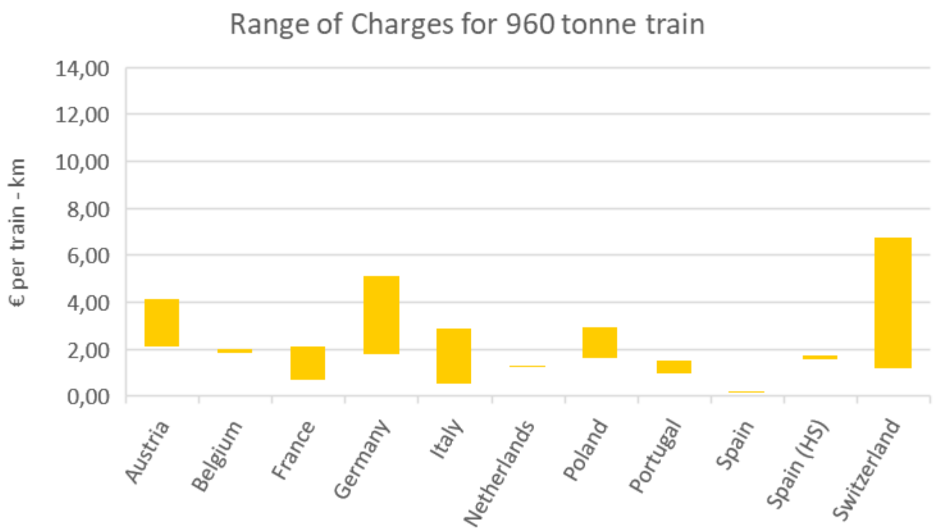


Figure 18 Range of charges for 960 tonne train

The figure 18 draws attention to the direct cost threshold appointed by Regulation 2015/909 – 2 € per train-kilometre for 1 000 tonnes train (at 2005 prices and exchange rates, which for 2021[10] year with inflation at level 33,5% gives 2,67 €). Five countries have been observed with a maximum charge below 2,67 €: Netherlands, Portugal, Spain, Belgium and France. Therefore, for those countries, the regulator may give up on strict control. The figures 17-19, present the charges that besides direct cost include mark-ups, hence there is no point to compare the threshold with the charges that exceed it. For example; the German maximum direct cost for a standard freight train is equal to 1,50 € per train-km. The mark-up increases due to type of service. Including the mark-up, a charge for the minimum package can reach even over 5 € per train-km. In the next subsection the direct cost and mark-ups levels are discussed more thoroughly.

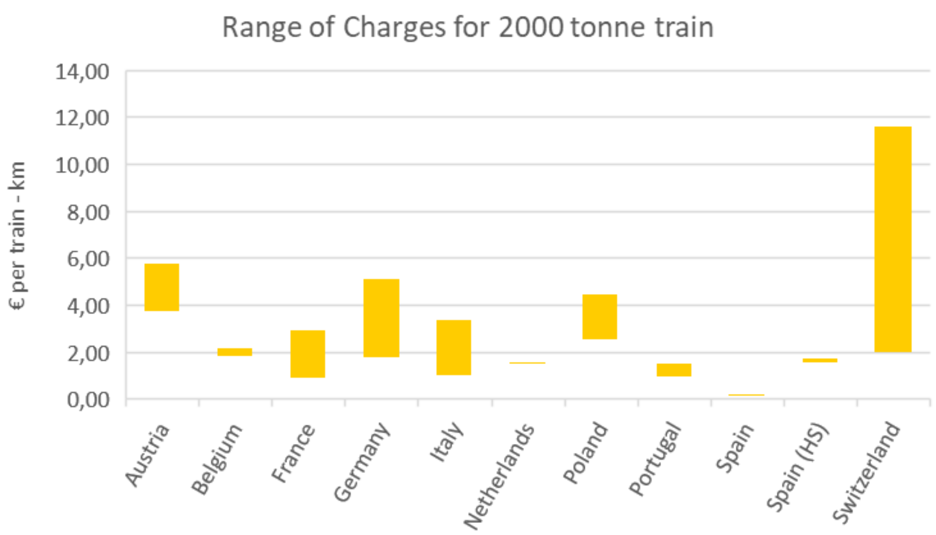


Figure 19 Range of charges for 2000 tonne train

The figure 19 presents weight ranges for the 2000 tonnes train. It was noted that levels of charges vary significantly. The highest maximum charges have been observed for Switzerland, Germany and Austria.

[10] Data from Eurostat on average index and rate of change only available up to 2021 year

The lowest maximum fees are charged in Spain, Portugal, Netherlands and Belgium and all of them are lower than 2,67 € per km.

3.3.2. National OD pairs

In this part charges for chosen origin destination pairs in each of selected countries are compared. The approach chosen for this analysis is to start with a general presentation, discussing the results for all of the selected systems together and then get into the details, demonstrating the differences between the charges for each country. The figure 20 shows a box plot containing charges from all the selected countries.

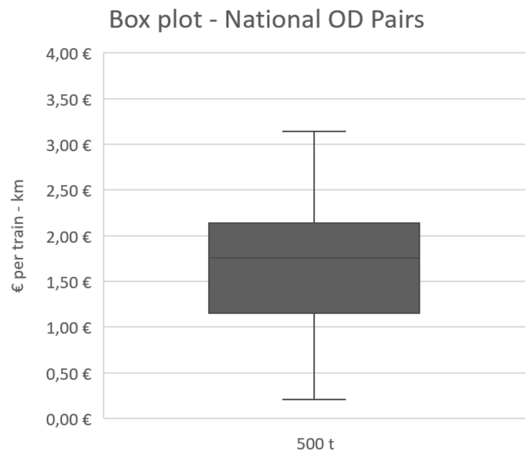


Figure 20 Box plot - range of prices for selected National OD Pairs

The presented boxplot shows that distribution of charges for 500 t trains is almost symmetrical. The charges fluctuate from 0,20 € per km to 3,14 € per km. The majority of tariff systems have prices below 2 € per km. 50% of the charges are between 1,1 € per km and 2,2 € per km. Median value equals 1,76 € per km. Table 4 presents the charges calculation results for each country involved in the scope.

Table 4 National OD Pairs (500-tonne train) - Calculation Results

Country	OD Pair	Path length [km]	Total charge 2023 [€]	Avg charge per km 2023 [€]	Line Cost 2023 [€]	Terminals 2023 [€]	Energy access 2023 [€]	Energy use 2023 [€]
Austria	Austria (Vienna – Salzburg)	320,67	641,34	2,00	641,34	0,00	0,00	0,00
Belgium	Belgium (Namur – Antwerp)	109,87	212,60	1,93	196,78	0,00	15,82	0,00
France	France (Perpignan – Metz)	943,8	1491,70	1,58	1024,44	0,00	467,26	0,00
Germany	Germany (Hamburg – Mannheim)	586,5	1841,61	3,14	1841,61	0,00	0,00	0,00
Italy	Italy (Milano – Rome)	603,23	1389,84	2,30	1361,49	0,00	28,35	0,00
Netherlands	Netherlands (Rotterdam – Venlo)	142,4	118,23	0,83	118,23	0,00	0,00	0,00
Poland[11]	Poland (Warsaw – Katowice)	376,634	735,93	1,95	717,91	0,00	18,02	0,00
Portugal	Portugal (Lisbon – Porto)	336,1	514,70	1,53	514,70	0,00	0,00	0,00
Spain	Spain (Madrid – Irun)	625,7	127,83	0,20	109,87	0,00	17,96	0,00
Switzerland	Switzerland (Lausanne – Buchs)	324,95	408,97	1,26	407,05	1,92	0,00	444,33

In the first column, a route length is presented. The darkest blue represents the longest route and the brightest blue - the shortest route. Other columns contain information on charges. The darkest red stands for the highest charge and the brightest represent the lowest one.

The majority (8 of 10) of the routes are longer than 300 km. The longest route is in France between Perpignan and Metz. The shortest route is in Belgium (Namur – Antwerp).

Total charge is constituted by line cost, terminals cost and energy access cost. The biggest part of total charge is line charge. In 4 countries total charges include only line cost. In France over 30% of total charge is determined by energy access cost, in the rest 3 countries line cost determine about 90% .

The high value of total charge may be the result of high value of charge per km, or big distance between origin and destination. The 3 biggest total charges are Germany, Italy and France. Even though the French path is the longest it has the lowest total charge of that 3. The German path is 1,6 times shorter than the French one, nonetheless, it obtained the biggest total charge. It also includes the biggest average charge per km (2 times bigger than French one). The lowest charge for national OD pairs has been observed for Belgium, Netherlands and Spain. Although Spain has the second longest path, its total charge is the second lowest, Spain stands out from other countries with height of charge per km (0,20 €). Figure 21 facilitates comparison between charges per km. Additionally, a direct cost part of the charge was added.

[11] For Poland intermodal type of transport was considered for the corridors and was not considered for the national OD.

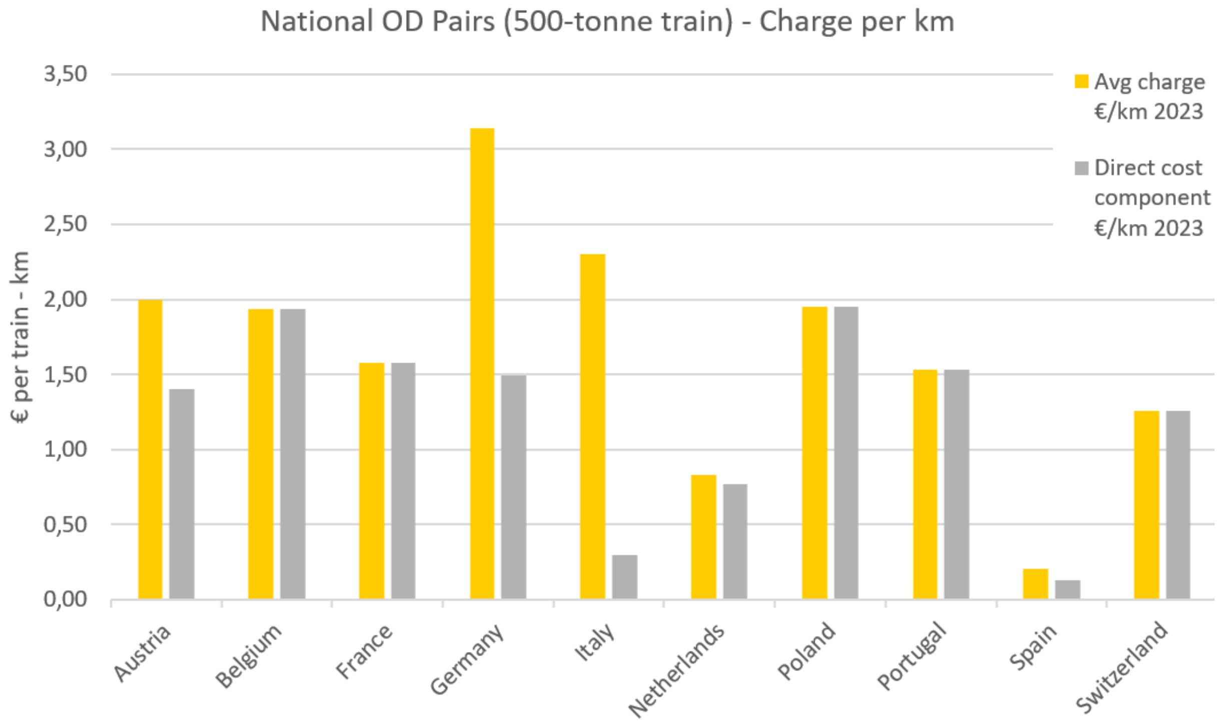


Figure 21 National OD Pairs (500-tonne train) - charge per km

As it was noticed on the boxplot (figure 20), most of the prices are below 2 € per km. Only the Italian and German price system charge per km for a 500-tonne train is bigger than 2 € per km. An enormous part of their charges is taken by the mark-up. For both countries it is over half of the charge value. Interestingly, Italy has the second lowest direct cost, but also the highest mark-up. In other countries there is no or small mark-up. In Poland there is a mark-up, but only for trains heavier than 660 tonnes that are not intermodal.

On the other hand, only Spain and the Netherlands have prices below 1 € per km. Even though total charge for the Belgian path was one of the lowest, value of charge per km does not outstand from other countries.

3.3.3. EFC OD pairs

The charges for European Freight Corridors are often different from charges for National OD pairs, as market segments and lines category may be charged differently. The figure 22 shows a box plot containing charges from all the four selected freight corridors.

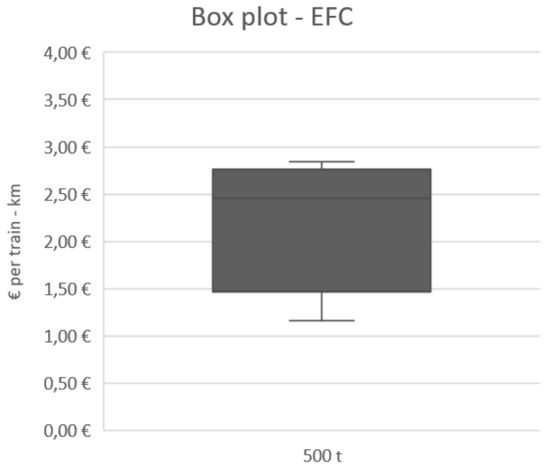


Figure 22 Box plot - range of prices for selected EFC OD Pairs

The presented boxplot shows that the distribution of charges for 500 t trains is negatively skewed. The charges fluctuate from 1,17 € per km to 2,84 € per km. Half of the charges per km are above 2,5 € per km. Table 5 presents the charges calculation results for selected corridors.

Table 5 EFC OD Pairs (500-tonne train) - Calculation Results

Corridor	OD Pair	Path length [km]	Total charge 2023 [€]	Avg charge per km 2023 [€]	Line Cost 2023 [€]	Terminals 2023 [€]	Energy access 2023 [€]	Energy use 2023 [€]
EFC1	Netherlands - Italy (Rotterdam - Genova)	1257,00	2998,94	2,39	2988,12	1,92	8,90	436,88
EFC3	Germany - Italy (Flensburg - V. S. Giovanni)	2463,82	7003,35	2,84	6940,98	0,00	62,37	0,00
EFC4	Portugal - France (Lisbon - Metz)	2216,20	2585,82	1,17	1993,09	0,00	592,74	0,00
EFC8	Belgium - Poland (Antwerpen - Terespol)	1565,55	3949,83	2,52	3895,31	0,00	54,52	0,00

The corridors EFC3 and EFC4 have the longest routes (respectively 2464 and 2216 km). For the corridor EFC3 only the sections going through Germany, Austria and Italy were selected – Swedish and Danish sections were excluded from calculations. The corridors EFC1 and EFC8 are significantly shorter (their lengths are respectively 1257 and 1566 km).

Only corridor EFC4 charge include other significant element than line charge. Over 20% of its total charge is determined by energy access cost.

Even though EFC4 path is one of the longest, it has the lowest total charge of analysed corridors. The EFC3 is the longest corridor and has the biggest total charge and average charge per km - 2,84 € per km. The second biggest charge is for EFC8 and equals 2,52 € per km. The EFC4 has the lowest average charge per km – 1,16 € per km.

The figure 23 presents disparity within corridors. The bolded value in the middle of each box is a mean charge per km for entire corridor. It is a weighted average, that means the member of the corridor that has the longest route influences the most the mean charge.

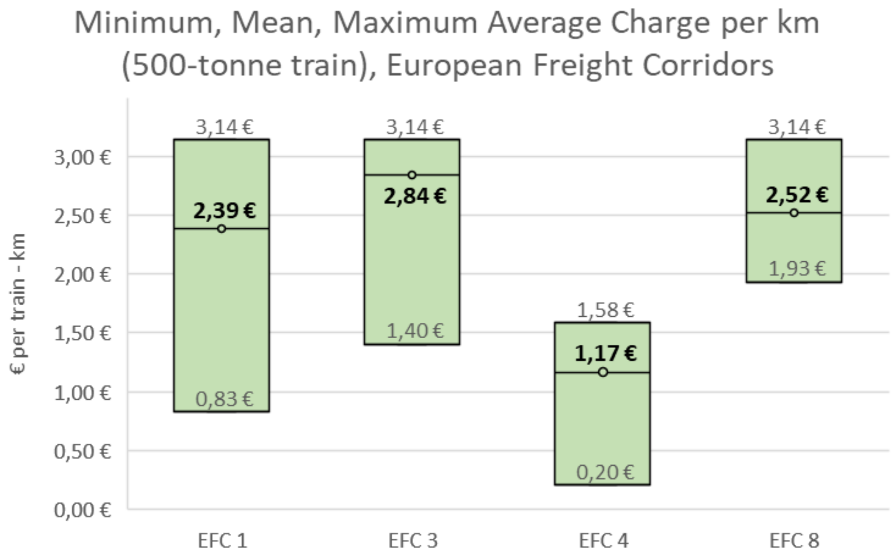


Figure 23 EFC OD Pairs (500-tonne train) - minimum, mean and maximum charges per km

The biggest difference between minimum and maximum charge has been observed in EFC1. The charges fluctuate from 0,83 € per km to 3,14 € per km. On the other hand, the smallest difference between minimum and maximum charge has been observed in EFC8. They are equal respectively 1,93 € per km and 3,14 € per km.

Three of the corridors go through Germany, which increases their charges. Mean charges of the three most expensive corridors are higher than maximum charge on EFC4, which stand outs with its level of charge per km. Its mean charge is 2 times lower than the second lowest mean charge. EFC3 obtained the highest mean value. Although the difference between it and mean value is significant it does not stand out as much as the lowest charge.

The figures 24 to 27 shows how the charges change from country to country within corridors. The black lines represent average rate per-kilometre.

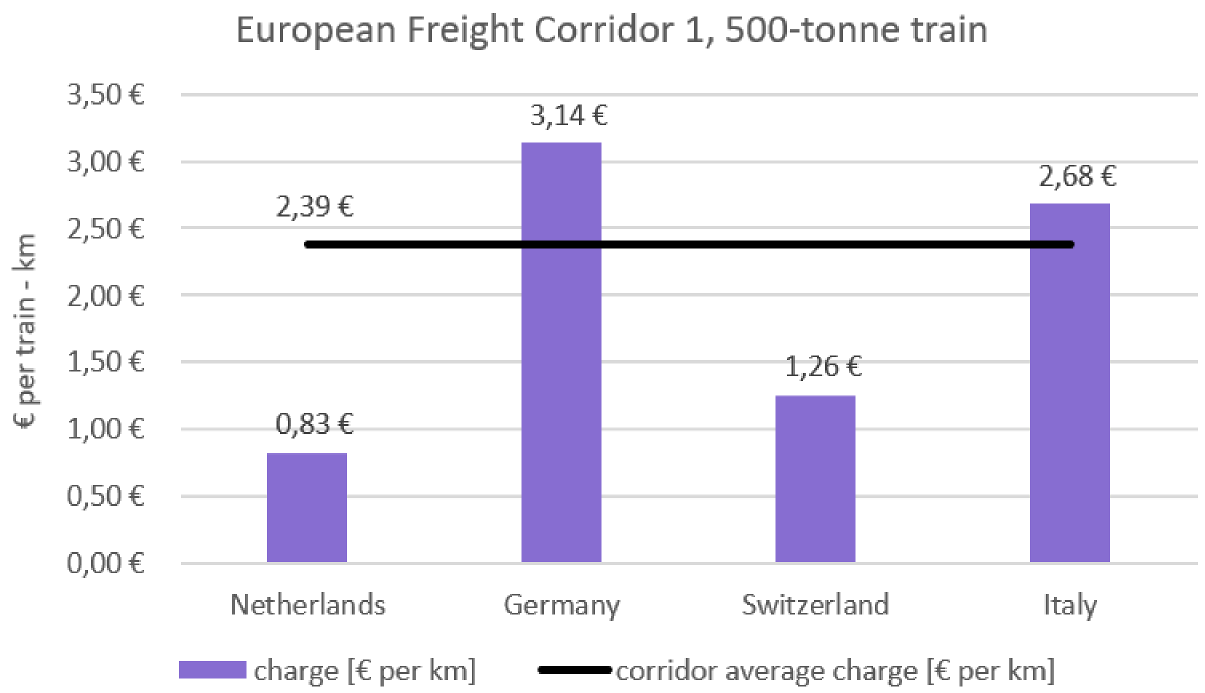


Figure 24 Cross-border Comparison: EFC 1, 500-tonne train

In EFC1 German and Italian sections increase the average charge significantly. It is important to point out, that charges of those countries are highly impacted by the mark-up, whereas Dutch and Swiss systems provide very small or no mark-up.

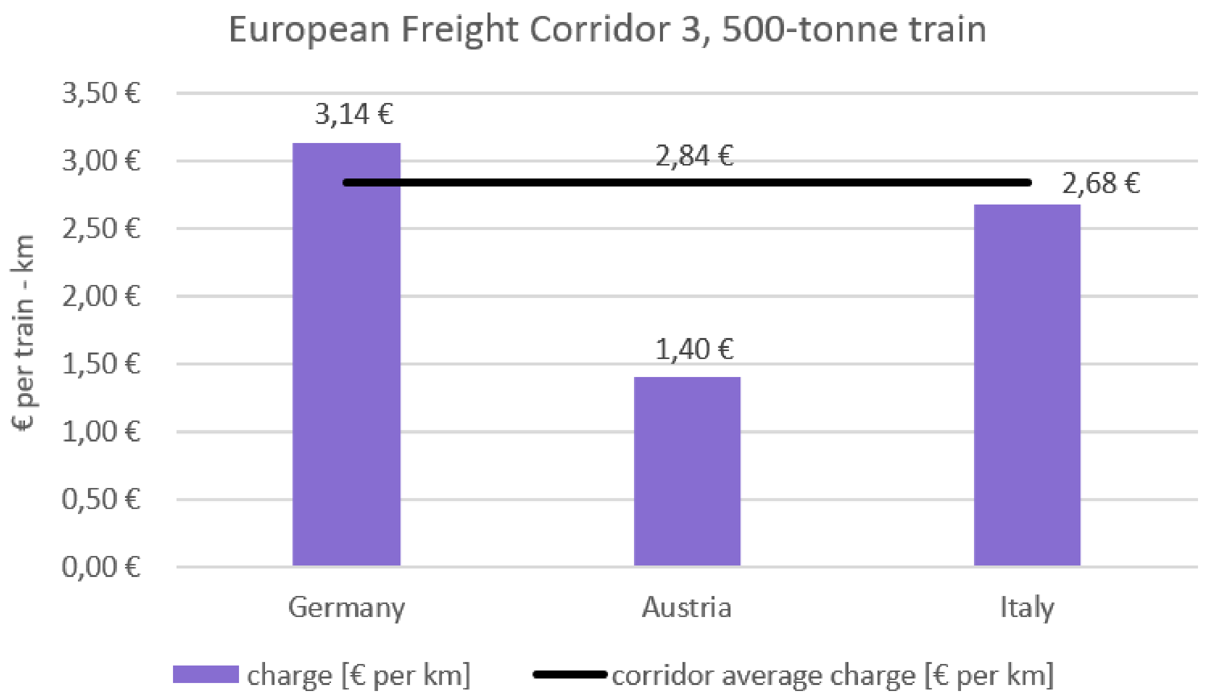


Figure 25 Cross-border Comparison: EFC 3, 500-tonne train

Similarly, as in previous situation German and Italian sections increase the average charge. In case of international corridors Austrian IM do not involve mark-up.

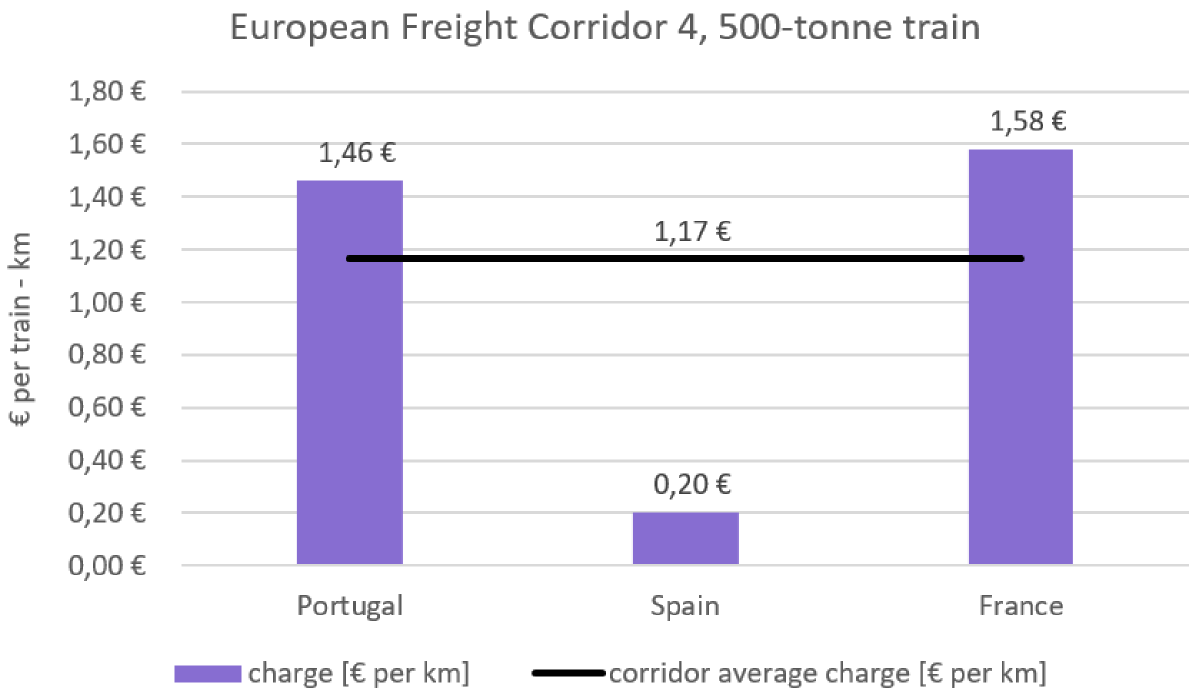


Figure 26 Cross-border Comparison: EFC 4, 500-tonne train

In this case, Spain is the only country that involve a mark-up in its charge. However, the Spanish charge is the lowest and it stands out significantly. The charges in Portugal and France are also very low, however that differences raise a question on the direct cost calculation methodology.

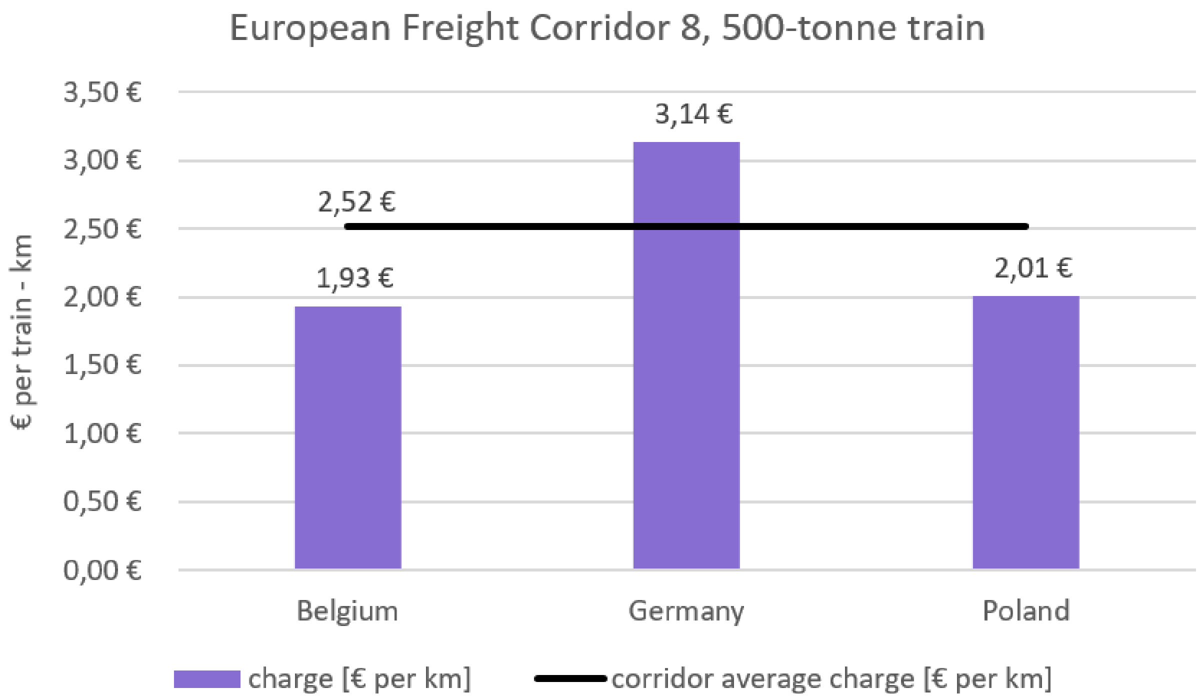


Figure 27 Cross-border Comparison: EFC 8, 500-tonne train

This corridor is the most balanced in terms of charge levels. The high charge in Germany increase the average charge. It´s above 1 € per km higher than in other countries. The Belgian and Polish level of charges are similar. For 500 tonnes freight trains both of the systems do not levy the mark-up.

3.3.4. Sensitivity analysis

This part focuses on train weight importance on the infrastructure charges. Generally, it's better for the IM to have less freight trains with bigger weight than more freight trains with lesser weight because of capacity optimization. For instance: it's better to allocate one 1000 t train, than two 500-tonne trains. On the other hand, bigger train weight implies bigger damage to infrastructure. Moreover, it may be more beneficial for RU to allocate two 500 t trains, due to flexibility and possibility to manage with frequency of distribution. To accomplish its goals, IM adapts charges for capacity (line class) and for weight. The charge for weight may be expressed for instance in: € per tkm, € per axle load, € per axle-km or different charges € per km for the weight classes designated by IM. Some IMs also use incentives to limit the infrastructure damage and capacity scarcity. The Swiss IM applies long train discount, for trains longer than 500 m, which in result may encourage RU to use more wagons with less axle load. For the sake of the charges and discounts, RU is to choose the weight and number of trains and route choice.

In this analysis, three weight categories are analysed, that is, trains weighting 500, 960 and 2000 tonnes. The analysis includes juxtapositions of the charges for the given weights and relative changes of the charges. Subsequently, cost per tonne increase (between 500 and 2000 tonnes), expressed in eurocents, is presented. As in previous parts, this one also starts from general observations and then goes deeper into details. The analysis is done for both National and European Freight Corridor OD pairs.

The figure 28 shows a box plots containing charges from all the selected countries.

Figure 28 Sensitivity analysis. Box plots - range of prices for selected National OD Pairs

It was observed the bigger the weight of the train the bigger the price disparity. The maximum and minimum price for 500 and 960 tonnes is similar, however prices for 500 t trains are more concentrated and distribution for 960 t is negative-skewed. The prices vary between 0,20 € per km and 4,35 € per km. Minimum prices for all of the types of train are equal. This is the Spanish charge, which, as it was noted in previous analysis, is an outlier for the selected set of pricing systems. The maximum price for 2000 tonnes train path is significantly higher than max price for 500 and 960 tonnes trains.

Over 50% of analysed pricing systems contain prices over 1,75 € per km for 500 tonnes trains, over 2,0 € per km for 960 tonnes trains and over 2,5 € per km for 2000 tonnes trains.

Comparing the 500 t box plot and 2000 t box plot, it was observed that over 25% countries with the lowest charges have smaller charges for a 2000 tones than over 50% countries with the highest charges for 500 tonnes.

The 25% countries with lowest charges are Spain, Portugal and Netherlands. The 50% countries with highest charges are Germany, Italy, Austria, Poland and Belgium.

Figure 29 shows a box plots containing charges for the selected European Freight Corridors.

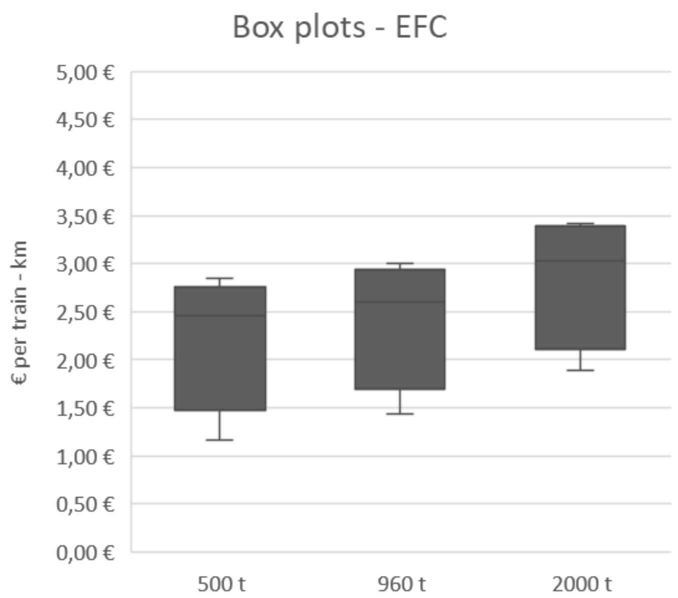


Figure 29 Sensitivity analysis. Box plots - range of prices for selected EFC OD Pairs

Unlike the National OD pairs, the bigger the weight of the train the lesser the price disparity. However, the disparities are very similar. The biggest for 500 tonnes trains – almost 1,70 € per km, the smallest for 2000 tonnes trains – about 1,50 € per km. This smaller disparity than in the case of the national OD pairs is caused by smaller number of entities in the group and each entity is a corridor constituted by several countries, whose charge is a weighted average of charges of those countries. The prices vary between 1,17 € per km and 3,42 € per km. The maximum and median prices for each weight category are rather similar. Bigger differences have been observed for the minimum prices.

Over 50% of analysed pricing systems contain prices over 2,40 € per km for 500 t trains, over 2,60 € per km for 960 t trains and over 3,00 € for 2000 t.

That means that charges in chosen corridors are generally more expensive than charges for countries for national freight transport. The lowest price for each weight category are the charges of corridor EFC4.

The figure 30 presents a juxtaposition of charges for 500, 960 and 2000 tonnes trains for the selected countries.

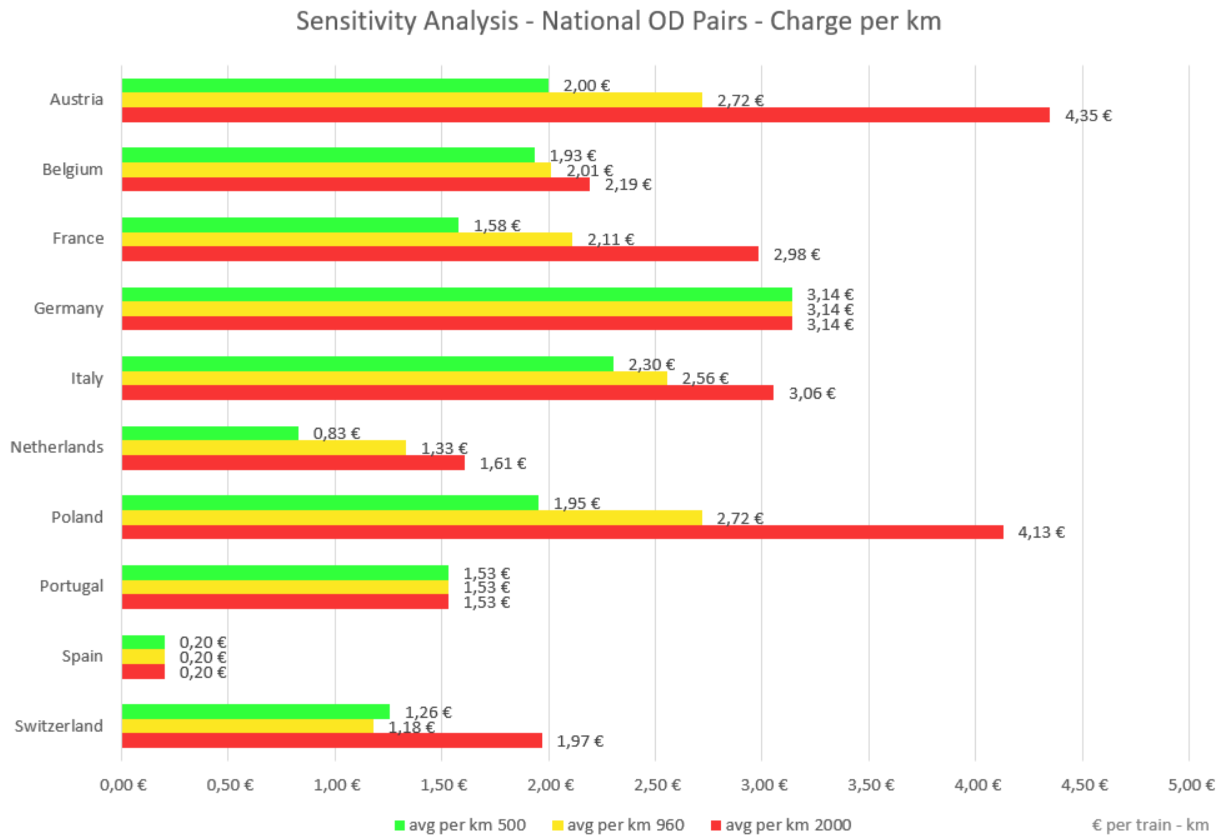


Figure 30 Sensitivity analysis. Charge per km for selected National OD Pairs

The biggest charges for 500 and 960 tonnes trains occur in Germany. The second highest charge for 960 tonnes is in Austria and Poland (2,72 € per km for both countries). For the heaviest 2000-tonne train, the highest charges are in Austria – 4,35 € per km and in Poland – 4,13 € per km.

The charges don’t change due to weight in Germany, Portugal and Spain. In the case of Spain and Portugal charges are equally low, which is good, they encourage the formation of heavier trains without discouraging allocation of lighter trains. In a different manner perform the German pricing systems. Charges there are equally high for all of the selected train categories. Seems like charges for lighter trains should be lower. In Switzerland the charge for 960 tonnes train is lower than charge for 500 tonnes train. It is because of the discounts for long trains[12].

Besides countries mentioned above the charges increase the least for countries like Belgium and Italy.

Spain, Portugal, Netherlands and Switzerland charge 2000 tonnes trains less than 2 € per km.

The figure 31 presents a juxtaposition of charges for 500, 960 and 2000 tonnes trains for the selected European Freight Corridors.

[12] It was assumed that 500 tonnes trains are 500 meters long, 960 t – 600 m and 2000 t – 750 m.

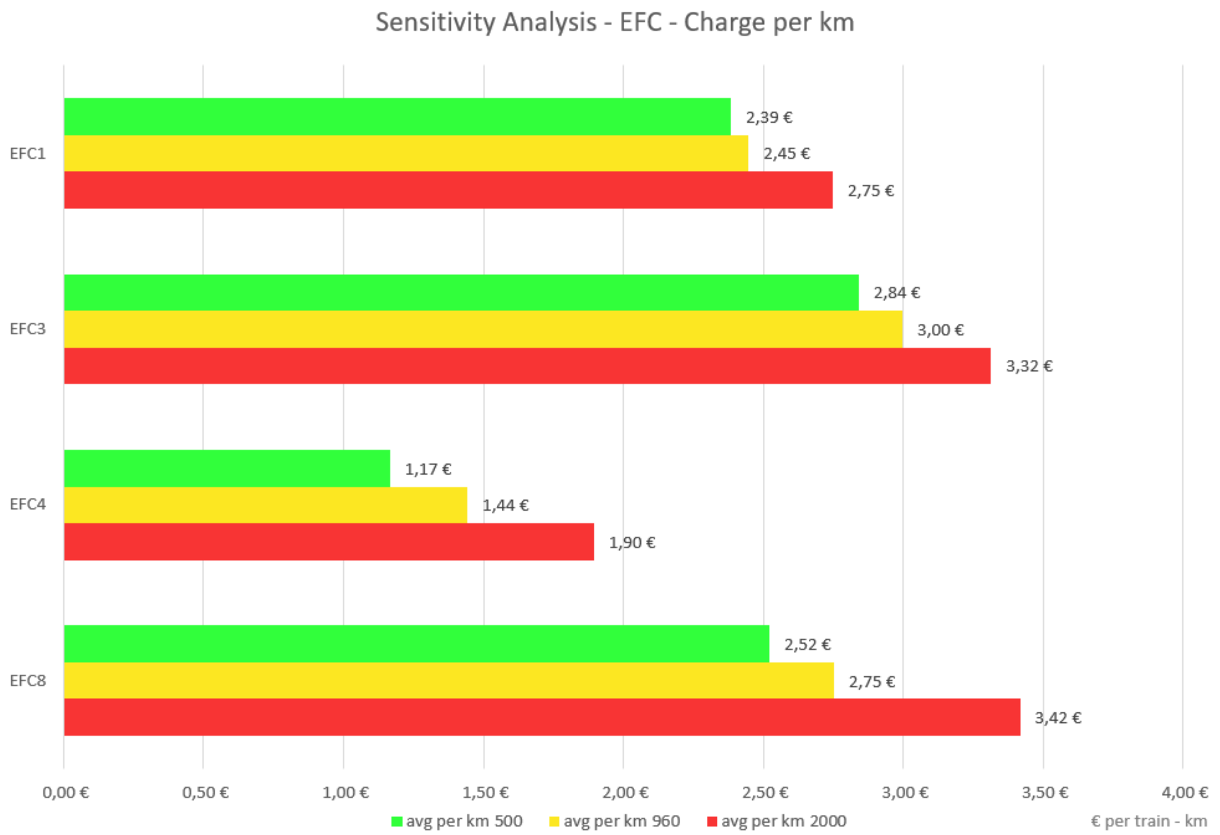


Figure 31 Sensitivity analysis. Charge per km for selected EFC OD Pairs

The difference between fees for different weight categories for EFC OD Pairs aren't that huge as in case of National OD pairs. The biggest charge for 500 and 960 tonnes trains turns out to be in EFC3, respectively 2,84 € per km and 3,00 € per km. For the heaviest 2000-tonne train, the highest charges are in EFC8 – 3,42 € per km. On the contrary, EFC4 charge 2000 t trains is below 2 € per km. The level of its charges are highly influenced by Spain, whose charges are very low (0,20 € per km) for each category. Moreover, it makes a significant part of the corridor's route – above than ¼ of its length. In other analysed corridors charges for all of the weight categories are close or above 2,4 € per km.

Figure 32 shows the relative increase in infrastructure charges for 960 and 2000 tonnes trains compared to base case 500-tonne train for selected countries.

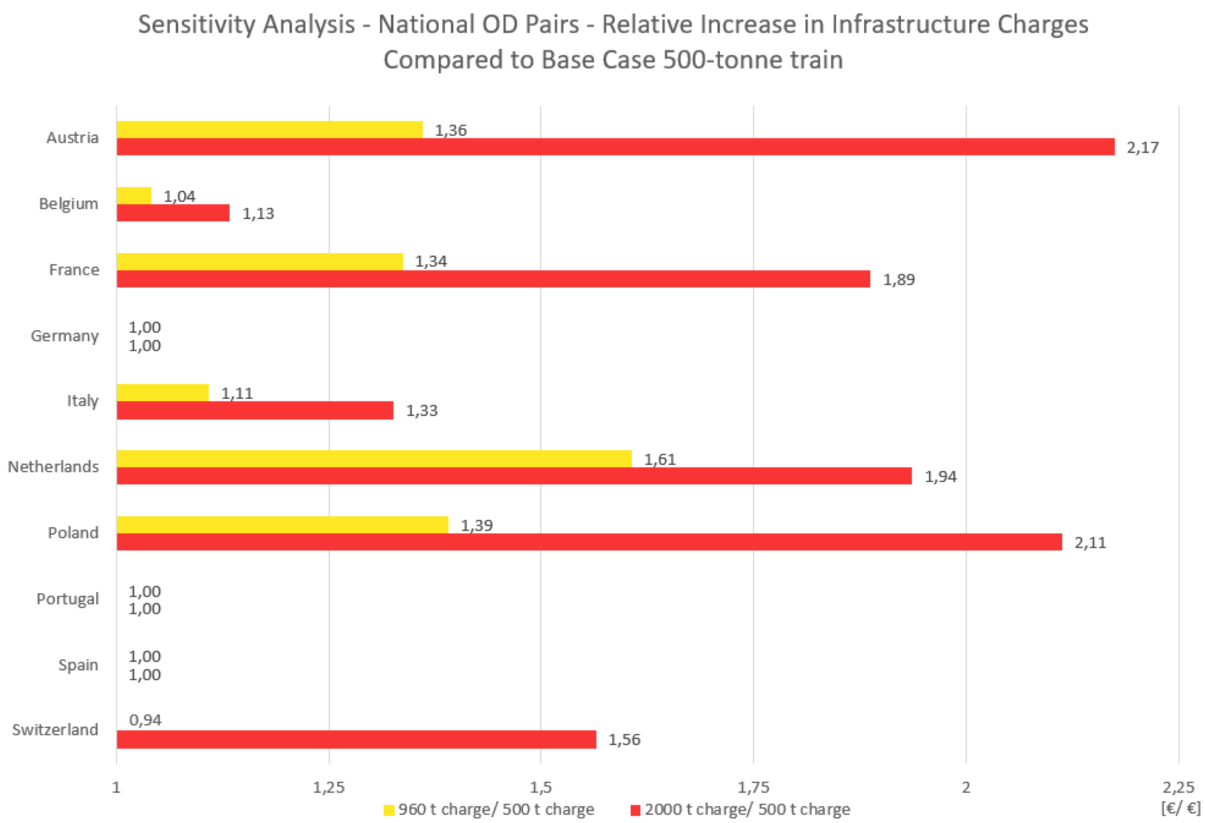


Figure 32 Sensitivity analysis. Relative increase in infrastructure charges compared to base case 500-tonne train - National OD Pairs

It was concluded that, generally, all of the countries encourage the use of heavier trains. Increasing the weight 2 times (from 500 to 960 t) increases charge not more than 1,6 times. Increasing the weight 4 times (from 500 to 2000 t) increases the charge not more than 2,2 times.

The biggest relative charge increase accompanying weight change from 500 to 960 tonnes (1,61) has been noted in the Netherlands. Interestingly the relative charge increase for change from 500 to 960 tonnes is just a bit higher – 1,94. This remark raises attention. A closer look at the Dutch pricing systems, namely, its relation to train weights, will be discussed in next chapter.

The figure 33 shows the relative increase in infrastructure charges for 960 and 2000 tonnes trains compared to the base case of a 500-tonne train for selected European Freight Corridors.

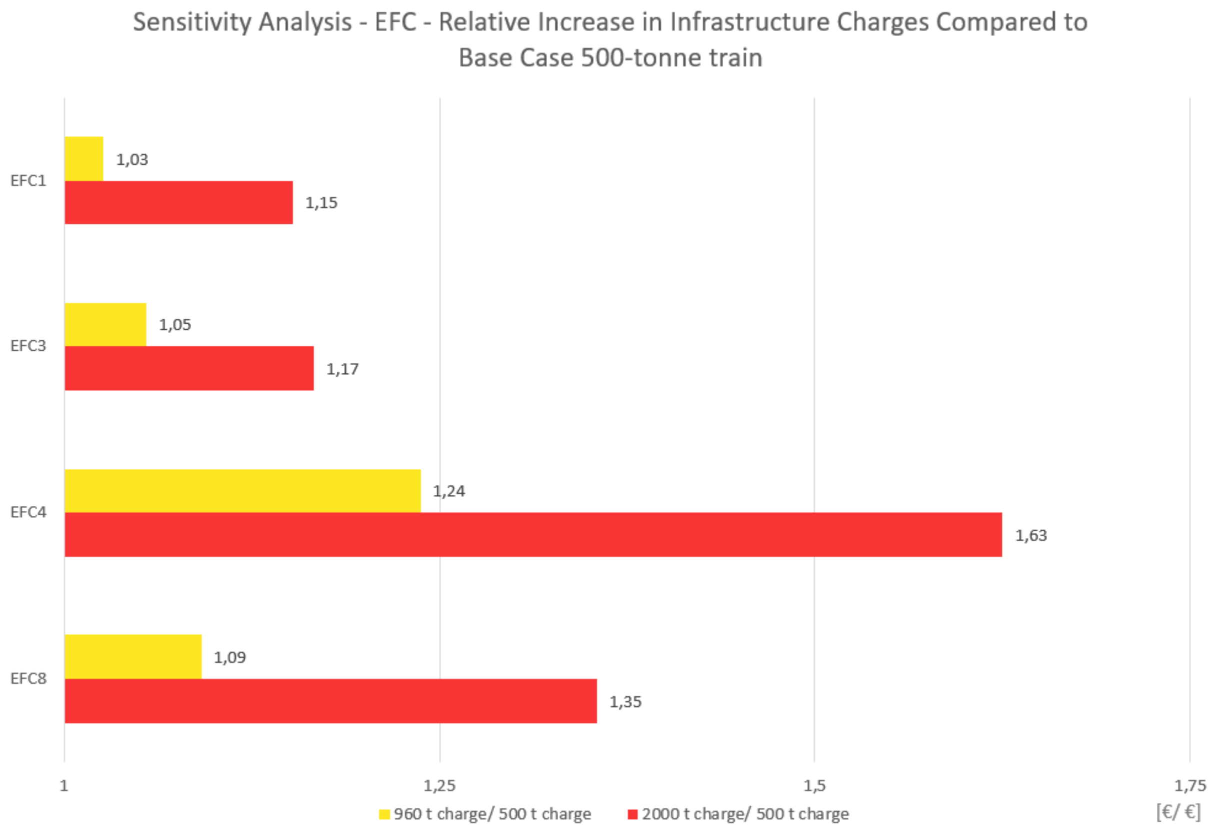


Figure 33 Sensitivity analysis. Relative increase in infrastructure charges compared to base case 500-tonne train - EFC OD Pairs

Generally, all the corridors encourage the use of heavier trains. Increasing the weight 2 times (from 500 to 960 t) increases the charge not more than 25%. Increasing the weight 4 times (from 500 to 2000 t) increases the charge not more than 65%. Train weight influence charges the most for corridor EFC4. Other corridors include Germany which not only has the same prices for every weight category, but also high levels of charges and long routes in each of the corridors. That significantly influences the obtained results.

The figures 34 and 35 show how much cost (in eurocents) change of weight from 500 to 2000 tonnes for selected countries and corridors.

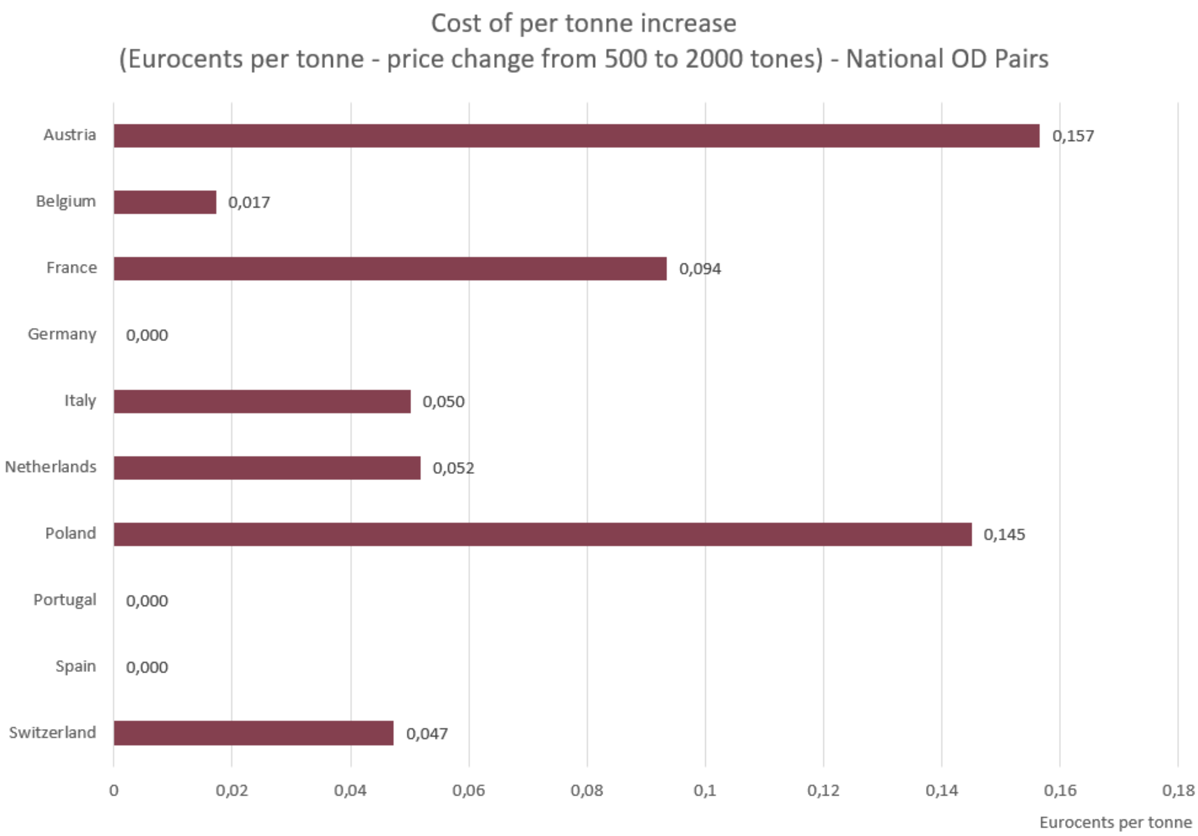


Figure 34 Cost per tonne increase (price change from 500 to 2000 tonnes) - National OD Pairs

A big disparity was observed for the National OD Pairs. Some countries do not charge per tonne-km, others charge about 0,05 eurocents per tkm or less, others about 0,1 eurocents per tkm or more.

The biggest price has been observed in Austria – 0,157 eurocents per tkm, followed by Poland - 0,145 eurocents per tkm. Even though Switzerland pricing system include a variables, which severely increase charge due to train weight like “basic price by weight” (directly dependent on weight), “Surcharge for trains hauled by combustion-based motive power” (directly dependent on weight, not included in OD pairs calculations as electric train has been assumed), Dangerous goods surcharge for freight traffic (dependent on number of axles, not included in calculations), it includes also a lot of discounts like “low-noise bonus for freight traffic” (dependent on number of axles) or “Discount for long trains” (dependent on train length above 500 m). As a result, the overall charge for a regular train is not very dependent on weight.

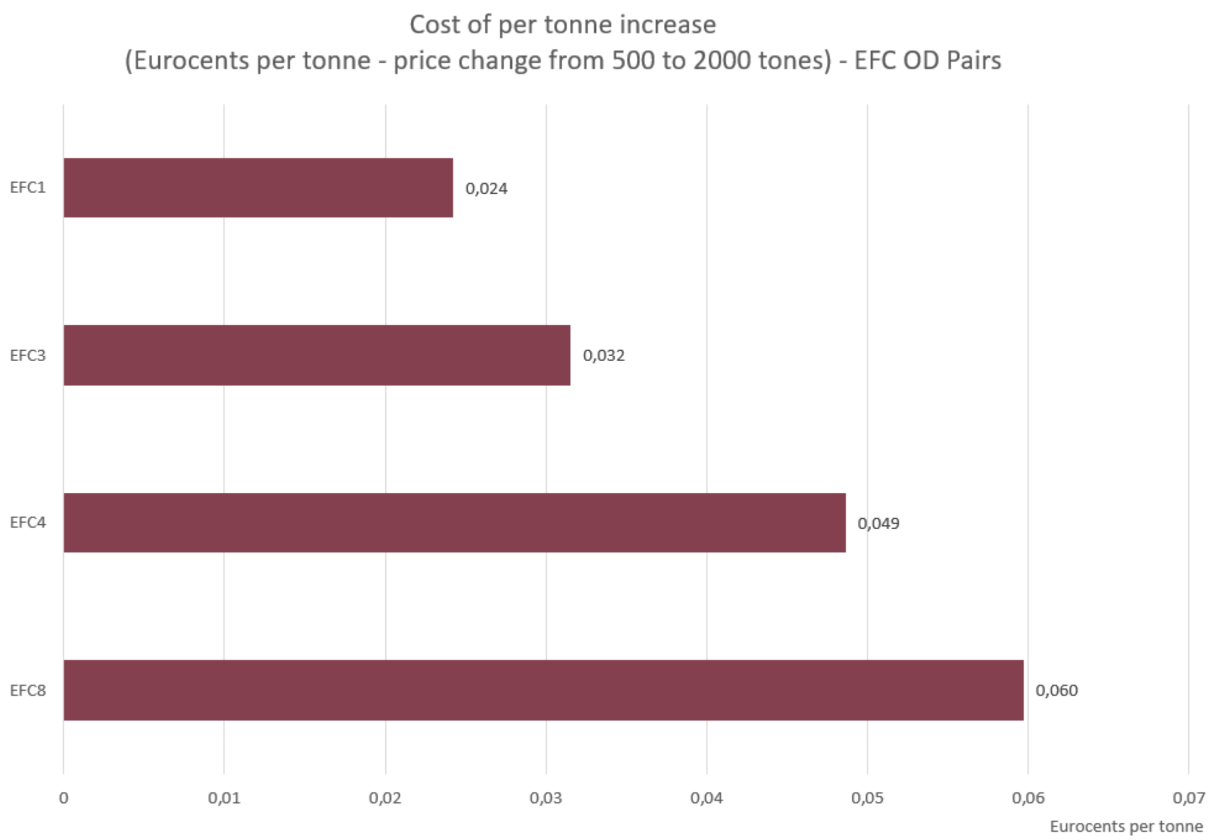


Figure 35 Cost per tonne increase (price change from 500 to 2000 tonnes) - EFC OD Pairs

Naturally for the corridors lesser disparity was observed. The most expensive price per tonne has been noticed for EFC8 (0,060 eurocents). The least expensive price per tonne has been noticed for EFC1 (0,024 eurocents). For all of the analysed corridors the price per tonne is rather small.

3.4. Comparison of freight pricing in road and rail transport

The type of transport mode is chosen due to many factors. One of the most important factor are prices for infrastructure usage, which are set by the infrastructure manager for rail and in case of roads by public or private entities. This chapter focuses on running charges comparison of those modes.

The issue of competition between road and rail transports comes with following questions:

- Are the charges competitive, which mode of transport is more beneficial for the shippers?
- Are the differences between the modes in terms of prices fair?
- Do road charges provide enough budget to fulfil maintenance costs?

This section aims to answer these questions.

To compare the modes, the paths and charges from quantitative analysis were used for rail and compared with representative road routes and their charges between the same origins and destinations. The values of fees for road transport were obtained from the toll calculator [26] or website of the particular road [27]. The truck is considered to be in the category HGV (heavy goods vehicle) with 7 axles. The charges were expressed in its total for the entire path, per train/ truck-km, and in eurocents per tonne-km. The value of charge in eurocents per tonne-km was obtained by dividing the charge per km by the mass of the train or in case of trucks by the maximum permissible weight in a given country

[28] (as there is no fee depending on weight of truck on the roads). The results are presented in table 6.

Table 6 Comparison between rail and road transport for National OD Pairs - running charges.

OD Pair	Path length [km]			Total charge 2023 [€]		Avg. charge per km 2023 [€ per km]			EUROCENTS per tkm (500 tonnes trains, HGV - 7 axles)			PERMISSIBLE MAX. WEIGHTS OF LORRIES (in tonnes)
	Rail	Road	Difference	Rail	Road	Rail	Road	Difference	Rail	Road	Difference	Road
Austria (Vienna – Salzburg)	320,67	299,40	-21,27	641,34	126,16	2,00	0,42	-1,58	0,400	1,053	0,65	40
Belgium (Namur – Antwerp)	109,87	104,80	-5,07	212,60	18,23	1,93	0,17	-1,76	0,387	0,395	0,01	44
France (Perpignan – Metz)	945,10	919,80	-25,30	1491,70	239,40	1,58	0,26	-1,32	0,316	0,592	0,28	44
Germany (Hamburg – Mannheim)	586,50	566,60	-19,90	1841,61	105,20	3,14	0,19	-2,95	0,628	0,464	-0,16	40
Italy (Milano – Rome)	603,23	572,10	-31,13	1389,84	101,50	2,30	0,18	-2,13	0,461	0,403	-0,06	44
Netherlands (Rotterdam – Venlo)	142,40	163,10	20,70	118,23	0,00	0,83	0,00	-0,83	0,166	0,000	-0,17	50
Poland (Warsaw – Katowice)	370,26	303,20	-67,06	735,93	7,16	1,95	0,02	-1,93	0,391	0,059	-0,33	40
Portugal (Lisbon – Porto)	336,10	315,20	-20,90	514,70	55,10	1,53	0,17	-1,36	0,306	0,397	0,09	44
Spain (Madrid – Irun)	625,70	469,20	-156,50	127,83	35,27	0,20	0,08	-0,13	0,041	0,188	0,15	40
Switzerland (Lausanne – Buchs)	324,95	184,90	-140,05	408,97	84,80	1,26	0,46	-0,80	0,252	1,147	0,89	40

In the first part of the table, a route length is compared. The darkest blue represents the longest route and the brightest blue - the shortest route. Other parts contain information on charges. The difference between road and rail transport is presented by green red color scale palette, in which the darkest green means the highest difference with benefit for rail and the darkest red the highest difference with benefit for road. The last column is a complementary information on maximum permissible weight of lorries due to regulations provided by given countries [28].

The routes are rather shorter for roads than for rail. It was expected as the road geometry restriction demanded less for radii and inclination. The highest difference in routes were observed for Spain – 157 km and Switzerland 140 km. It is a result of mountain terrain in those regions.

The highest tolls for road freight transport are charged in Switzerland and Austria (respectively 0,46 € per km and 0,42 € per km). The lowest tolls are in the Netherlands, Poland and Spain (respectively

0,00 € per km, 0,02 € per km and 0,08 € per km). Germany is a country with the highest running charge – 3,14 € per km for train freight transport and relatively low charge for road freight transport – 0,19 € per km.

Bearing in mind capacity difference and weight limits for both modes of transport, more relevant comparison should include the effect of mass of transported goods on charge. Therefore the last part of the table presents eurocents per train tonne-km. The charge for trains was calculated by dividing charge for 500 tonnes trains by 500 and for lorries by dividing charge per km by the maximum permissible weights for each country. The results are presented in the table above and additionaly presented on the figure 36. To enrich the analysis, the diagram additionally includes a charge for 960 tonnes train and a marginal cost threshold imposed by EC for the rail transport. The additional bar in the graph for 960 tonnes is to consider the possibility of the rail freight market starting to be competitive just after some weight threshold. The marginal cost thresholds' unit was transformed from € per 1000 tkm to eurocents per tkm (2,67 € per tkm = 0,267 eurocents per tkm). It is important to emphasize that the marginal cost for road transport is higher than for rail transport [8] (as it was mentioned in chapter 2).

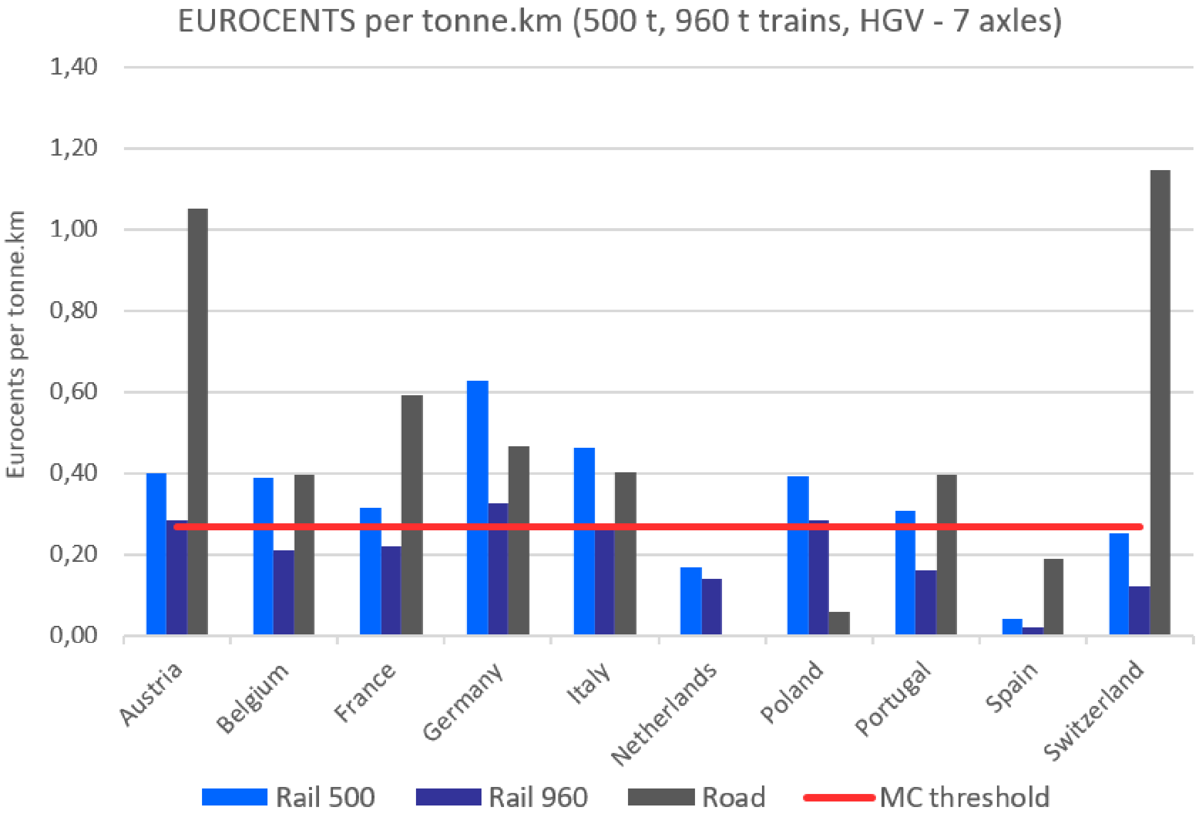


Figure 36 Comparison between rail and road transport for National OD Pairs - running charges in eurocents per tkm

The charges for road freight transport are much more dispersed than for rail freight transport. They fluctuate from 0,00 eurocents per tkm – for Netherlands to 1,15 eurocents per tkm – for Switzerland.

In four countries it is cheaper to transport goods by road than train (in terms of running charge). The biggest difference of the charges is in Poland – the road transport is 0,33 eurocents per tkm cheaper. In Netherlands, Germany and Italy the differences are smaller – from 0,17 to 0,06 eurocent per tkm.

Switzerland, Austria and France discourage using roads for freight transport, as it is respectively 0,89, 0,65 and 0,28 eurocents per tkm more expensive than rail freight transport. In other countries, where the charges for road are higher than for rail, the differences are not big enough to consider relevant.

In relation to the marginal cost threshold, it is important to highlight that there is no regulation imposing on road transport to base its infrastructure charge on maintenance costs. Moreover, the road charges considered in this analysis are the toll prices from the motorways. There exist other alternative highways on which the tariffs may be omitted. Nevertheless, existing examples in which the road transport is cheaper than rail transport, shows that the competition (even with the roads with tolls) is not completely fair. For instance, in Poland the charges for rail exceed the marginal cost threshold, whereas charges for road transport are far from reaching it, even though the maintenance cost per tkm is higher for road than for rail [8].

In regards to charge for 960 t trains, it was observed that Belgium, Germany, Italy and Portugal gained a lot of competitiveness, as the charges at this weight level became lower than for road transport.

Table 7 presents results of the analysis for chosen European Freight Corridors. For every corridor the maximum permissible weight limit for trucks was considered 40 t.

Table 7 Comparison between rail and road transport for EFC OD Pairs - running charges.

Corridor	OD Pair	Path length [km]			Total charge 2023 [€]		Avg. charge per km 2023 [€ per km]			EUROCENTS per tkm (500 tonnes trains, HGV - 7 axles)		
		Rail	Road	Difference	Rail	Road	Rail	Road	Difference	Rail	Road	Difference
EFC1	Netherlands - Italy (Rotterdam - Genova)	1257,00	1201,80	-55,20	2998,94	272,48	2,39	0,23	-2,16	0,477	0,567	0,09
EFC3	Germany - Italy (Flensburg - V. S. Giovanni)	2463,82	2529,20	65,38	7003,35	255,60	2,84	0,10	-2,74	0,568	0,253	-0,32
EFC4	Portugal - France (Lisbon - Metz)	2221,40	2076,90	-144,50	2585,82	277,45	1,17	0,13	-1,03	0,233	0,334	0,10
EFC8	Belgium - Poland (Antwerpen - Terespol)	1563,48	1457,00	-106,48	3949,83	196,13	2,52	0,13	-2,39	0,505	0,337	-0,17

As for national OD pairs, the routes are rather shorter for roads than for rail.

The highest tolls for road freight transport are charged in corridor EFC1 between Netherlands and Italy – 0,23 € per km. The highest average charge difference occurs for corridor EFC3. This corridor has the highest running charge – 2,84 € per km for train freight transport and very low charge for road freight transport – 0,10 € per km.

The charges expressed in eurocents per tonne-km are presented on the figure 37.

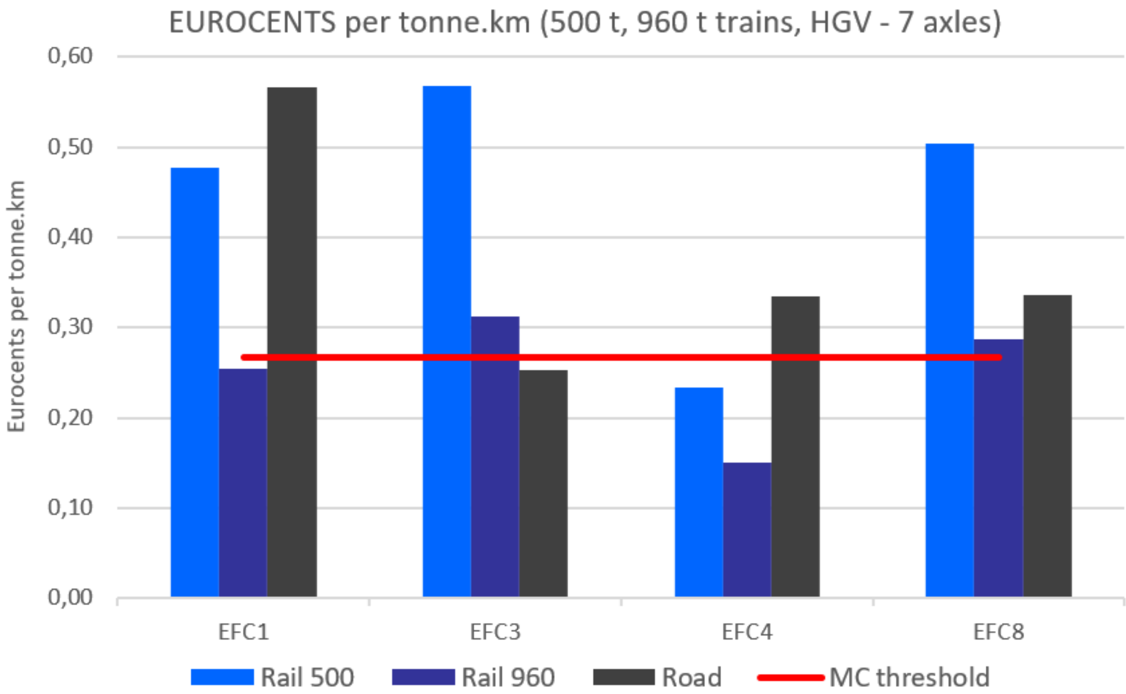


Figure 37 Comparison between rail and road transport for EFC OD Pairs - running charges in eurocents per tkm

The charges for road freight transport fluctuate from 0,25 eurocents – for EFC3 to 0,57 eurocents - for EFC1.

In EFC3 and EFC8 it is cheaper to transport goods by road than train (due to running charge). The biggest difference of the charges is in EFC3 – the road transport is 0,32 eurocents per tkm cheaper. In EFC8 the difference is smaller – 0,17 eurocents per tkm.

EFC1 and EFC4 have a little bit smaller charges for rail freight transport - respectively 0,09 and 0,10 eurocents per tkm cheaper than road freight transport.

In relation to the marginal cost threshold, in EFC3 the charges for rail exceed the marginal cost threshold, whereas charges for road transport do not reach it.

In regards to charge for 960 t trains, it was observed that EFC1 and EFC8 gain a lot of competitiveness. For EFC8 the charges at this weight level became lower than for road transport and for EFC1 from similar charges for 500 t they became much lower for 960 t trains.

3.5. Critical analysis of Network Statements

This section involves discussion whether the pricing systems align with the European Commission´s directives and regulations.

Firstly, the analysis focuses on Network Statement Overview. It involves comments on its features associated with intelligibility and comprehensibility. The Network Statements presents the rules for the year 2023.

Table 8 presents the features of the Network Statement (NS). The "+" means that the country complies with the feature, "o" – that the criterion is not fully complied, and "-" means no compliance.

Table 8 Network Statement Overview

Country	Up-to-date NS in Local Language(s)	Up-to-date annexes in Local Language(s)	Up-to-Date NS in English	Up-to-Date Annexes in English	English Translation Adequate	Charging System Described in NS	Prices for Infra Use Listed in NS	No Excessive References to Annexes	NS is User-Friendly	Info on Segmentation Available	Complete Info to Calculate Infra Charge
Austria	+	+	+	-	+	+	+	+	+	-	o
Belgium	+	+	+	+	+	+	-	+	+	o	+
France	+	+	+	o	+	o	-	+	+	+	+
Germany	+	+	+	-	+	+	o	-	o	-	o
Italy	+	+	+	+	+	+	+	+	+	-	o
Netherlands	+	+	+	o	o	+	+	+	o	-	o
Poland	+	+	+	+	+	+	-	+	+	+	+
Portugal	+	+	+	+	+	+	+	+	+	-	o
Spain	-	-	-	-	+	+	+	+	+	o	o
Switzerland	+	+	+	-	+	-	-	-	o	-	o

Generally, the Network Statements presented for 2023 are comprehensive and don't impede its use in order to calculate the infrastructure charges. However, the calculation of the charge per km was not always possible, as Network Statements seldom contain information on segmentation (or it was incomplete or difficult to find), which is an important part for the Railway Undertaking to calculate the distance and time of the transport. As a result, the last column was completed with many "o"s.

Both Network Statements and Annexes were to be presented in local language and English. Spain didn't announce the Network Statement for 2023. The one from 2022 was assessed. Some of the annexes for Austria, Germany and Switzerland were only available in local language. France and Netherlands presented all the annexes in both languages, except the explanation of the marginal cost calculation method.

Inclusion of price list in Network Statement facilitates charges calculation and makes it faster. Only half of countries compiled this criterion. Germany presented the charges in the Network Statement only for the standard paths. Other charges were presented in the annex. The rest of the countries included the charge lists in the annexes.

Austria

Even though Austrian NS contain multiple annexes, they are well described and facilitate navigation rather than hinder it. It biggest con was that it was usually presented only in German.

Belgium

Belgian description of tariffs is very simple and user-friendly. The charges for freight trains are not dependent on many variables. They contain just 2 components: charge per km and charge per tonne-km. The Network Statement didn't include segmentation. It only contained the distance between stations and nodes, which is not a convenient form of presentation, due to total charge calculation.

France

The French charging system is partly described in Network Statement, partly in multiple annexes.

Germany

Charges listed in the annex with description of mark-up and direct cost determination are only available in German. The Network Statement was considered not friendly in terms of navigating difficulties. Although there is no Segmentation available, German Infrastructure Manager provides a portal, which allows generating information on chosen routes.

Netherlands

In the Network Statement of the Netherlands non-standard formulations were used for example: word "compensation" instead of "charge" or "fee" “titleholder” instead of RU and “Network Manager” instead of “Infrastructure Manager”. Some tables included in NS (for instance table with information on categories of capacity restrictions) are not translated and moreover are attached as a picture not as table, which hinders further translation.

Spain

Spanish Network Statement contains adequate English translations. The “-“ it got for the first four columns is caused by the fact the NS is given for 2022 year instead of 2023. Although Line Classification by Types is available, there is no break down into sections between nodes. The length given is the length of the entire line.

Switzerland

NS refers to multiple sources which are available only in local language. Moreover, there are 3 different Infrastructure Managers and each of them published one network statement. The Network Statement that contains tariff information is presented in uncomfortable form, that is, it is only available on a website and there is no possibility to download it in the PDF form. However, the NS is User-friendly in terms of charge explanation. Every price is explained with details and calculation examples are given for each of them.

The table 10 shows how the compliance of the network statements with the legislations imposed by the EC.

Table 9 Network Statements compliance with the Directives and Regulations

Country	MC based system	MC calculation methodology available	MC<2€(2,67€)/tra in km for a 1000(960)-ton	Holding Company	Separate IM and Operators	Capacity Allocation Body	New IMs	Number of total active RUs 2020 [29]	Number of freight RUs 2020 [29]	Number of total active RUs 2013 [30]	Number of freight RUs 2013 [30]
Austria	MC+	-	+	+	-	-	-	59	44	33	28
Belgium	MC	-	+	-	+	-	-	14	11	15	13
France	MC	o	+	+	-	-	-	28	24	23	20
Germany	MC+	o	+	+	-	-	-	344	242	311	226
Italy	MC+	-	+	+	-	-	-	39	23	44	19
Netherlands	MC+	o	+	-	+	-	-	41	28	27	19
Poland	MC+	+	+	+	-	-	-	100	88	72	61
Portugal	MC	-	+	-	+	-	-	4	2	4	2
Spain	MC+	-	+	-	+	-	-	13	12	9	8
Switzerland	MC	o	+	+	-	-	-	58	25	60	42

All of the analysed pricing systems fulfil the demand to be based on the marginal cost. That is a significant modification in regards to what was observed before in the previous chapter. The deadline to implement the obligation to base the system on marginal cost, bearing in mind a possibility of gradual adaptation, was set to the year 2019. Therefore, that modification was expected. However, the pricing systems still were constructed in various ways. The systems were considered as MC+, when the mark-up was provided for freight trains. Sometimes their structures were unequivocally MC+. For some systems a charge component was not defined as mark-up, but since it depended on the market segment and didn’t depend on direct cost it was interpreted as a mark-up. For instance, in Spain there is a tariff for capacity allocation, which depends solely on type of service and line type. In Poland as the mark-up may be perceived the “Portion of the fee related to the type of the transports carried out”. None of those refer directly to willingness to pay. On the other hand, in Belgium, France and Portugal there is no mark-up for freight transport, but there are mark-ups for other segments. In Switzerland there is no component of charge that can be explained as mark-up.

On contrary to fulfilment of the first criterion, for the majority, the MC calculation methodology remained unavailable, or only available in local language (the countries marked with “o”).

Nonetheless, countries defend themselves in another criterion. The MC was compared to the value of 2,67 €, which is a threshold given by the EC till which the regulatory body may accept the calculation, without a strict control.

All of the countries have MC lower than 2,67 €. Therefore, even though only Poland fulfilled the three criteria and rest either partially fulfilled them (providing the explanation of MC calculation only in local language) or did not fulfil desisting to explain the MC calculation methodology, all of the countries have the marginal cost lower than the given threshold, thus may evade control of regulator.

The full separation between managing a network and operating is slightly less popular than separation through a holding company. Neither capacity allocation body nor new IMs emerged in selected countries.

The last column of the table refers to how the market changed in the case of the number of RUs. A better insight on this data is provided with the figures 38 and 39.

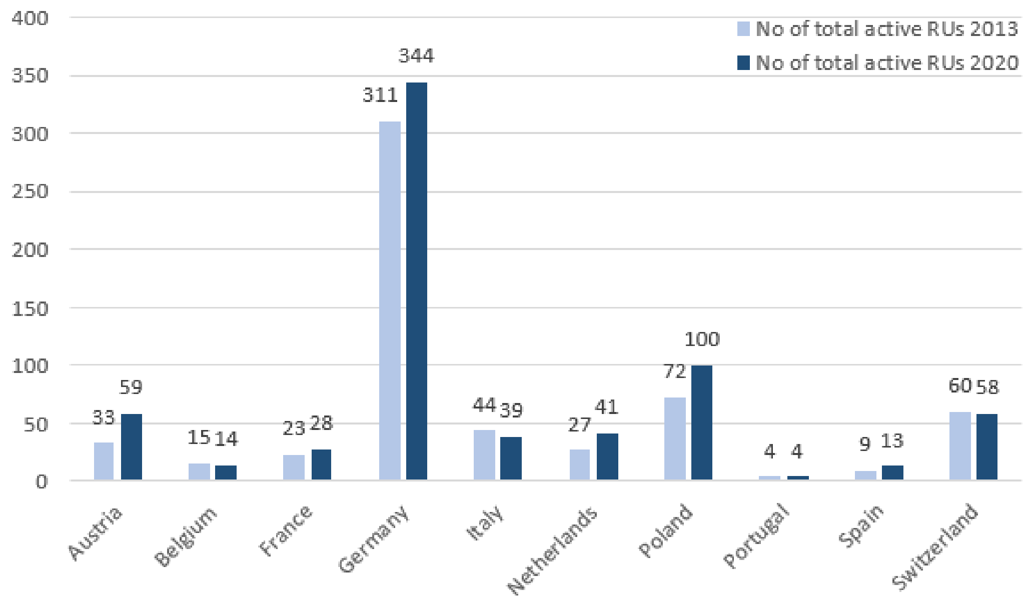


Figure 38 Number of total active RUs in 2013 and 2020[13]

Only in Belgium, Italy and Switzerland the number of total active RUs decreased, however slightly. In Austria, Germany and Poland it got higher by about 30 new RUs. In other countries didn't change much.

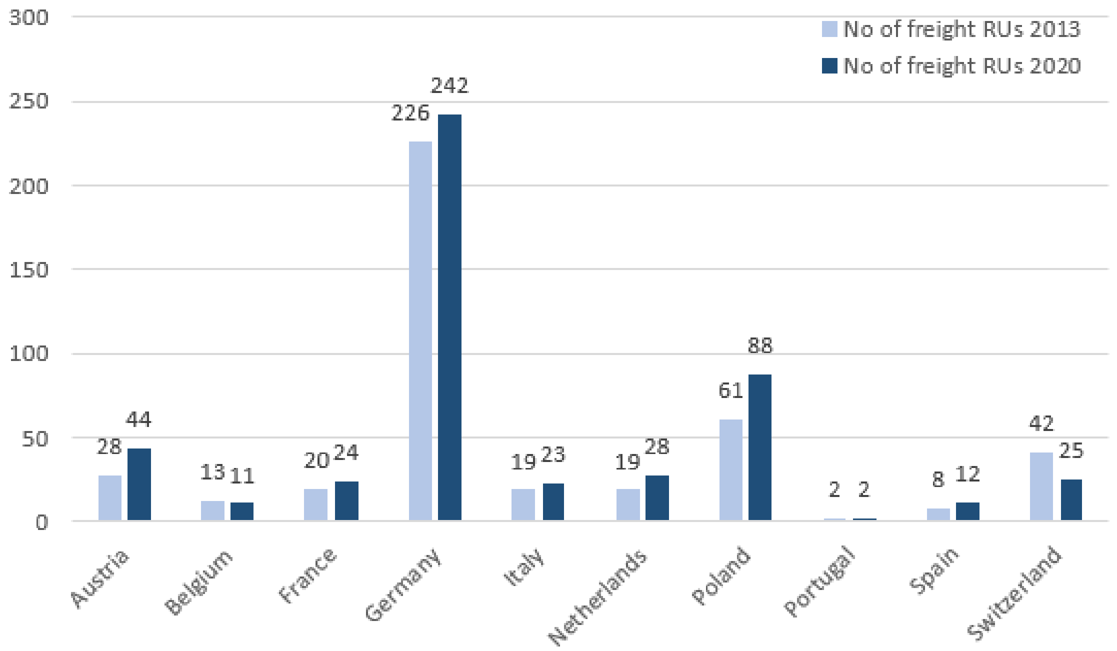


Figure 39 Number of active freight RUs in 2013 and 2020[13]

In terms of number of active freight RUs, it dropped a bit in Belgium and significantly in Switzerland. Same as in the previous case notably more freight RUs appeared in Austria, Germany and Poland.

[13] The figure uses data from IRG Annual Market Monitoring Reports [29], [30]

4. Analysis of the evolution of railway infrastructure pricing systems for freight in the last 10 years

4.1. Methodology

The methodology applied in this chapter corresponds with the previous chapter. The analysis from chapter 3 is extended by the results from UIC report [2] concerning 2013 pricing systems. The assumptions made are exactly the same in order to maintain consistency and relevance.

Chapter 4. involve analysis of pricing systems evolution divided on two subsections. The first one concerns charging systems qualities and the second one focuses on charge levels using various assumptions. The last subsection contains discussion, in which all the analyses are confronted.

4.2. Evolution of systems structure

This section focuses on the evolution of infrastructure pricing systems for rail freight transport in terms of variables and system construction.

The figure 40 shows the variables and charge categories evolution. The figure 16 is compared with one from the UIC report [2] concerning 2013 pricing systems. In the annex the original figure and one with explanation of the variables is attached. On the figure with "-" and red colour were marked variables that were removed from the particular pricing system. In case of no change regarding a particular variable, the field was marked with "o". When the new variable was added within 10 years, the cell was highlighted with green colour and "+".

	Austria	Belgium	France	Germany	Italy	Netherlands	Poland	Portugal	Spain	Switzerland
What Is Charged (only for freight trains)										
Time-of-day pricing	-	-	-	o	o	o	o	+	-	o
Train Frequency	o	o	o	o	o	o	o	o	o	o
Train speed	-	-	o	o	o	o	o	o	-	+
Train Type (Physical Characteristics)	o	-	+	+	+	+	+	o	o	+
Axle load	o	o	o	o	o	o	o	o	o	o
Loco/Traction Type (characteristics)	o	+	+	o	+	o	+	o	+	o
Service Type (Service Pattern, distance)	+	-	-	+	+	o	+	o	-	o
Train-path quality	o	o	o	o	o	o	o	o	o	o
Line Type (importance categorization)	o	-	o	-	-	-	+	-	-	o
Line Type (capacity)	o	o	-	-	o	o	o	o	+	+
Capacity maximization Charge	o	-	o	-	o	o	-	o	o	o
Scarcity Surcharge	o	o	o	-	o	-	o	o	o	+
Low-speed penalty	o	o	o	-	o	o	-	o	o	o
How is Usage Charged										
Flat Fee	o	o	+	o	o	o	o	o	o	o
Fee per train-km	o	o	o	o	o	o	o	o	o	o
Fee per tonne-km	o	o	o	o	o	-	-	o	o	o
Fee per min	o	o	o	o	-	o	o	o	o	o
Node fee	o	o	o	o	-	o	o	o	o	o
Axle-km	o	o	o	-	o	o	o	o	o	o
Axle load	o	o	o	o	o	o	-	o	o	o
Charge Categories										
Reservation Fee	+	o	-	-	-	o	+	o	o	o
Cancellation Fee	o	o	o	o	+	o	+	o	o	o
Running Charge	o	o	o	o	o	o	o	o	o	o
Admin Fee	o	-	-	o	o	o	o	o	o	o
Access Fee	o	o	o	o	+	o	o	o	-	o
Security Fee	+	o	-	o	o	o	o	o	-	o
Accident Insurance Charge	o	o	o	o	o	o	o	o	o	o
Environmental Surcharge	o	-	o	o	o	o	o	o	o	o
Special Infrastructure Fees	+	o	o	o	+	o	o	o	o	+
Dangerous goods transport	+	o	-	+	+	o	o	o	o	+
Noise fee/discount	o	o	o	-	o	-	-	o	o	+
ETCS fee/discount	o	o	o	o	o	o	o	o	o	o
Performance Scheme	o	o	o	o	o	+	+	o	o	o
Freight Subsidy / Discount	o	o	o	o	o	-	o	o	o	o
Traction Current and Fuel										
Traction Current - access	+	o	o	o	o	o	+	o	o	o
Traction Current - management	o	o	o	o	o	+	o	o	-	o
Traction Current - use fee	o	o	+	o	o	+	o	+	-	o
Fuel - management	o	o	o	o	o	o	o	o	o	o
Fuel - dispensing	o	o	o	o	+	o	o	+	o	o
Fuel - access	o	o	+	o	+	o	o	o	+	o
Varying rates for Diesel/Electric	+	+	+	o	+	o	o	o	+	o

Figure 40 Variables and Categories of Charges evolution in last 10 years

It was observed that the least changes occurred in Portugal, whereas the rest changed a lot. The most changes occurred in France, Italy, Poland and Spain. In France the number of new variables is similar to removed ones. Switzerland added quite many new variables and didn't remove any.

Even though Italy added more variables than removed, its system is not very complicated anymore. The charging rules are explained briefly and clearly. No more node fee nor fee per minute is applied, which facilitates calculations substantially.

Belgium, Germany and Spain simplified their systems significantly. They removed many variables from the first category (What is charged). Poland substituted charges per tonne-km and per axle load with weight categories, which also may be perceived as simplification.

Both "Train Type" and "Loco/ Traction Type" variables have been added in 5 pricing systems. The other variables that gained popularity are "Service Type" and "Dangerous goods Transport".

The variables that were withdrawn most often are “Time-of-day pricing”, “Line type (importance categorization)”, “Train speed” and “Service Type” (this variable was removed by 3 countries and added by other 3).

There are also some variables that are not included in the figure, as they were not included in the one from the UIC 2013 report. These variables are Discount for Long Train and Infrastructure Characteristics (radius). Both of them are applied solely by the Swiss IM.

4.3. Evolution of tariff levels

4.3.1. Interval variation, 2013 and 2023 charges comparison

The first part of the tariff levels evolution analysis concerns ranges of charges for each country’s charging system. It expands the quantitative analysis from chapter 3 by adding results for 2013. The assumptions remained the same. The set of diagrams with results of the calculations are presented on figure 41.

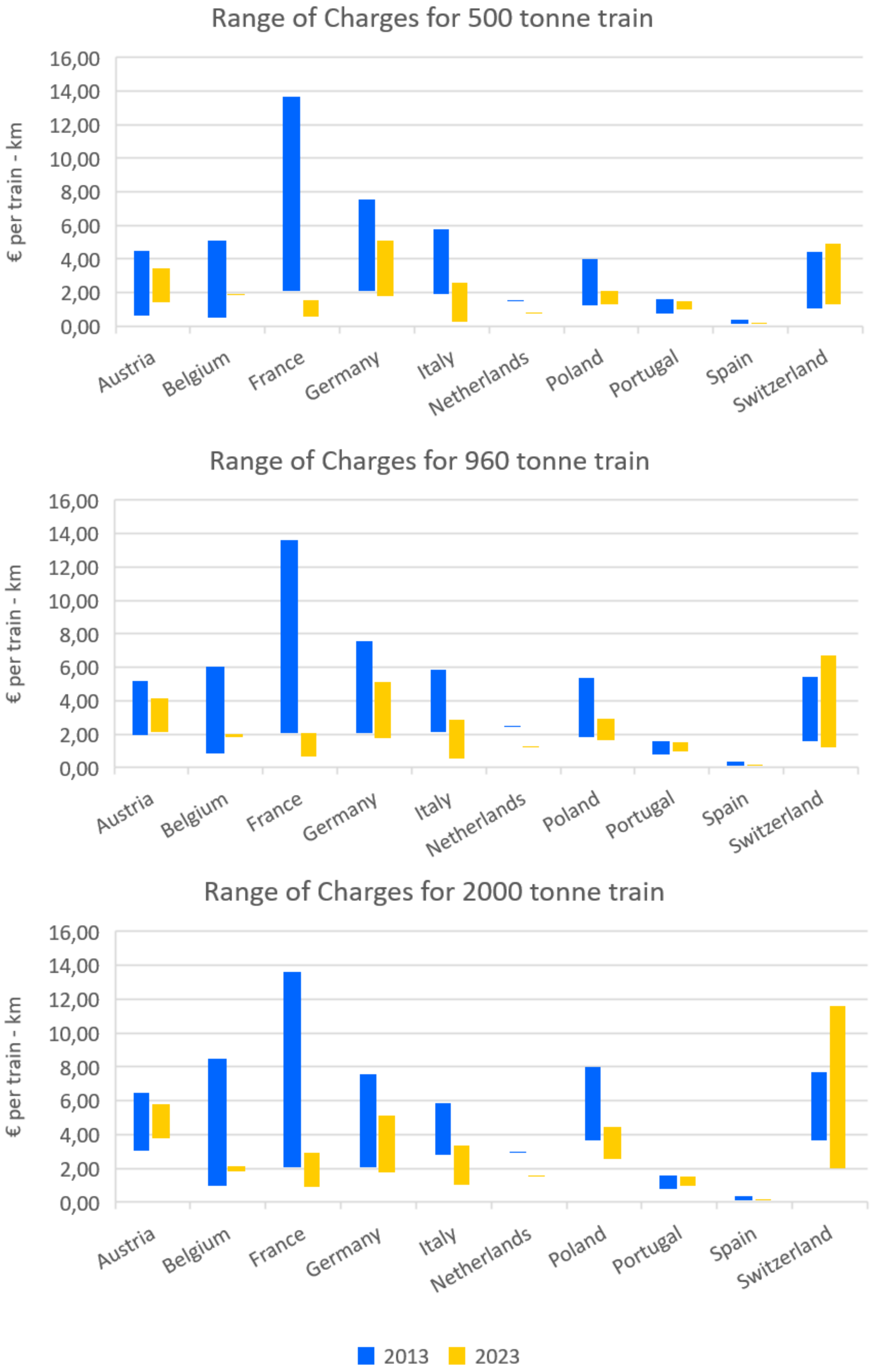


Figure 41 Range of charges for 500, 960 and 2000 tonne train, 2013 and 2023 comparison

Generally, the ranges of charges got more concentrated. Only Switzerland is an exception, whose charge variation increased significantly. For Switzerland the ranges of price difference get bigger with increase of weight. This enormous difference is the result of the high value of surcharge for trains hauled by combustion-based motive power and lack of this surcharge for electric trains.

The biggest change in intervals was observed for France. For 500 tonnes trains the maximum charge in 2023 is lower than minimum charge in 2013. Minimum charge is about 1,5 € per km lower and maximum charge is over 12 € per km lower now. Those values change a bit for heavier trains. The charge in France used not to depend on weight. Now it does. A smaller change, nonetheless also evident, in intervals has been observed for Italy.

Belgium used to have a wide range of prices. It changed for 2023 year. There are only 2 possible heights of charges for freight trains and the difference between them is only between 0,14 – 0,40 € per km. For 500 t trains minimum charge increased about 1,3 € per km and maximum charge is about 3,2 € per km lower now.

Belgian charges used to be significantly dependent on weights. Now the maximum charge changes slightly due to weight.

In Austria, Germany, Italy and Poland the maximum possible charge for freight trains decreased at least 1 € per km.

4.3.2. National OD pairs, 2013 and 2023 charges comparison

In this part charges for chosen origin destination pairs in each of selected countries are compared. The approach chosen for this analysis is to start with a general presentation, discussing the results for all of the selected systems together and then get into the details, demonstrating the differences between the charges for each country. The following analysis expands the previous section by adding results for 2013. The figure 42 shows a box plot containing charges from all the selected countries.

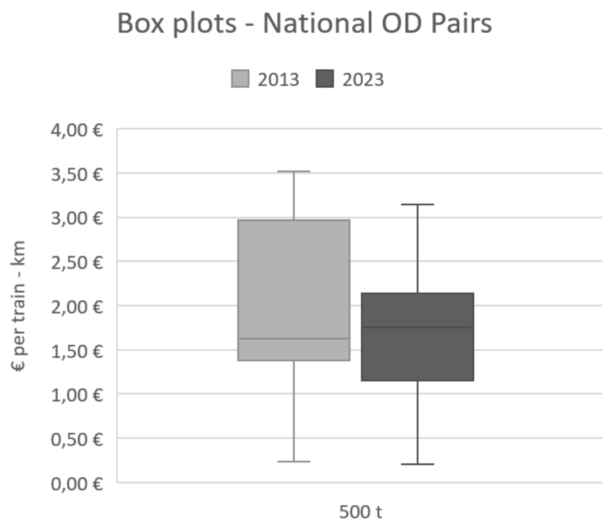


Figure 42 Box plot - range of prices for selected National OD Pairs for 2013 and 2023

Generally, the charges for National OD pairs for 500 tonnes trains didn't change fundamentally. The range of charges narrowed slightly. Minimum charge in 2013 was almost the same as in 2023 – it decreased from 0,24 to 0,20 € per km. Median value for 2023 increased 0,16 € per km. The biggest drop was observed in the upper quartile – charge decreased from 2,96 € per km to 2,08 € per km. In consequence interquartile range got more compacted. The results of the calculations are presented in table 10.

Table 10 National OD Pairs (500-tonne train) - Results for 2013 and 2023 comparison

OD Pair	Path length [km]	Total charge 2013 [€]	Total charge 2023 [€]	Total charge diff. [€]	Avg. charge per km 2013 [€/km]	Avg. charge per km 2023 [€/km]	Avg. charge per km diff. [€/km]	Line Cost 2013 [€]	Line Cost 2023 [€]	Terminals 2013 [€]	Terminals 2023 [€]	Energy access 2013 [€]	Energy access 2023 [€]	Energy use 2013 [€]	Energy use 2023 [€]
Austria (Vienna – Salzburg)	320,67	791,48	641,34	-150,14	2,47	2,00	-0,47	791,48	641,34	0,00	0,00	0,00	0,00	0,00	0,00
Belgium (Namur – Antwerp)	109,87	186,65	212,60	25,95	1,70	1,93	0,24	157,21	196,78	29,44	0,00	0,00	15,82	0,00	0,00
France (Perpignan – Metz)[14,15]	945,10	2650,65	1491,70	-1158,95	2,80	1,58	-1,22	2413,43	1024,44	0,00	0,00	237,22	467,26	0,00	0,00
Germany (Hamburg – Mannheim)	586,50	2014,85	1841,61	-173,24	3,44	3,14	-0,30	2014,85	1841,61	0,00	0,00	0,00	0,00	0,00	0,00
Italy (Milano – Rome)	603,23	861,28	1389,84	528,56	1,43	2,30	0,88	861,28	1361,49	0,00	0,00	0,00	28,35	200,30	0,00
Netherlands (Rotterdam – Venlo)	142,40	221,67	118,23	-103,44	1,56	0,83	-0,73	221,67	118,23	0,00	0,00	0,00	0,00	0,00	0,00
Poland (Warsaw – Katowice) [14]	370,26	1304,20	735,93	-568,27	3,52	1,95	-1,57	1304,20	717,91	0,00	0,00	0,00	18,02	0,00	0,00
Portugal (Lisbon – Porto)	336,10	493,24	514,70	21,46	1,47	1,53	0,06	493,24	514,70	0,00	0,00	0,00	0,00	0,00	0,00
Spain (Madrid – Irun)	625,70	147,39	127,83	-19,56	0,24	0,20	-0,03	147,39	109,87	0,00	0,00	0,00	17,96	0,00	0,00
Switzerland (Lausanne – Buchs)	324,95	397,96	408,97	11,01	1,22	1,26	0,03	397,96	407,05	0,00	1,92	0,00	0,00	435,91	444,33

As in previous tables, results highlighted with more intensive colours are higher. Additionally, columns "Total charge difference" and "Average charge per km difference" contain a green-red color scale palette, in which the darkest green stands for the biggest price drop and the darkest red the biggest price increase.

In most of the countries total charge elements remained the same contribution level. The Belgian pricing system no longer charges for terminal access. The French total charge is much more dependent on electricity access than 10 years ago. In Italy total charge increased about 60%. For the Milano – Rome it's 528 € higher. It's the only country in which the total charge increased significantly. The second biggest increase of total charge is in Belgium and equals 26 €. In the Netherlands, France and Poland total charge decreased about 45%. Being the longest, the French route obtained the biggest drop of total charge equalling 1160 €. Second biggest decrease of total charge obtained by Poland equals 570 €. Other significant decreases obtained by Germany, Austria and Netherland were equal respectively: 170 €, 150 € and 100 €. Figure 43 facilitates comparison between charges per km.

[14] For France and Poland, the paths lengths were calculated. Obtained values were different than those from the UIC study. For France it is now 1,30 km shorter and for Poland 6,37 km longer.

[15] French National OD pair charge is compared to subsidized one, because for 2023 freight trains will be also subsidized.

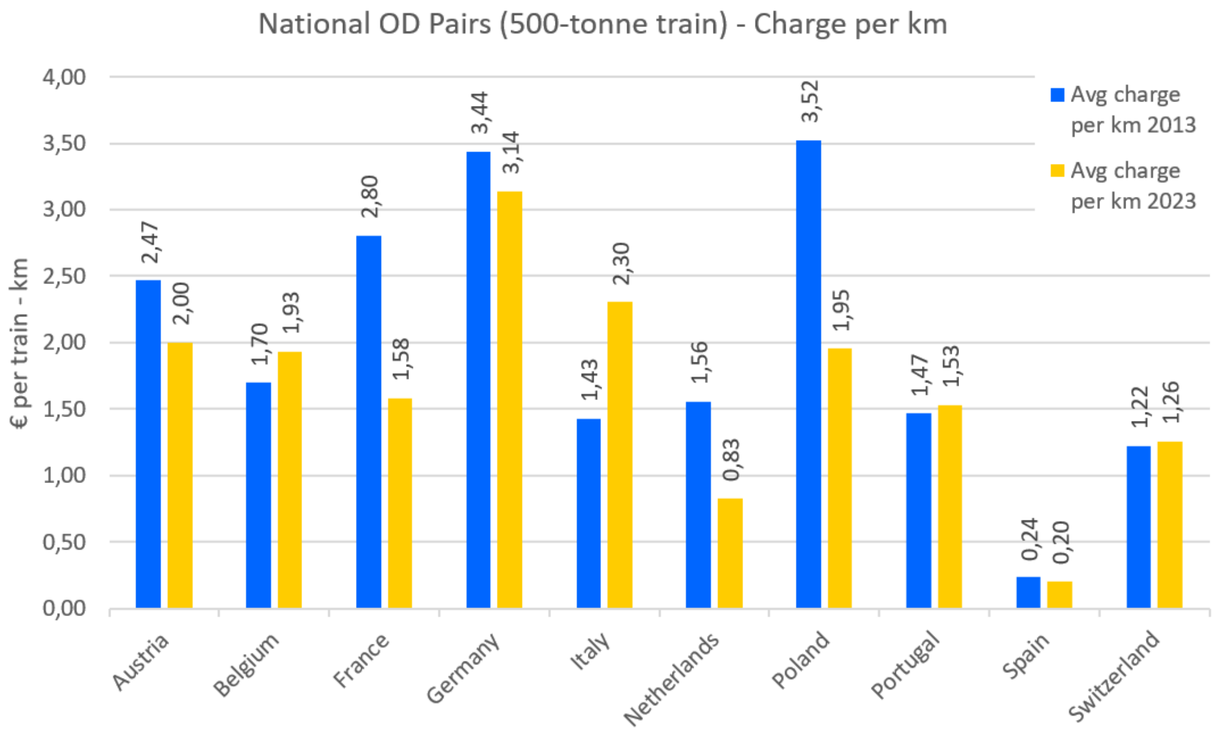


Figure 43 National OD Pairs (500-tonne train) - charge per km for 2013 and 2023

The biggest decrease of charge per km has been observed for Poland, France and Netherlands. The Polish pricing system, which used to have the biggest charge per km (in the selected set of countries), obtained the biggest decrease charge per km equal 1,57 € per km. The second biggest decrease was obtained by France – 1,22 € per km. Nonetheless, the Spanish charges remained the cheapest one.

The increases of prices have been registered for Italy, Belgium, Portugal and Switzerland. The Italian price increased a lot. Belgian charge went up slightly, whereas Portuguese and Swiss increases of prices are rather insignificant.

To notice the significance of the price increases, figure 44 presents percentage change of charges.

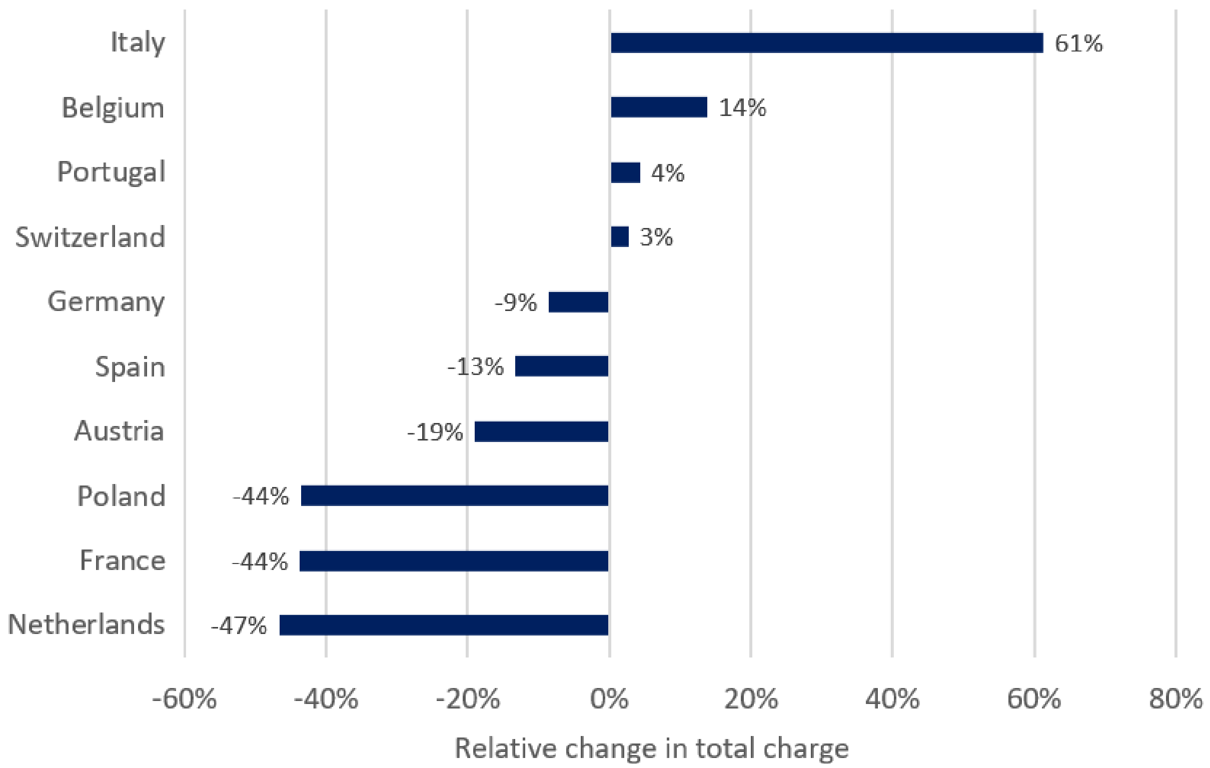


Figure 44 Relative change in total charge [%] for National OD pairs, 500 t train

The biggest relative change in price was observed for Italy – about 61%. On the other hand, the biggest relative decrease of charge was observed for the Netherlands, France and Poland – from 44 to 47%.

To conceive the significance of the price increases, figure 45 contains juxtaposition of percentage change of charges with inflation rate. Due to data accessibility, the diagram describes inflation between years 2013 and 2021 [31].

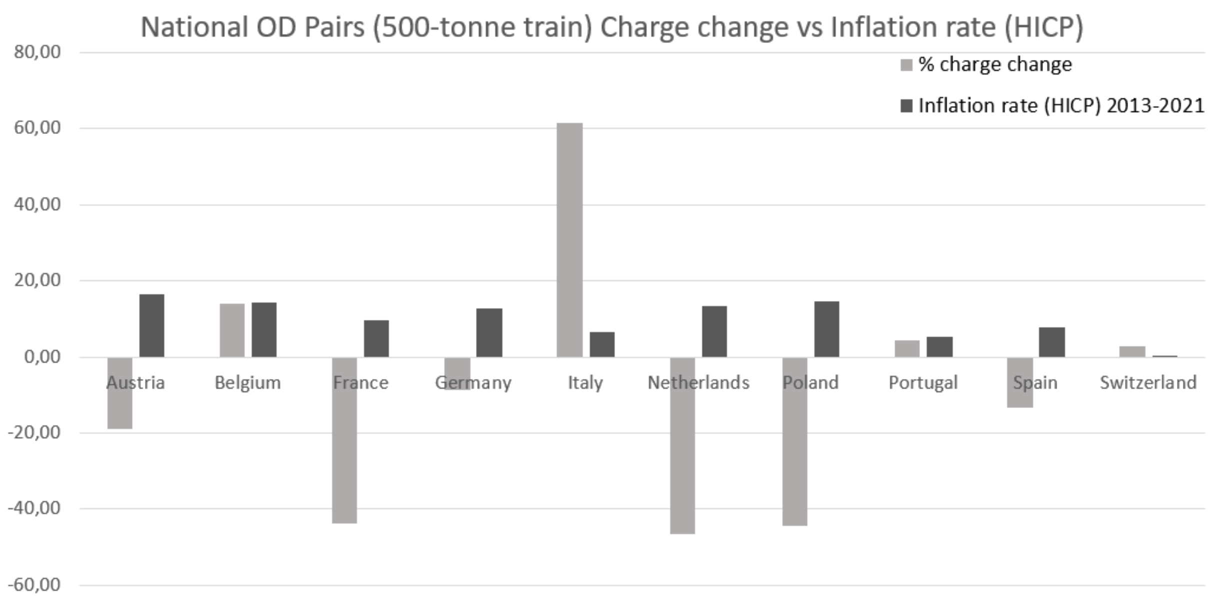


Figure 45 National OD Pairs (500-tonne train) - charge change compared to inflation rate (HICP). Source Eurostat [31] and own elaboration.

The increase of charge level in Belgium is similar to inflation. In Portugal it is lower than the inflation rate. In other countries inflation rate and percentage have totally different values, thus its comparison is irrelevant.

4.3.3. EFC OD pairs, 2013 and 2023 charges comparison

This part focuses on charges comparison for European Freight Corridors for years 2013 and 2023. The figure 46 shows a box plot containing charges from all the four selected freight corridors.

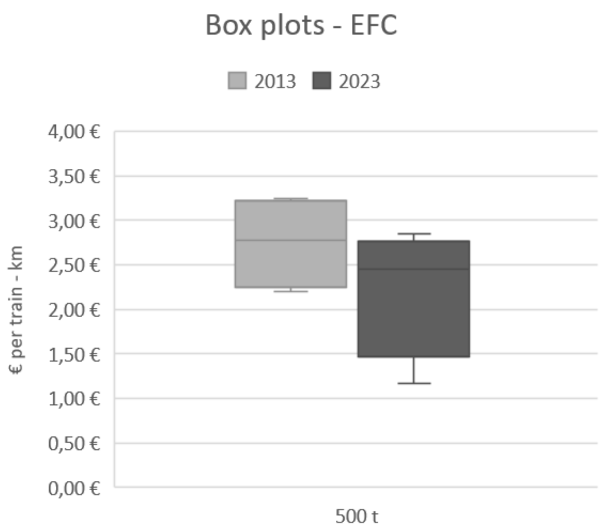


Figure 46 Box plot - range of prices for selected EFC OD Pairs for 2013 and 2023

Generally, the charges for EFC for 500 tonnes trains decreased. However, the range of charges for observed corridors widened considerably. Minimum charge in 2013 was 2,21 € per km. For 2023 it decreased to 1,17 € per km. Median value in 2023 is about 0,30 € per km higher than minimum charge in 2013. Table 11 presents the charges calculation results for selected corridors.

Table 11 EFC OD Pairs (500-tonne train) - Results for 2013 and 2023 comparison

Corridor	OD Pair	Path length [km]	Total charge 2013 [€]	Total charge 2023 [€]	Total charge diff. [€]	Avg. charge per km 2013 [€/km]	Avg. charge per km 2023 [€/km]	Avg. charge per km diff. [€/km]	Line Cost 2013 [€]	Line Cost 2023 [€]	Terminals 2013 [€]	Terminals 2023 [€]	Energy access 2013 [€]	Energy access 2023 [€]	Energy use 2013 [€]	Energy use 2023 [€]
EFC1	Netherlands - Italy (Rotterdam - Genova)	1257,0	2771,79	2998,94	227,14	2,21	2,39	0,18	2771,79	2988,12	0,00	1,92	0,00	8,90	491,44	436,88
EFC3	Germany - Italy (Flensburg - V. S. Giovanni)	2463,8	5895,34	7003,35	1108,01	2,39	2,84	0,45	5895,34	6940,98	0,00	0,00	0,00	62,37	440,59	0,00
EFC4	Portugal - France (Lisbon - Metz)[16]	2221,4	6992,98	2585,82	-4407,16	3,15	1,17	-1,98	6702,50	1993,09	0,00	0,00	290,48	592,74	0,00	0,00
EFC8	Belgium - Poland (Antwerpen - Terespol)[16]	1563,5	5067,85	3949,83	-1118,02	3,24	2,52	-0,72	5067,85	3895,31	0,00	0,00	0,00	54,52	0,00	0,00

[16] For France and Poland, the paths lengths were calculated. Obtained values were different than those from the UIC study. For France it is now 2,07 km longer and for Poland 5,20 km shorter.

In most of the countries total charge elements remained the same contribution level. EFC4s' total charge is much more dependent on electricity access than 10 years ago. The price of it increased almost 2 times, but what is more important, line charge decreased by about 70%. High influence on that change had the revolution of the French pricing system, which now also subsidizes international transport, what decreased its prices fundamentally. In effect the corridor from the most expensive[17] became the cheapest. Total charge decreased by about 4400 €. EFC8s' total charge also decreased significantly - above 1100 €. It's the result of the great decrease of charge in Poland. On the other hand EFC3s' total charge increased greatly - above 1100 €. It's the result of Italian charge increase (especially on that section) and retaining international/ national distinction, in which the international segment is more expensive. EFC1s' total charge increased slightly. The average charge in Germany and Italy increased considerably (respectively 0,42 € per km and 0,16 € per km), whereas charge in Switzerland remained similar and the charge in Netherlands decreased. Figure 46 facilitates comparison between charges per km.

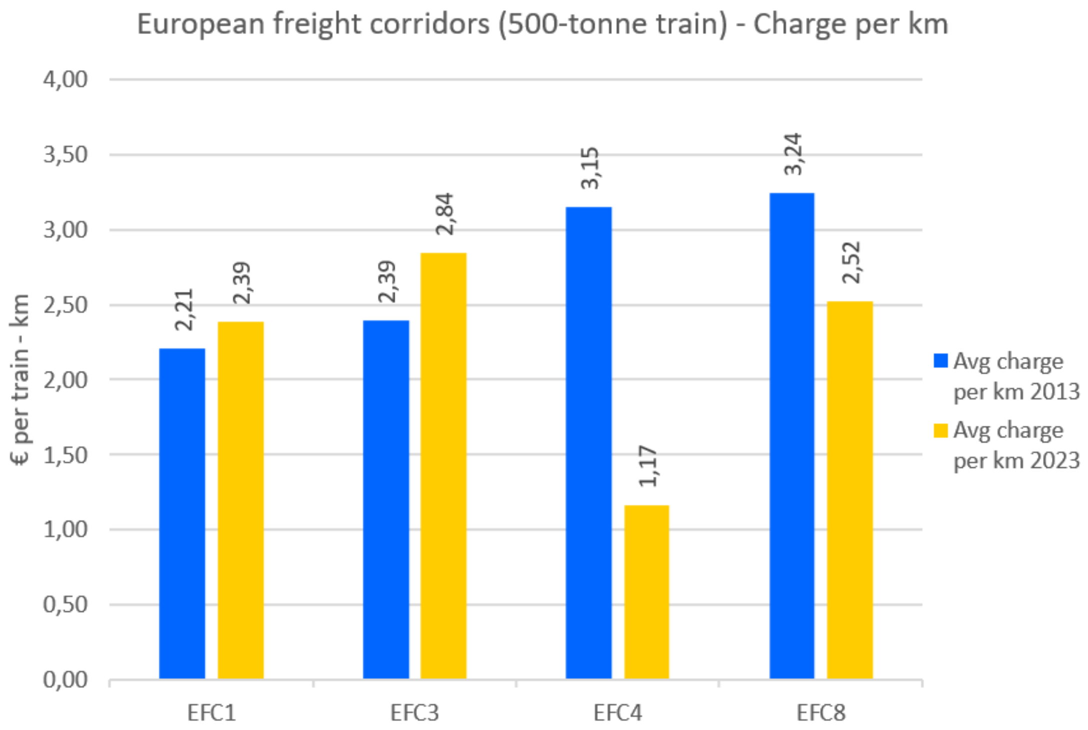


Figure 47 EFC OD Pairs (500-tonne train) - charge per km for 2013 and 2023

The EFC4 obtained outstanding change of average charge per km – 1,17 € per km which is 1,98 € per km less than in 2013. Less impressive decrease was registered for EFC8. The charge dropped by 0,72 € per km. The EFC3 noted the biggest charge increase – 0,45 € per km.

The figure 48 shows the relative change of charges.

[17] The most expensive of the analysed group of 4 corridors

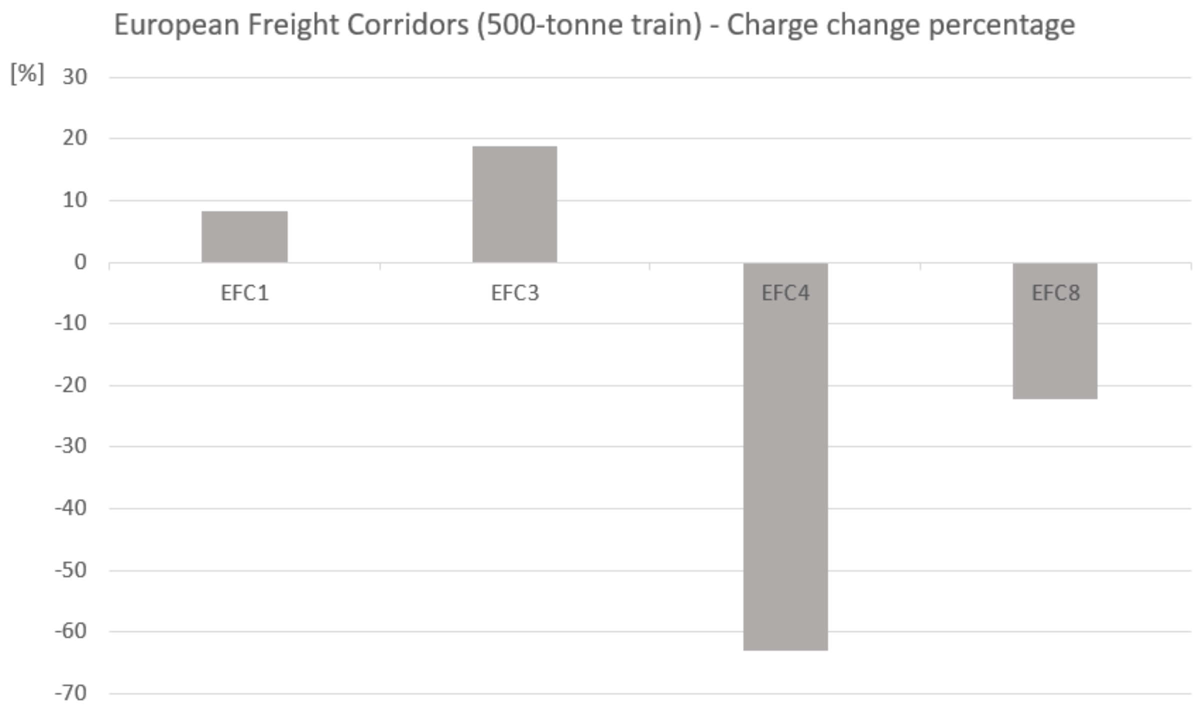


Figure 48 EFC OD Pairs (500-tonne train) - charge relative change

The decreases of charges in EFC4 and EFC8 are substantially bigger than increases in EFC1 and EFC3.

4.3.4. Sensitivity analysis, 2013 and 2023 charges comparison

The following analysis expands the previous section by adding results for 2013. The figures 49 and 50 show box plots containing charges from all the selected countries and corridors.

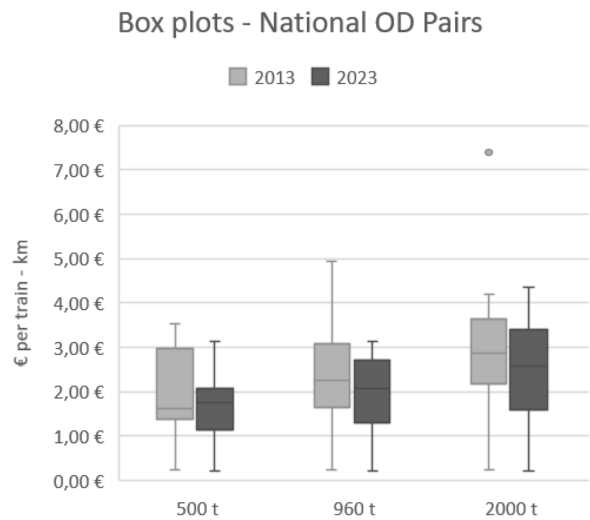


Figure 49 Sensitivity analysis. Box plots - range of prices for selected National OD Pairs for 2013 and 2023

It was observed that the dependency on weight in 2013 used to be bigger than now. However, the median values for all of the weights remained similar. Now the median is slightly higher for a 500 tonnes train and slightly lower for 960 and 2000 tonnes trains. The charges got more concentrated now for a 500 tonnes train, keeping similar maximum and minimum values. For a 960 tonnes train the majority of prices retained similar concentration of majority of prices, similar minimum. The maximum price is now much lower. It dropped almost 2 € per km.

For a 2000 tonnes train there is a higher disparity in the interquartile range. The minimum price remained similar, but a big difference was observed between maximum values. In 2013 the maximum charge was obtained by Poland and equal 7,40 € per km, which significantly stood out from the array.

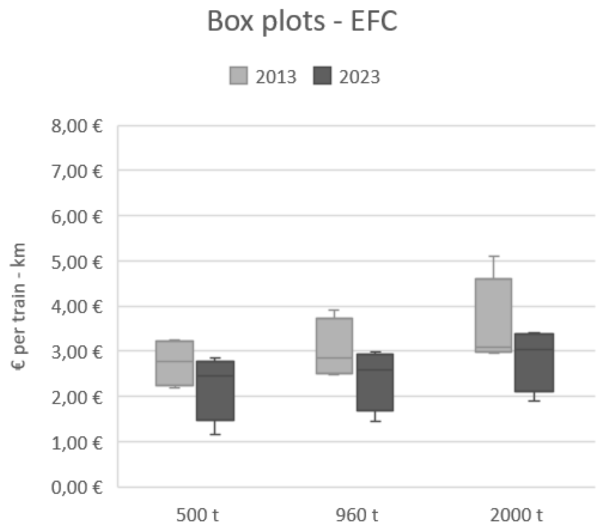


Figure 50 Sensitivity analysis. Box plots - range of prices for selected EFC OD Pairs for 2013 and 2023

Although the dependency on weight for analysed corridors in 2013 used to be much bigger than now, the median values for all of the weights remained similar.

The ranges, however, changed significantly. For 500 tonnes trains it got wider. Although the maximum price decreased slightly (0,40 € per km), the minimum price decreased significantly - over 1 € per km. For 960 tonnes trains the range got slightly wider – both maximum and minimum price decreased significantly - respectively about 0,90 € per km and about 1 € per km. For a 2000 tonnes trains the range got narrower. Both maximum and minimum prices decreased significantly - respectively about 1,80 € per km and about 1 € per km.

The changes between charges in years 2013 and 2023 are fundamental. The maximum charge for 2000 tonnes train in 2023 is only slightly higher than the maximum charge for a 500 tonnes train in 2013. The minimum charge for 2000 tonnes train in 2023 price system is significantly smaller than minimum charge for 500 tonnes train in 2013 price system.

4.4. Discussion on best practises and recommendations

In this part the evolution observed is discussed. The section refers also to chapters 2 and 3 as both of them provide snapshots of the pricing systems in particular periods.

In the 2010s a number of papers recommended simplifying the pricing system. In this study it was observed that within the last ten years many systems were simplified, indeed. Some countries substituted the old variables with new ones, which could seem as a hindrance due to lack of stability, however those changes often simplified the calculation process. For instance, Italian IM added more variables than removed, but explained the charging rules briefly and clearly. They withdrew the node fee and fee per minute, which earlier was claimed to be vexation. Nevertheless, the system that got extended the most, involved the variables relevant from the direct cost point of view and directives' recommendations. Swiss IM is the only that included in the charge calculation number and of axles, infrastructure characteristics, Discount for Long Train, Environmental Surcharge, Noise fee/discount and ETCS fee/discount. The most complex system was also one of the best explained one. For each variable clear description and example of calculation were provided.

It shows that simplification may be achieved not necessary only by reducing the number of variables. The Swiss pricing system evolution set a benchmark for other IMs on how to develop their pricing systems.

However, the wide array of variables resulted for Switzerland in significant increase of charge variation, whereas for other countries the ranges, generally, got more concentrated.

The legislation demands from IMs to demonstrate the direct cost calculation methods. Besides this part of charge, it is interesting how they calculate the mark-up, especially for international services. Sometimes in two neighbouring countries making one corridor, not only the charges differ but their market segment dependence.

The Italian and German charges involve enormous mark-ups. It is more than half of the charge value. In other countries the mark-up is very low or even 0. That results in heterogeneity within the European Freight Corridors and shows how open is the interpretation of pricing system construction.

Concerning the distinction in tariff system between international and national segments, three different approaches were observed. In Austria and Poland trains taking part in intermodal transport are exempted from paying the mark-ups. In Belgium, France, Netherlands, Portugal, Spain and Switzerland there is either no mark-up or freight transport is a segment itself without any further segmentation. The approaches of Italy and Germany are more complex. They divide freight segments further on multiple segments. Both of the countries have significantly lower mark-ups for local transport. Italy additionally has a low mark-up for trains with distance travelled above 800 km and Promo segment for new commercial services (defined in the catalogue by the IM), that are exempt from paying mark-ups. Italian IM also provides an international segment, which has the highest mark-up.

The differences between direct costs seem to be more reasonable than the differences between the mark-up for the international segment (in case of countries involved in the same corridors). The first depends on infrastructure and train characteristics, maintenance policy, and operation speed. The second depends on willingness to pay for particular segments' services. The one common mark-up for the entire corridor could be a fairer solution. On the other hand, one country may be involved in multitude international paths, each with different willingness to pay. Possible resolution to this question may be further dividing the market, at least creating a market segment for TEN-T corridors. However, there are also a lot of different trains with different assets, operating on these corridors.

Seeing the difference in the charge levels within the corridors, one starts to understand that it is no of the interest of infrastructure managers, which do not apply high mark-ups to participate in them. Perhaps this is the reason for postponing the changes to unify the systems along Europe.

In this thesis, it is suggested that to treat fairly IMs of different member states, not the charges but rather the mark-ups should be unified. Bearing in mind different investments in each member state, the unification should be introduced gradually. That should come together with imposing the same or at least similar method for MC calculation. At the moment the MC levels are substantially different. The unification of MC calculation methods is hindered as the IMs do not show how they calculate it, which results in little patterns, templates and role models. Therefore, it should be in the interest of the EC to provide some patterns of methodologies. The tariff levels should not necessarily be exactly the same for the entire continent. On the other hand, the threshold as it was used in regulation is also a good idea, however it may be abused. Some countries do not apply mark-ups but the direct cost is elevated up to the limit. It may seem that they increased the direct cost and the mark-ups are covered by them. On the contrary the Italian charging system has the second lowest direct cost, but the most elevated mark-up.

Generally, all of the countries encourage the use of heavier trains. The train weight increase comes either with no change of charge or much lesser relative charge change. The biggest relative charge increase accompanying weight change from 500 to 960 tonnes (1,61) has been noted in the Netherlands. As this result stood out from the rest, it was decided to look closely at how this system distributes prices due to weight change. The Dutch weight categories for freight trains have very wide intervals (table 12).

Table 12 Dutch pricing system - weight category charges

Weight category of the train	Compensation (per train kilometre)
up to 120 tons	€ 0.3499
from 121 to 160 tons	€ 0.4374
from 161 to 320 tons	€ 0.5564
from 321 to 600 tons	€ 0.7733
from 601 to 1,600 tons	€ 1.2422
from 1,601 to 3,200 tons	€ 1.4976
from 3,201 tons	€ 1.6236

The weight intervals increase with weight increase. The first interval is equal to 40 and the last 1600. As a result, some cases seem unreasonable. For instance, the change weight from 601 to 3200 tonnes (>530% increase) comes with only a 21% charge increase. In result 601 and 3200 tonnes trains would be charged almost equally. Putting together this example with a big increase of charge for a weight change from 500 to 2000 tonnes, makes one notice a contradiction. This raises a question: how is the Dutch infrastructure damage assessed? Unfortunately, the marginal cost calculations are available only in local language. Despite low charges for heavy trains, the sections have weight limits, which often don't permit heavy train allocation. The maximum permissible axle load on the Dutch network never exceeds 22,5 tonnes, (except Betuweroute, which is the section connecting Rotterdam and Germany and is a part of European Freight Corridor 5). Maybe the very low charge for lighter trains (up to 600 tonnes weight limit) is an incentive to smaller shippers, arising from willingness to pay particular market segments. That approach may be relevant in terms of competition with road freight transport. As it was noted before, in many countries and corridors the rail freight transport started to be competitive just for 960 t, as the charge per tonne-km started to be lower than for road freight transport.

One of the components of liberalization of the market is the number of railway undertakings. The most new freight RUs between years 2013 and 2020 appeared in Poland, Austria and Germany. Interestingly, in Switzerland this number decreased about 40%. Nevertheless, in every of these 4 countries a decrease of rail freight transport share was noted, while the drop in Poland was the biggest [32]. It shows that increase of competition not always come with increase of rail freight transport share, that is, modal shift.

The competition between the modes will remain hindered as long as road transport is not duly regulated. There is no regulation imposing on road transport to base its infrastructure charge on maintenance costs and there often exist other alternative highways without tariffs. Existing examples in which the road transport with tolls is cheaper than rail transport, shows that the competition (even with the roads with tolls) is not completely fair. For instance, in Poland the charges for rail exceed the marginal cost threshold, whereas charges for road transport is far from reaching it, even though the maintenance cost per tonne-km are higher for road than for rail [8].

5. Conclusions

In this study, the current state of the practice and existing problems related to railway freight pricing systems in Europe were analysed and discussed.

In the qualitative analysis infrastructure pricing systems for rail freight transport of selected countries were described and compared. It focused on the components of the charge for the minimum access package. Within the last ten years many systems were simplified.

The Swiss IM is found as a benchmark, as it involved variables relevant from the direct cost point of view and adequate to directives' recommendations. They included in the charge calculation number and of axles, infrastructure characteristics, Discount for Long Train, Environmental Surcharge, Noise fee/discount and ETCS fee/discount. For each variable clear description and example of calculation were provided. The simplification may be achieved not only by reducing the number of variables.

In the Quantitative analysis the interval variation of charge levels was examined. Then the charges for the National and EFC OD pairs were analysed. In the last part the train weight impact on the infrastructure charge levels was analysed.

Only the Italian and German price system charge per km for a 500-tonne train is bigger than 2 € per km. An enormous part of their charges is taken by the mark-up. In other countries the mark-up is very low or even 0. That results in heterogeneity within the European Freight Corridors and shows how open is the interpretation of pricing system framework.

Due to weight impact on charge it was observed that all of the countries encourage the use of heavier trains.

Comparison of freight pricing in road and rail transport was done by using the paths and charges from quantitative analysis were used for rail and compared with representative road routes and their charges between the same origins and destinations. It was found that in many countries and corridors the rail freight transport started to be competitive just for 960 t, as the charge per tonne-km started to be lower than for road freight transport. It is important to point out that, there is no regulation imposing on road transport to base its infrastructure charge on maintenance costs and there often exist other alternative highways without tariffs.

Critical analysis of Network Statements involves comments on its features associated with intelligibility and comprehensibility. Generally, the Network Statements presented for 2023 are comprehensive and don't impede its use in order to calculate the infrastructure charges. However, the calculation of the charge per km was not always possible, often the Network Statement did not contain information on segmentation. All of the analysed pricing systems fulfil the demands to be based on the marginal cost and to have MC lower than 2,67 € per km. The full separation between managing a network and operating is slightly less popular than separation through a holding company.

The evolution of railway freight pricing systems in the last decade was evaluated. It extended the quantitative analysis with results from 2013. It was found that in most of the pricing systems the level of charges decreased. The biggest relative change in price was observed for Italy – about 61%. The charges for EFC for 500 tonnes trains decreased. However, the range of charges for observed corridors widened considerably. High influence on that change had the revolution of the French pricing system, which now also subsidizes international transport, which decreased its prices fundamentally. In effect the corridor from the most expensive[18] became the cheapest.

Although the dependency on weight for analysed corridors in 2013 used to be much bigger than now, the median values for all of the weights remained similar.

[18] The most expensive of the analysed group of 4 corridors

References

[1] International Transport Forum, “Mode Choice in Freight Transport,” ITF Research Reports, OECD Publishing, Paris, 2022.

[2] UIC, “European Railway Infrastructure Charges for Freight. Universitat Politècnica de Catalunya (Prodan, Teixeira and Lopez Pita).,” 2014.

[3] Eurostat, “Modal split of freight transport [TRAN_HV_FRMOD] in European union (27 countries - from 2020),” 2022. [Online]. Available: https://ec.europa.eu/eurostat/databrowser/view/TRAN_HV_FRMOD__custom_3657915/default/table?lang=en.

[4] Eurostat, “ Modal split of passenger transport - TRAN_HV_PSMOD in European union (27 countries - from 2020):,” 2022. [Online]. Available: https://ec.europa.eu/eurostat/databrowser/view/TRAN_HV_FRMOD__custom_3657915/default/table?lang=en.

[5] I. e. a. Vierth, “FALCON Handbook Understanding what influences modal choice,” 2017.

[6] Y. Crozet, “Rail freight development in Europe: how to deal with a doubly-imperfect competition?,” 2017.

[7] P. Wheat, A. Smith and C. Nash, “CATRIN Cost Allocation of TRansport INfrastructure cost, D8 – Rail Cost Allocation for Europe,” 2009.

[8] EUROPEAN COMMISSION, “Overview of transport infrastructure expenditures and costs,” 2019.

[9] A. S. Smith, K. Odolinski, S. Hossein-Nia, P.-A. Jonsson, S. Stichel, S. Iwnicki and P. Wheat, “Estimating the marginal maintenance cost of different vehicle types on rail infrastructure,” 2021.

[10] B. MC, “Whole life rail model application and development for RSSB continued development of RCF damage parameter,” 2004.

[11] A. PRODAN, P. Fonseca TEIXEIRA and A. LOPEZ-PITA, “EU RAILWAY INFRASTRUCTURE TARIFF SYSTEMS: 2005-2012 ANALYSIS AND TRENDS,” 2012.

[12] S. C. R. B. Lopes, “Tarifação da infraestrutura ferroviária para serviços de mercadorias na Europa,” 2014.

[13] UIC, “CHARGE4RAIL 2017 RAILWAY INFRASTRUCTURE CHARGES FOR PASSENGER SERVICES,” 2017.

[14] A. PRODAN, P. Fonseca TEIXEIRA and A. LOPEZ-PITA, “EU Railway Infrastructure Tariff Systems: 2007-2012 Trends and Benchmarking,” 2012.

[15] P. Teixeira, A. Prodan, J. Cunha and R. Maciel, “CHARGE4RAIL 2017 RAILWAY INFRASTRUCTURE CHARGES FOR PASSENGER SERVICES A UIC STUDY,” 2017.

[16] ÖBB-Infrastruktur AG, *2023 Network Statement,* 2022.

[17] Infrabel, *Network Statement Valid from 11/12/2022 to 09/12/2023,* 2022.

[18] SNCF Réseau, *NETWORK STATEMENT OF THE NATIONAL RAIL NETWORK 2023 Timetable,* 2021.

[19] DB Netz AG, *DB Netz AG Network Statement,* 2021.

[20] Rete Ferroviaria Italiana S.p.A. (RFI), *Network Statement 2023,* 2021.

[21] ProRail, *Network Statement 2023,* 2022.

[22] PKP Polskie Linie Kolejowe S.A., *NETWORK STATEMENT 2022/2023,* 2021.

[23] Infrastructure Portugal, S.A. (IP), *NETWORK STATEMENT 2023,* 2021.

[24] Administrador de Infraestructuras Ferroviarias, Adif, *NETWORK STATEMENT 2022,* 2022.

[25] SBB Infrastructure (SBBI), "Network Statement 2023," 2023. [Online]. Available: https://vorgaben.sbb.ch/en/content/23871?jump-to=23872.

[26] TollGuru, "TollGuru," 2022. [Online]. Available: https://tollguru.com/.

[27] Autostrada Wielkopolska S.A., "autostrada-a2," 2022. [Online]. Available: http://www.autostrada-a2.pl/oplaty/cennik-kategoria-4/.

[28] itf-oecd, "PERMISSIBLE MAXIMUM WEIGHTS OF LORRIES IN EUROPE (in tonnes)," [Online]. Available: https://www.itf-oecd.org/sites/default/files/docs/weights-2019.pdf.

[29] Independent Regulators' Group – Rail, "Tenth Annual Market Monitoring Working Document," 2022.

[30] IRG-Rail, "3rd Annual Market Monitoring Report 2014," 2015.

[31] Eurostat, "HICP - annual data (average index and rate of change)," 2022. [Online]. Available: https://ec.europa.eu/eurostat/databrowser/view/PRC_HICP_AIND__custom_3139153/default/table?lang=en.

[32] EUROSTAT, "Modal split of freight transport - Data browser," 2022. [Online]. Available: https://ec.europa.eu/eurostat/databrowser/view/TRAN_HV_FRMOD__custom_2937341/default/table?lang=en.

[33] T. Delft. [Online]. Available: https://d1wqtxts1xzle7.cloudfront.net/61210473/82847382-Modern-Railway-Track_120191113-130303-majm58-with-cover-page-v2.pdf?Expires=1644058868&Signature=XAFetGni5aq28fu2VQdoX~3SmHXamTZ3zJ0M846JPj~gPXDERMpTU6aJiduc566jKBGViHi0lmHf-xlKEQ0cjXeV-KFCYEZlnBRVsl.

Annex

Table 13 Matrix of Variables – Definitions [2]

Variable	Description
What Is Charged	
Time-of-day pricing	Differentiation of pricing by time of the day
Train Frequency	Price changes based on how often a train runs on the network during the timetable period (e.g. ad-hoc, weekly, daily, etc.)
Train speed	Change in charge based on variation of speed
Train Type (Physical Characteristics)	Dimensions, mass, etc.
Axle load	Number of tons per axle
Loco/Traction Type (characteristics)	Loco performance on the network (usually by some sort of IM test)
Service Type (Service Pattern, distance)	e.g. Local vs. long distance vs. shunting; trip length in km
Train-path quality	e.g. fast, normal, economy
Line Type (importance categorization)	Line importance for IM
Line Type (capacity)	Categorization of line based on line use patterns and how close the line is to capacity
Capacity maximization Charge	A charge to prioritize some type of traffic and penalize some other type of traffic, resulting in homogeneous traffic, thus maximizing line capacity
Scarcity Surcharge	If a line is declared as scarce, a scarcity surcharge applies. This surcharge may go above full costs
Low-speed penalty	Penalty for having an (average) speed lower than a threshold. Similar to Capacity Maximization Surcharge, to avoid unnecessarily tying up the line
How It is Charged	
Flat Fee	A single fee per use
Fee per train-km	A fee per train-kilometer
Fee per tonne-km	A fee per tonne-kilometer
Fee per min	A fee per minute of line use
Node fee	A fee for entering a node (a pre-defined area, usually around a large hub)
Fee per axle-km	A fee per kilometer that is charged per train axle
Axle load	A fee that varies with a train´s axle
Charge Categories	
Reservation Fee	A fee for reserving capacity
Cancellation Fee	A fee for cancelling capacity, usually varies by how close RU cancels capacity order
Running Charge	A charge for using the capacity
Admin Fee	An administration fee for allocating capacity
Access Fee	A fee to access the network
Security Fee	A fee for security of the network
Accident Insurance Charge	A fee to internalize external costs
Environmental Surcharge	Used to internalize external costs. May be negative for railways if positive benefit exists.

Variable	Description
Special Infrastructure Fees	Fees for using special infrastructure (e.g. bridges, tunnels, special track sections)
Dangerous goods transport	Surcharge for transporting dangerous goods
Noise fee/discount	Bonus/Penalty for operating with quiet/loud wagons
ETCS fee/discount	Bonus/Penalty for operating with/without ETCS
Performance Scheme	A bonus/Penalty algorithm to promote efficient operation
Freight Subsidy / Discount	Discount/subsidy for freight operations for certain train types
Traction Current and Fuel	
Traction Current - access	Access to traction current
Traction Current - management	IM fee, passed on to user for using traction current (administrative costs)
Traction Current - use fee	IM fee, passed on to user for using traction current (usually recovery of traction network maintenance costs)
Fuel - management	Recovery of fees, associated with logistics of acquiring fuel
Fuel - dispensing	Recovery of fees, associated with logistics of dispensing fuel
Fuel - access	Recovery of fees, associated with logistics of providing access to fuel
Varying rates for Diesel/Electric	Differentiation of rates by type of traction
Facility Charges (in Network Statement)	
Pricing by Facility Importance	Differentiation by facility importance
Maintenance Facilities Access	Charge for accessing maintenance facility
Parking at stations	Charge for parking at a station/terminal
Parking in Sidings	Charge for parking in a siding
Parking Time (short v. long-term)	Differentiation of pricing by how long a parking area is rented out/used
Marshaling yards - access	Access to marshaling yards
IM vs. Non-IM operated facility	Differentiation in pricing if a facility is not operated by IM
Train formation - access	Fee for accessing to train formation yards
Train formation - use	Fee for using to train formation yards
Facility Services (in Network Statement)	
Shunting Services	Provision of shunting services
Gauge changing equipment - use	Fee for using gauge changing equipment
Brake Test Facility	Fee for using a brake testing facility
Track Weighbridges	Fee for using weight bridges
Loading Area	Fee for using a loading area (normally truck to train)
Handling of ITUs	Fee for handling intermodal containers
Other Facility Types - access	Fee for accessing other facility types

Table 2-4: Matrix of Variables	Austria	Belgium	Bulgaria	Croatia	Czech Rep.	Denmark	Estonia	Finland	France	Germany	Greece	Hungary	Ireland	Italy	Latvia	Lithuania	Luxembourg	Netherlands	Norway	Poland	Portugal	Romania	Slovakia	Slovenia	Spain	Sweden	Switzerland	UK - HS1	UK - Netw.Rail	UK - N. Ireland	TP Ferro	Eurotunnel	Oresund
What Is Charged																																	
Time-of-day pricing									•		•			•											•							•	
Train Frequency																																•	
Train speed	•	•												•											•							•	
Train Type (Physical Characteristics)		•		•	•				•	•	•	•			•		•		•	•			•	•	•			•	•		•		
Axle load											•																						
Loco/Traction Type (characteristics)	•							•							•						•	•	•	•		•	•		•				
Service Type (Service Pattern, distance)		•		•					•															•	•								
Train-path quality				•						•																	•						
Line Type (importance categorization)	•	•		•	•				•	•	•	•		•				•		•	•		•	•	•		•						
Line Type (capacity)									•	•	•										•	•				•							
Capacity maximization Charge	•	•				•				•	•									•									•				
Scarcity Surcharge										•							•	•										•					
Low-speed penalty										•										•													
How It is Charged																																	
Flat Fee																													•				
Fee per train-km	•	•	•	•	•	•	•		•	•	•	•		•	•	•	•	•		•	•	•	•	•	•	•	•	•	•				•
Fee per tonne-km	•	•	•	•	•	•	•	•				•	•		•	•	•	•	•	•		•	•	•		•	•		•	•			•
Fee per min														•														•					
Node fee														•												•							
Axle-km										•																	•						
Axle load											•								•	•													
Charge Categories																																	
Reservation Fee					•							•		•														•					•
Cancellation Fee		•	•		•				•	•							•							•			•						
Running Charge	•	•	•		•	•	•	•	•	•	•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•				•
Admin Fee		•							•														•		•							•	
Access Fee																									•								
Security Fee									•																•								
Accident Insurance Charge																										•							•
Environmental Surcharge		•																								•	•	•	•				
Special Infrastructure Fees						•			•										•							•							
Dangerous goods transport									•																		•						
Noise fee/discount										•								•		•							•						
ETCS fee/discount																											•						
Performance Scheme	•	•		•	•			•	•	•	•		•	•			•				•	•	•			•			•	•			
Freight Subsidy / Discount									•									•											•				
Traction Current and Fuel																																	
Traction Current - access		•							•			•		•		•	•	•	•		•		•		•				•				
Traction Current - management												•					•		•		•				•				•				
Traction Current - use fee		•		•							•		•	•			•								•		•	•	•				
Fuel - management												•													•								
Fuel - dispensing																									•								
Fuel - access												•					•							•									
Varying rates for Diesel/Electric					•			•							•				•	•	•	•	•			•	•		•				
Facility Charges (in Network Statement)																																	
Pricing by Facility Importance		•										•											•										
Maintenance Facilities Access		•							•			•												•	•								
Parking at stations		•																•							•		•						
Parking in Sidings		•	•	•					•			•					•				•				•	•					•		
Parking Time (short v. long-term)		•		•														•								•							
Marshaling yards - access									•								•						•	•		•	•						
IM vs. Non-IM operated facility																									•								
Train formation - access																							•	•	•								
Train formation - use	•	•		•																					•		•						
Facility Services (in Network Statement)																																	
Shunting Services	•			•																					•		•				•		
Gauge changing equipment - use																									•								
Brake Test Facility	•	•																								•							
Track Weighbridges				•								•															•						
Loading Area																									•	•							
Handling of ITUs																									•								
Other Facility Types - access		•							•																•								

Figure 51 Variables and Categories of Charges [2]