PERFORMANCE ANALYSIS OF RAILWAY INFRASTRUCTURE AND OPERATIONS

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ABSTRACT

Research on performance assessment of railway networks and companies has been stimulated by the European policy of deregulation of transport markets, the opening of national railway networks and markets to new entrants and separation of infrastructure and train operation. Recent international benchmarking studies of railways based on statistical data compiled by UIC show a considerable variation of scope concerning the input and period of data analysis, while the selected output performance measures are very limited. A more comprehensive approach for benchmark analysis is proposed, which includes relevant technical and economic key performance criteria and indicators for assessing the transport and traffic output, effectiveness, productivity, and efficiency performance of infrastructure management and train operations respectively. The assessment methods consist of standard parametric (regression) analysis of empirical technical and commercial data for the year 2009. The detailed results of a recent benchmark analysis for 11 mid-size European railway networks and undertakings are reported.

Keywords: infrastructure management, operations, effectiveness, efficiency, benchmarking

INTRODUCTION

The transport and railway deregulation policy of the European Union has led to an increased interest of governments, advisors and researchers for appropriate methods to assess the effects of reorganization of the railway industry and the factors that govern the effectiveness and efficiency of railway networks and train operations. Available international benchmark studies are based on statistical data from different periods and sets of railway infrastructure managers and train operating companies (TOC) compiled since decades by the Union International of Railways (UIC).

The major problems that endanger the reliability of the existing performance assessment methods, their explanatory power and the robustness of (political) conclusions are threefold: weaknesses of the database, complexity of measurement and risk of biased evaluation. It is known that the definitions for the UIC Railisa database, in practice, are not always applied correctly and completely by UIC members, some essential data are missing (Smith, 2010) and private train operators are not obliged to report in sufficient detail. The measurement of railway infrastructure management, passenger and freight transport work, energy and costs is very difficult due to the multiplicity of outputs, inputs, joint costs and economies of scale, as well as differences in the environment including geographical factors and government intervention (Nash & Smith, 2007). Benchmark analyses may be stimulated ex-post by governments and researchers with the aim to support previously decided strategies to separate infrastructure and train operations, and introduce competition in order to demonstrate their benefits. This may have an influence on the selection of the consultant and lead to prejudicial choice of methods and interpretation of results.

The aim of this paper is to synthesize the relevant technical and economic criteria and indicators for performance analysis such that the variety and impact of some quantitative input variables on the output, in first instance, can be explained qualitatively on the basis of a small number of railway networks and railway undertakings and data. The data used is limited due to lack of available resources to only one year, while the smaller and the larger railway networks in Europe have been excluded, so far, from the empirical analysis. The contribution of the paper is better interdisciplinary insight into the main drivers and constraints of railway network performance.

The paper is organized as follows. First, the existing assessment methods for benchmarking are briefly reviewed, the criteria and key performance indicators are presented. Then, the database used is explained and the infrastructure and transport network characteristics of the investigated 11 mid-size networks in Europe are described. The preliminary results of the performance analysis for the railway networks regarding the network productivity, operating efficiency in 2009 are presented in the next section. The paper concludes with a summary of the main findings.

2. BENCHMARKING APPROACH

2.1 Assessment methods

The main objective of benchmarking is to measure and compare the realized output of a product or service with the amount of inputs. Network infrastructure, track maintenance and renewal expenditures have been analysed periodically by a number of UIC members (UIC, 2006). The input parameters contain network characteristics, their utilization and economic characteristics, while the output uses key performance indicators with regard to network use and life cycle costs (LCC) per track kilometre and transport unit respectively. The LCC costs of infrastructure, defined as yearly costs per main track kilometre, have been harmonized with regard to purchasing power, labour cost levels, degree of electrification, percentage of single tracks, switch density and track utilization. In general, UIC considers seven key performance indicators (KPI) relevant for benchmarking: Mobility & Accessibility, Safety, Service Quality & Reliability, Innovation & Growth, Asset Utilisation, Financial Effectiveness, and Efficiency.

Yu (2008) assessed the efficiency and effectiveness of 40 railways through network data development analysis in year 2002 from UIC members in Asia, Europe and Africa. He used (i) the length of railway lines, number of passenger cars, number of freight cars and number of employees as inputs, (ii) the passenger train-km, freight train-km as produced outputs, and (iii) passenger-km and tonne-km as consumed outputs. The gross national income per capita and population density were considered as environmental variables.

Lan & Lin (2006) examined panel data from 39 worldwide railway systems over the period 1995-2002 of UIC by a stochastic distance function with regard to technical efficiency and service effectiveness respectively. They used the same input and output variables as Yu and found the railways' technical inefficiency and service ineffectiveness to be negatively influenced by gross national income per capita, percentage of electrified lines, and line density. Significant changes of both efficiency and effectiveness frontiers during the 8 year period could not be observed. The elasticity of the input distance function with respect to the number of employees was greater than that with regard to the number of freight cars and passenger cars.

Nash & Smith (2007) presented an overview of railway performance models. They distinguish index number approaches (partial productivity measures, total factor productivity measures), econometric approaches and efficiency-based approaches (e.g. data envelopment analysis, corrected ordinary least squares, stochastic frontier analysis), and describe their principle features, benefits, limitations and typical applications. There is little consensus from the different studies regarding the relative efficiency and productivity performance of the railway periods prior to the mid-1990s.

Growitch & Wetzel (2009) tested the economies of scope in European railways by analysing the technical efficiency of in total 54 integrated and non-integrated railway undertakings from 27 countries by means of non-parametric data envelopment analysis (DEA) of the period 2000-2004. The input variables consist of number of employees, number of rolling stock, operating expenses and network length, while the output variables are train-km, passenger-km and tonne-km respectively.

Cantos et al. (2010) reported beneficial effects of organizational reforms on efficiency, productivity, and technical change in 16 national railway systems over the period 1985-2005. The number of employees, number of coaches, railcars and multiple-units for passenger transport, freight wagon strength and network length are considered as input variables, while the number of passenger-km and the number of tonne-km transported respectively are used as output variables. They use DEA to calculate the distance function.

Smith (2012) emphasizes the problems of lack of comparable data, capital cost measurement and controlling for cross-country network differences for international efficiency comparisons. He adopts a time varying inefficiency model using a panel dataset of 13 European rail infrastructure managers (1996-2006) of UIC in order to determine the efficiency of Network Rail against international best practice. The dataset comprises maintenance costs, renewal costs and total costs using Purchasing Power Parity exchange rate data from the OECD for conversion to a common currency and price level. The standard main output vector consists of passenger train-km and freight train-km respectively per route-km, while typical network variables as proportion of electrified track and the ratio of single track to route-km are taken into consideration.

Karlaftis & Tsamboulas (2012) discussed definitions, measurement and different methods as stochastic frontier production functions, Data Envelopment Analysis (DEA) and Neural Networks to assess transit efficiency and effectiveness. They used data from 15 European transit systems for the period 1990-2000, applied a range of performance assessment models, evaluated and compared the results. They found considerable efficiencies in European transit systems, but markedly lower effectiveness. Peer group comparisons and performance assessments based only on averages may yield erroneous findings and lead to skewed policy recommendations.

From the review of literature the following can be concluded. The performance of railway systems may vary a lot: railway network characteristics are rather different from area to area or line to line, the rolling stock cannot be easily used for other kinds of transport service and train operation is mostly limited regionally: There are only few or even no alternative uses once the infrastructure is built, while the train design, equipment and operations are closely related to the infrastructure. Transport service is a non-storable commodity. The surplus capacity at low demands cannot be used at high demands and is wasted. The input of railway transport (vehicles, labour, energy) and the output in larger networks (passenger and freight services) both are multiple.

In general, the impact of network characteristics, as density, share of single tracks, share of electrified tracks, and distribution of personnel between passenger and freight traffic on effectiveness and efficiency is not considered in the available models explicitly. The Railisa database of UIC unfortunately does not contain any information about the kind and number of passenger stations in the network, although the density of stations, distance between stations impact significantly on the transport volume, costs of infrastructure management, operational speed.

The scope and focus of existing studies is often limited to a number of European railways and simple efficiency indicators like costs per track-km, per train-km, per passenger-km and per freight tonne-km. The transport capacity of trains can vary very much from line to line and area due to different vehicle design (single or double deck, length, amount and density of passenger spaces), number and length of train units or cars, which means the units train and train-km are no uniform measurement units and can represent very different weights. Index and panel data from different periods used for DEA may restrict, too, the dependability and comparability of the results.

The performance of networks is evaluated on the basis of standard (economic) criteria and indicators for efficiency and effectiveness of the infrastructure and train operations respectively. The following paper is an extension of a previous benchmark analysis of five mid-size European railway networks and undertakings in 2009 in comparison to East Japan Railways for the special investigation committee of the Dutch Parliament (Hansen et al., 2011).

2.2 Performance criteria

The (economic) performance of railway infrastructure network and train operationss are evaluated in general by criteria as effectiveness, efficiency and productivity. Effectiveness is defined as capability of producing a desired result (e.g. number of passengers or train-km respectively per period). Efficiency is determined by the ratio of output (e.g. number of passenger-km) to input (e.g. number of train-km). Productivity is a specific measure of the efficiency of production related to the input needed to produce a desired output (e.g. number of passenger-km per network-km). The importance of the performance criteria may differ per stakeholder.

2.3 Key Performance Indicators

As the economy of railway systems and networks clearly depends on scale, international and interregional benchmarking analysis needs to be done for networks and transport volumes of about similar scope. The most important characteristics of railway infrastructure networks are the route length, track length, mean distance between stations, percentage single tracks, and percentage electrified tracks. The percentage of dedicated high-speed and freight route respectively is generally small, but the transport performance of the corresponding trains can be rather high because of the considerably higher operating speed.

The fleet size and composition of rolling stock is given by the number of trains, locomotives, rail cars and multiple unit train sets. However, the distribution of locomotives between passenger and freight trains of integrated companies is not fixed and depends on the scope of the freight transport business compared to the passenger transport market, as well as on the distribution of locomotive hauled rail cars and (electrical) multiple units. As the transport capacity of TOCs depends on the power of locomotives, maximum axle load, weight and length of trains, while the number and density of seats and standees varies a lot in large networks with mixed operation of passenger and freight trains, a comparison of yearly outputs (passenger-train-km, freight-train-km, passenger-km, tonne-km, ticket revenues, freight revenues) per train, locomotive, rail car and multiple unit train set respectively makes sense only for dedicated lines with similar transport services.

The principle Key Performance Indicators (KPI) that express best the effectiveness of railway networks and undertakings with regard to transport supply are: number of train trips, volume of freight load transported, number of passenger-km, train-km, and tonne-km per year.

The most relevant KPI regarding the efficiency of infrastructure management (IM) are the expenditure per network-km, per track-km, per train-km, and per gross tonne-km respectively. The activities and costs of IM can principally be further broken down into main areas of general administration, maintenance and repair, traffic control and (investment) projects. The accountancy of the staff and material costs, however, may be ambiguous due to the allocation of shared services especially if the railway undertaking is organized still as an integrated enterprise or a holding of the divisions IM, passenger train operation, cargo train operation, and power generation and distribution.

Some IM have subcontracted the (scheduled) track maintenance and/or other technical equipment to private companies, while the own staff manages only the planning, tendering, contracting and supervision of works like the procurement of major repair, renovation, construction and delivery of new technical equipment, while integrated undertakings may still employ own workshops and personnel for routine maintenance and repair. The most important revenues of IM are generated by government subsidies for maintenance, public funds for planning and construction of new lines and stations, and track charges. If the IM owns the ground and (station) buildings, significant costs and revenues may be accounted for maintenance and development of commercial properties.

The important KPI regarding the efficiency of train operations are the operating costs and revenues per train-km, per passenger and tonne or container transported, per passenger-km and tonne-km respectively, as well as the operating ratio of revenues and costs per line and per time period. The occupancy rate of the trains is an indicator of passenger transport comfort and transport efficiency. It is defined by the ratio of passengers and tonnes per train, passenger-km and tonne-km per train-km. However, the transport capacity (number and density of seats and standees, maximum weight) per train varies a lot depending on e.g. the width, length (number of wagons or train sets), height (single or double deck), maximum axle load, power and traction (locomotive hauled or diesel and electric multiple units). The output per train and train-km, therefore, may vary a lot, which can bias benchmarking results significantly. A more accurate efficiency indicator for the transport capacity consumption of passenger trains would be the number of passenger-km per seat-km and per passenger space-km provided that no standees are counted for long-distance trains and the same space and density per seat and standee is applied.

3. INFRASTRUCTURE AND TRANSPORT NETWORK CHARACTERISTICS

3.1 Database

In order to perform analysis on the KPI data have been examined from various Railway Undertakings, Infrastructure Managers and Train Operating Companies. The data in this publication are for the largest part taken from the Railisa Database (http://railisa.tsf.it/railisa/) as composed and provided by UIC. Data in Railisa are provided by individual members of UIC, typically large Train Operating Companies or Infrastructure Managers. The data examined comprises only the year 2009 due to the restricted time and resources.

Next to the aggregated datasets that are publicly available from Railisa, additional datasets are at disposal of members of UIC or consultants. These additional datasets contain less aggregate and more detailed information on economic indicators and have been used, too, for plausibility checks. The expenses and revenues of railway undertakings in countries with a different currency than Euro have been converted to Euro based on the official currency rates of December 31, 2009.

Since in some cases data of UIC seem not to be appropriate (especially in the case of integrated Railway Undertakings) additional sources of information are used in order to refine the original Railisa Dataset. These additional sources include Annual Reports of Railway Undertakings, Infrastructure Managers or Train Operating Companies and additional statistics provided by national statistical agencies and our foreign research partners.

Passenger transport data are quite consistently available in most countries under investigation. However, concerning freight transport, the Railisa Database unfortunately contains lots of gaps, since private freight operators are typically no member of UIC and do not report commercial data of specific railway networks. If it has been impossible to obtain and validate required data, the graphs show N/A as to data that are Not Available.

3.2 Railway networks

The networks length of the 11 selected mid-size railway networks in Europe ranges from about 2200 km in Denmark to 20,000 km in Poland (Fig. 1.a). The networks can be split into two sub-groups: seven smaller networks with a length of up to 5,300 km and four considerably

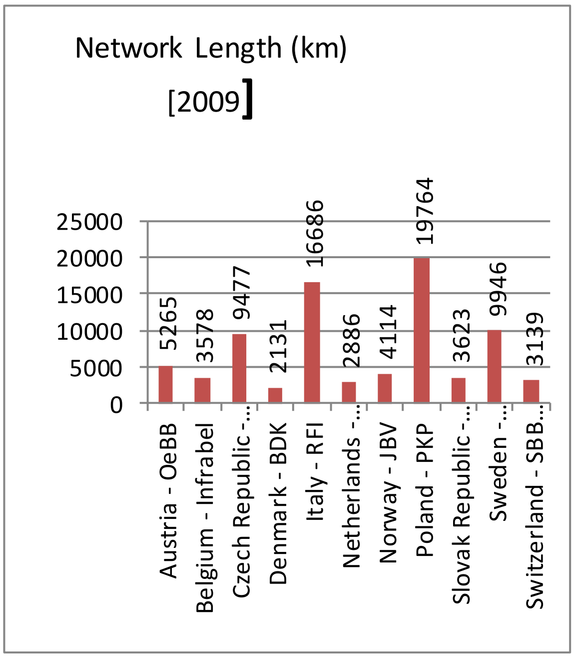


Figure 1.a – Network length of mid-size railway networks in Europe 2009

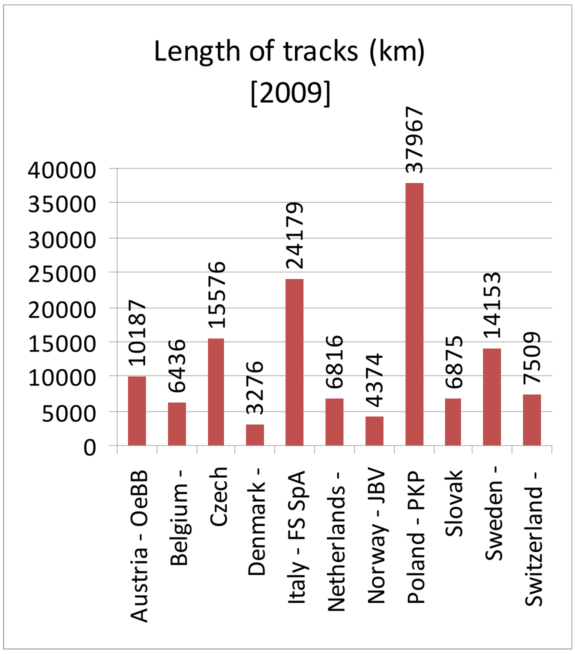


Figure 1.b – Track length of mid-size railway networks in Europe 2009

larger networks of 9,500 km up to 20,000 km. The total track length per network amounts from 3,276 km in Denmark to 37,967 km in Poland (Fig. 1.b). The mean track-km per network-km per networks varies between 1.5 km in Denmark to 2.4 km in the Netherlands and in Switzerland SBB. The network–km length is used as common basis for comparison of the traffic density, while the track-km length is better suited for an assessment of the track maintenance efficiency.

The percentage of electrified network length diverges a lot from 40% in Denmark up to 100% in Switzerland (Fig. 2). The degree of electrification is often used as indicator for the technological effectiveness of the railway network. Electrified networks are indispensable for high-frequency heavy rail rapid transit networks and heavy-haul freight trains in mountain areas, and can serve as indicator of traffic intensity. If the total traction energy consumption per train-km and per gross-tonne km respectively, as well as the percentage of non-fossil energy resources were available, these inputs could be used as indicators for energy efficiency and sustainability. However, most railway undertakings don't publish those data.

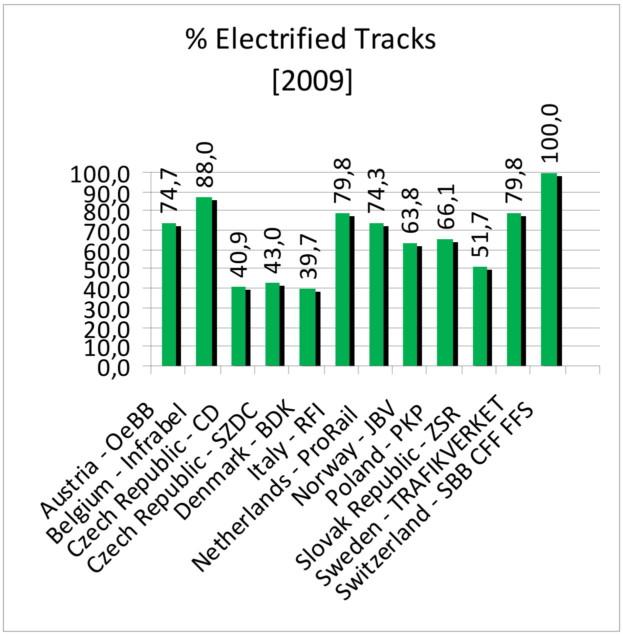


Figure 2 – Percentage electrified lines of mid-size railway networks in Europe 2009

3.3 Passenger train operations

The yearly passenger volume in 2009 per network varies between 36 million in Sweden and 583 million in Italy (Fig. 3.a). The transport work [volume?] is measured in passenger-km per year in 2009 and ranges from 2.2 billion in Slovakia to 44 billion in Italy (Fig. 3.b). Both are principal output indicators used for comparing the transport effectiveness of networks and assessing the transport productivity and efficiency of different inputs.

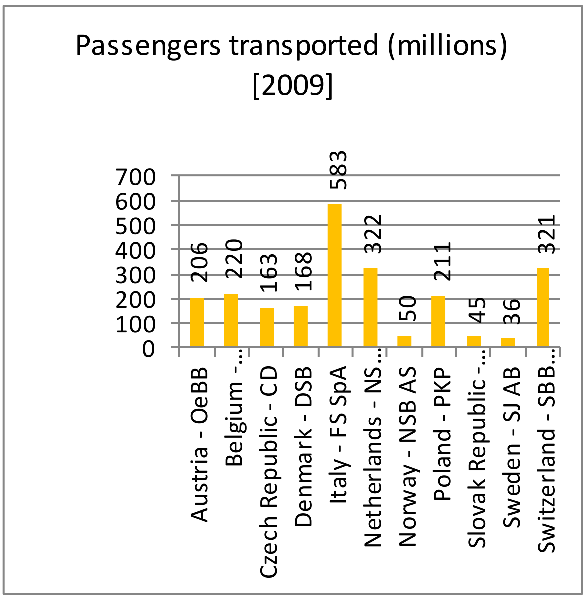


Figure 3.a – Passenger transport volume of mid-size railway networks in Europe 2009

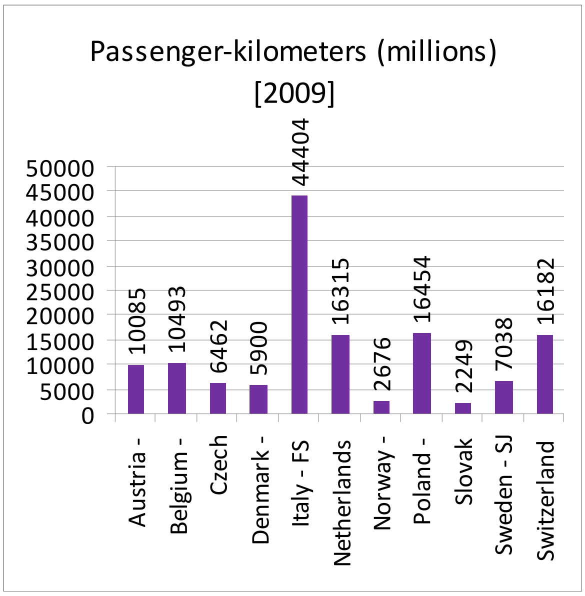


Figure 3.b – Passenger-km volume of mid-size railway networks in Europe 2009

The number of train-km in 2009 of passenger trains ranges from 28 million to 271 million (Fig. 4). This value is used as principal output indicator of the transport work of the network, train operating company, as well as for assessing the productivity and efficiency of inputs.

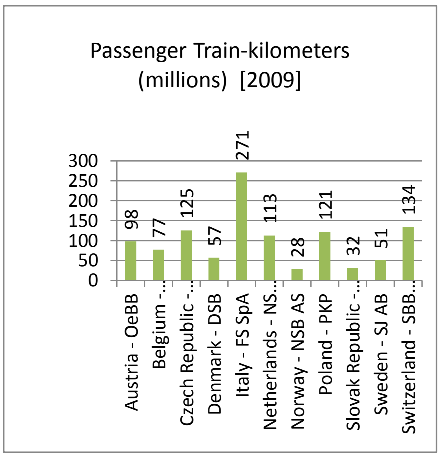


Figure 4 – Passenger train-km of mid-size railway networks in Europe 2009

3.4 Freight train operations

The total yearly freight transport volume in 2009 per network is only known for a small number of networks and some integrated railway undertakings. In many other networks the cargo transport statistics are incomplete due to missing data from other than the incumbent train operating companies. The gross-tonne-km transported varies a lot from 12.6 billion in Belgium to 63 billion in Poland 2009 (Fig. 5.a).

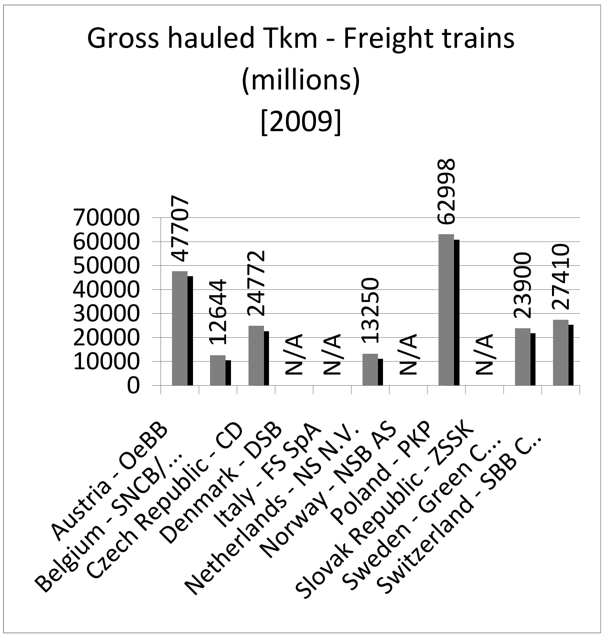


Figure 5.a – Volume of gross hauled freight tonne-km of mid-size railway networks in Europe 2009

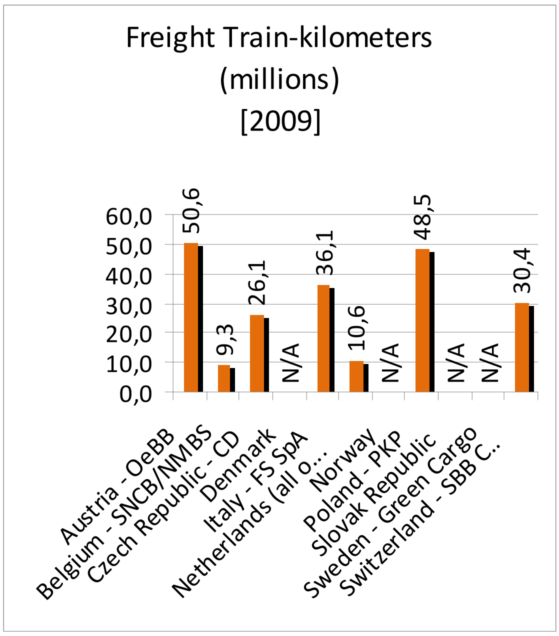


Figure 5.b – Number of freight train-km of mid-size railway networks in Europe 2009

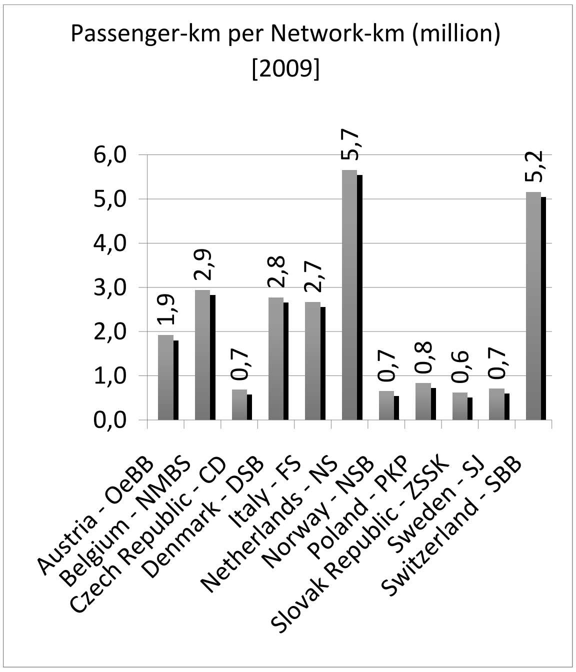
The yearly train-km of all freight trains is only reported for some of the networks (Fig. 5.b). It ranges between 9.3 million in Belgium to 50.6 million in Austria in 2009. The latter is even higher than in Poland due to the heavy transit traffic between Germany and Italy via the Brenner route. The private and international train operating companies, in general, do not publish specific data per (national) network due to commercial reasons as the governments still do not combine the transport concessions with more specific requirements for reporting.

4. PERFORMANCE ANALYSIS

The performance analysis is first based on productivity indicators regarding the generated output of transport and traffic volume per network length, train and staff in 2009. Then, the operating efficiency is measured by the expenditure of the incumbent passenger operator per network-km, train-km and passenger-km respectively. The performance of freight transport operators cannot be assessed due to the lack of sufficient business data from private entrants. The interdependence between a number of input and output variables is further analysed by means of regression analysis. Finally, a Data Envelopment Analysis is performed for certain productivity and efficiency indicators.

4.1 Network productivity

The passenger transport productivity of the Dutch (NS only) and SBB network is more than twice compared to Austria, Belgium, Denmark and Italy, while the passenger transport density in the Czech Republic, Norway, Poland, Slovakia and Sweden is much lower (Fig. 6.a). The passenger train traffic productivity in 2009 differs a lot between a minimum of 9,000



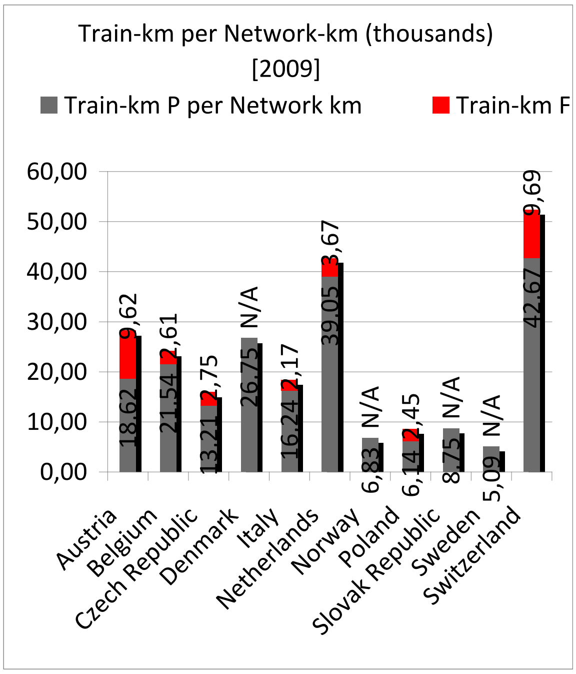


Figure 6.a – Passenger-km per network-km Figure 6.b – Passenger and freight train-km per network-km of mid-size railway networks in Europe 2009

train-km in Slovakia to a maximum of nearly 43,000 train-km per network-km in Switzerland (SBB only) (Fig. 6.b). While the network in Belgium, Slovakia and Switzerland (SBB) has about the same length of around 3,000 km, the passenger traffic volume generated of SBB is roughly two times higher than of SNCB, and four times higher than in Slovakia. The share of freight train-km in most networks, except Switzerland and Austria due to the heavy transit traffic crossing the Alps, is rather limited.

An indicative correlation analysis between the output-input values shows a weak increase of about one million passenger-km transported per network-km (Fig. 7). The regression function and correlation coefficient, however, should be treated very cautiously as the total number of networks observed is rather small and the correlation coefficient is very low.

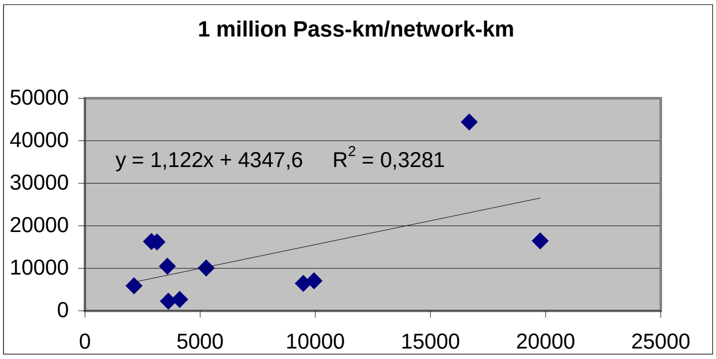


Figure 7 – Scatter diagram of incumbent passenger-km in mid-size European railway networks 2009

The passenger transport productivity ranges between a minimum of 52 passengers/train in the Czech Republic to a maximum of 164 passengers/train in Italy, while the mean train

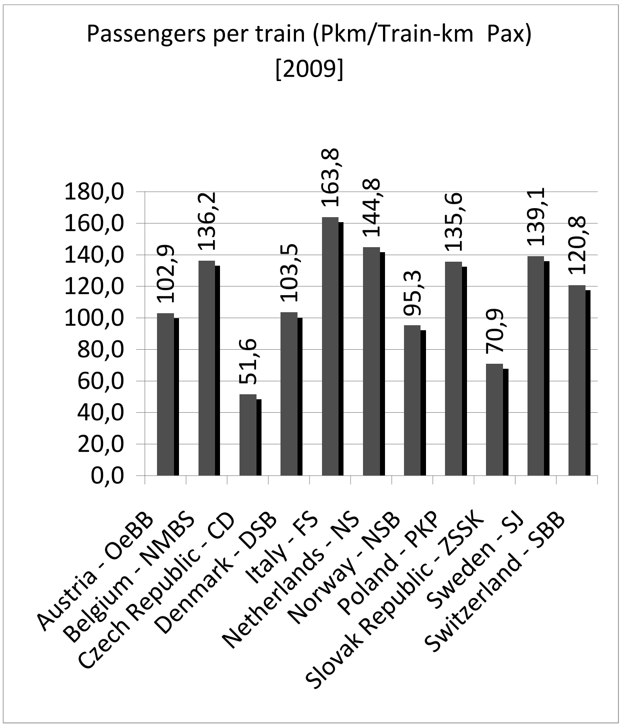


Figure 8 – Mean passenger volume per train of mid-size railway networks in Europe 2009

occupation in Belgium, the Netherlands (NS), Poland, Sweden and Switzerland (SBB) varies only a little between 120 and 145 passengers/train (Fig. 8). The passenger transport volume realized per train-km of the incumbent train operator in 2009 per network shows a remarkably high correlation (Fig. 9). The number of passenger-km increases approximately by 0.164% per train-km of the incumbent train operator.

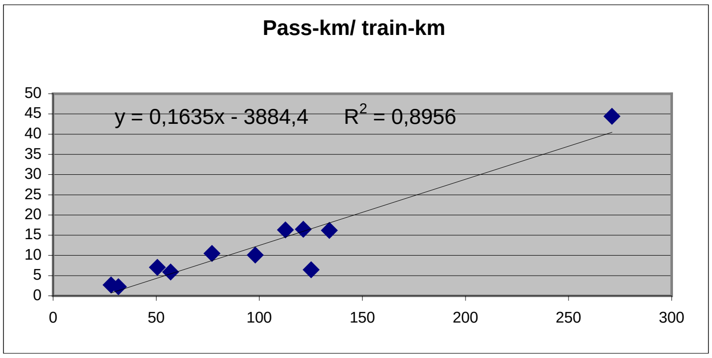


Figure 9 – Scatter diagram of passenger-km per train-km of incumbent operator in mid-size European railway networks 2009

The passenger transport productivity per staff member of the incumbent operator varies a lot between 250,000 per year in the Czech Republic and 2 million passenger-km in Sweden (SJ only) (Fig. 10.a). The top performance of SJ is due to the very high operating speed of its long-distance high-speed line network, while the regional passenger networks in Sweden are operated by other (private) operators. The traffic productivity of the staff of the incumbent train operator varies between a minimum of 2,100 passenger train-km in 2009 in Poland and a maximum of 14,380 train-km of SJ in Sweden (Fig. 10.b).

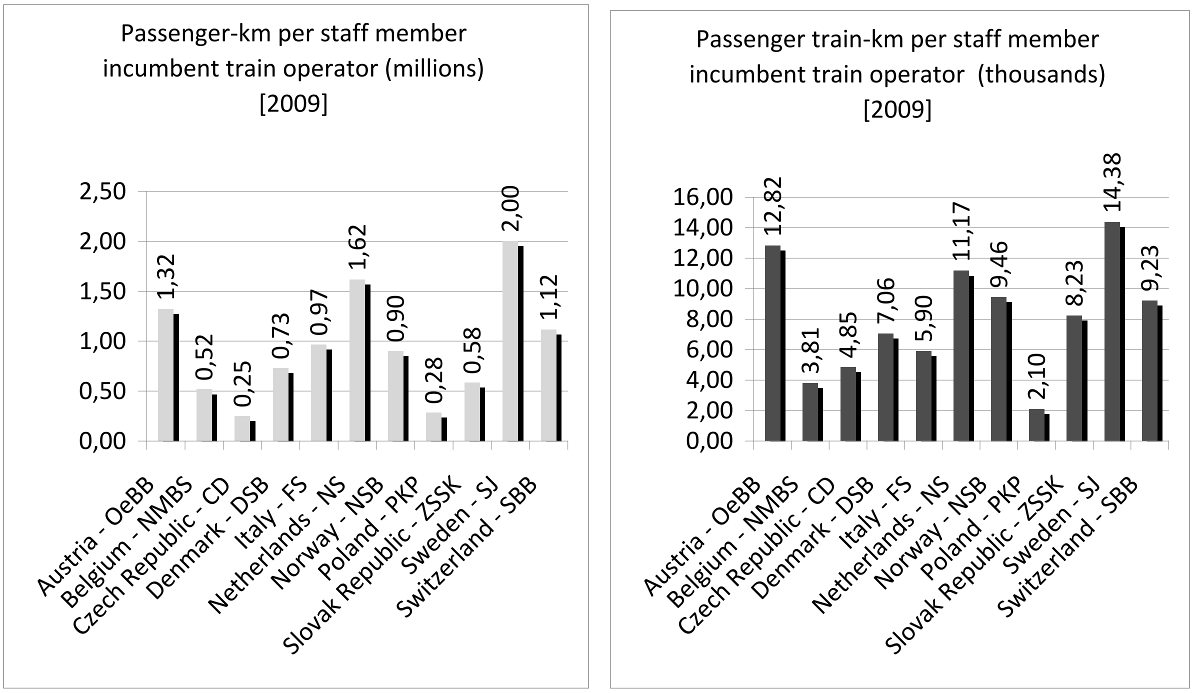


Figure 10.a – Volume of passenger-km per staff member Figure 10.b – Number of train-km per staff member of incumbent train operating company (TOC) of mid-size railway networks in Europe 2009

The transport productivity is weakly correlated with the number of staff. The transported number of million passenger-km per year grows slightly per staff member (Fig. 11). Traffic productivity of mid-size incumbent passenger train operators, measured in million train-km per year per staff member, grows rarely, while the correlation coefficient < 0.5 indicates only a weak relation between both variables.

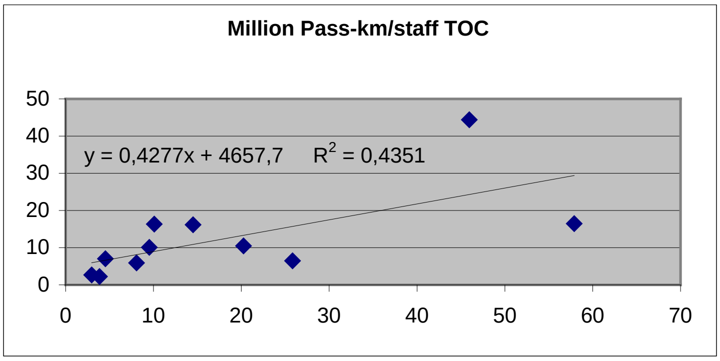
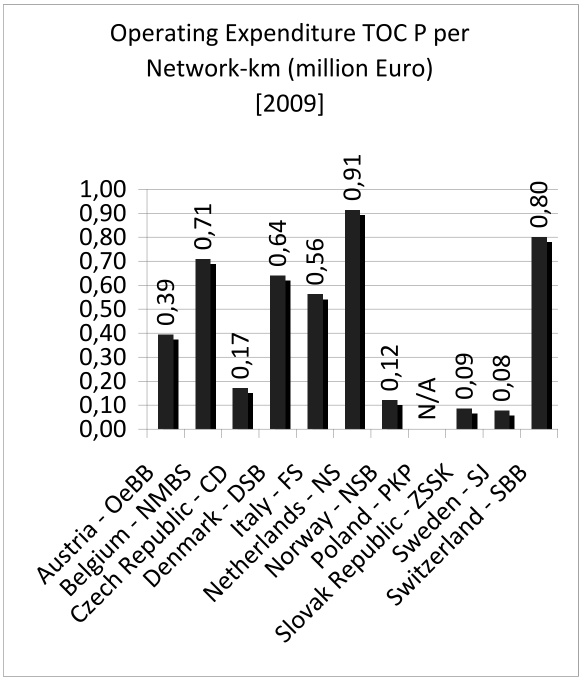


Figure 11 – Scatter diagram of million passenger-km per staff of incumbent operator in mid-size European railway networks 2009

4.2 Operating efficiency

The operating expenditure of the incumbent passenger train operator per network-km in 2009 shows a wide range of € 0.39 (ÖBB) to € 0.91 (NS) for the West and South European networks including Belgium (NMBS), Denmark (DSB) and Switzerland (SBB), while the East and North European networks are clearly at the bottom (Fig. 12.a). Dutch Railways NS spends in 2009 most in train operation with € 991,000 per network-km, followed by SBB with € 800,000 per network-km, as both companies exploit their trains and networks most intensively (Fig. 6.b). FS (Italy) and NMBS (Belgium) spend



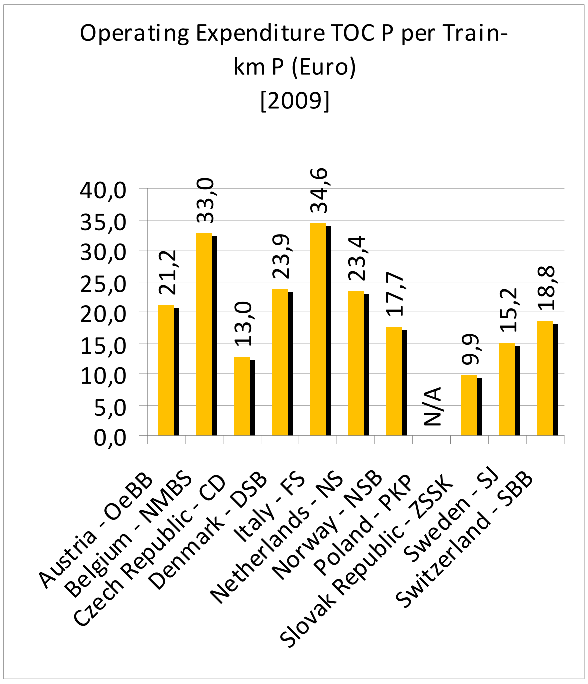


Figure 12.a – Operating expenditure per network-km Figure 12.b – Operating expenditure per train-km of incumbent train operator in mid-size railway networks in Europe 2009

in 2009 almost the same maximum of around € 34 per train-km, while NS, DSB, ÖBB spend about 25% less. SBB, NSB and SJ operate their trains even more efficiently (Fig. 12.b). The Polish Railways have not reported any operating costs in 2009.

The operating costs of the incumbent passenger train operators are correlated strongly and increase slightly with the number of train-km performed (Fig. 13).

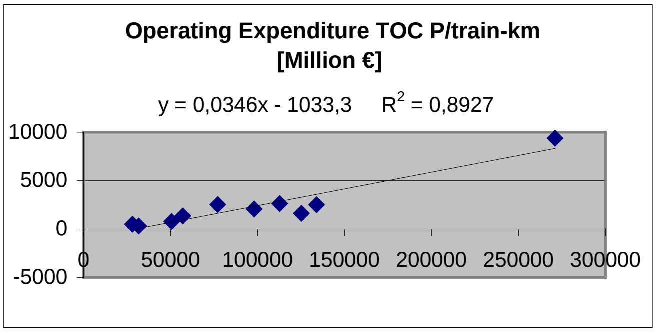
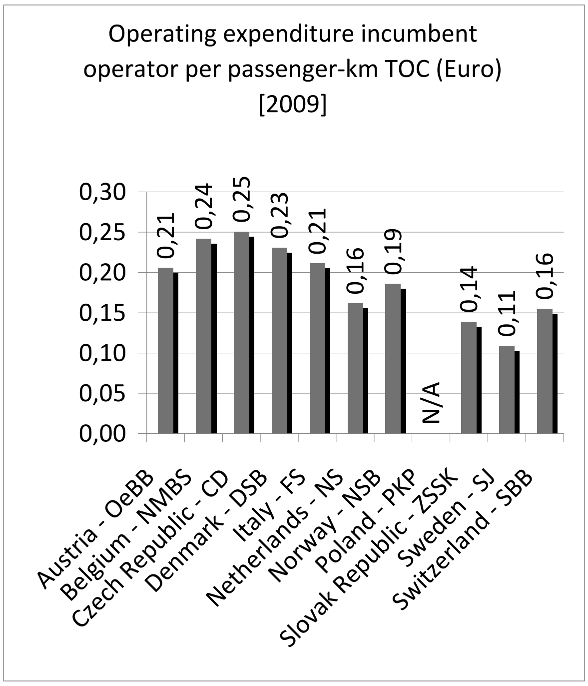


Figure 13 –Scatter plot of operating expenditure of incumbent passenger train operator per train-km in mid-size railway networks in Europe 2009

The operating expenditure in 2009 per passenger-km of the incumbent passenger train operator is shown in Fig. 14.a. About one half of the passenger train operators spend € 0.20 up to € 0.25 operating costs per passenger-km, while the minimum of only € 0.11 per passenger-km is achieved by SJ in Sweden. The operating costs of the incumbent train operator per staff member are highest for ÖBB and NS with about € 0.20 per staff member in 2009, whereas the least costs are generated by the Czech Railways with only € 0.06 per staff member (Fig. 14.b).



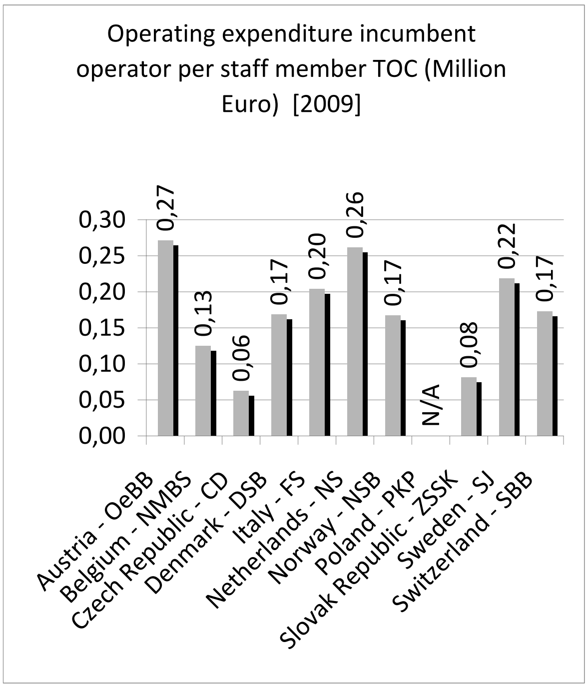


Figure 14.a – Operating expenditure per pass-km Figure 14.b – Operating expenditure per staff of incumbent passenger train operator of mid-size railway networks in Europe 2009

The operations costs of the incumbent passenger transport operator are strongly correlated with the number of staff employed (Fig. 15). The rate of increase of operating costs in million Euro as function of staff size (17.7%) is quite considerable.

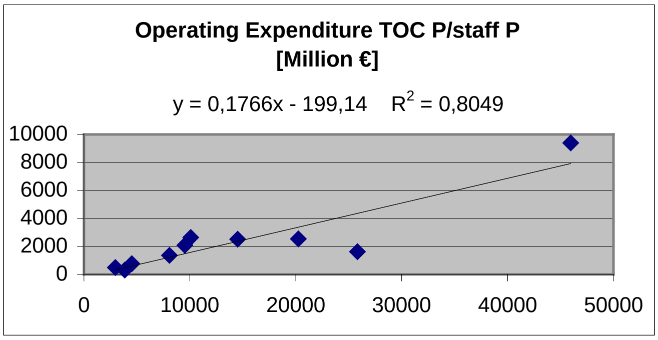
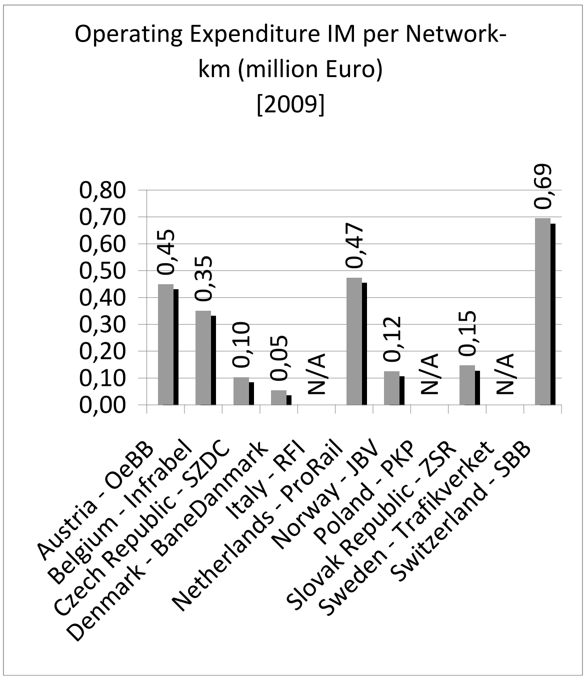


Figure 15 –Scatter plot of operating expenditure of incumbent passenger train operator per staff in mid-size railway networks in Europe 2009

The operating expenditure for infrastructure management in 2009, unfortunately, is not reported by RFI (Italy), PKP (Poland) and Trafikverket (Sweden), so that the total network expenditure can only be given for the remaining seven networks. The West European infrastructure managers of ÖBB, Infrabel, ProRail and SBB spend in 2009 between € 0.35 to € 0.70 per network-km and between € 0.20 to € 0.30 per track-km, while the expenditure of the Scandinavian (Banedanmark, JBV) and East European infrastructure managers is much less (Fig. 16.a and Fig. 16.b).



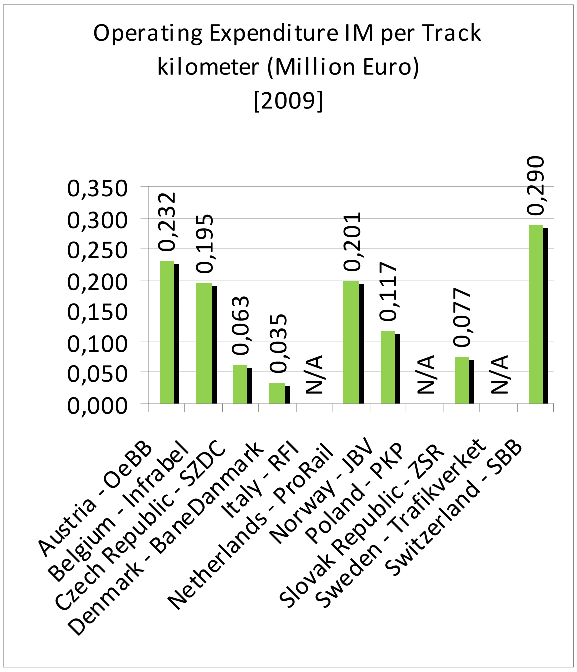


Figure 16.a – Operating expenditure per network-km Figure 16.b – Operating expenditure per track-km for infrastructure management in mid-size railway networks in Europe 2009

The operating expenditure for infrastructure management per train-km including passenger and freight trains (red columns) represents the efficiency of the network manager (Fig. 17). The values belonging to the green columns are estimated by splitting the total operating costs according to the market share of passenger trains in each network, which results in

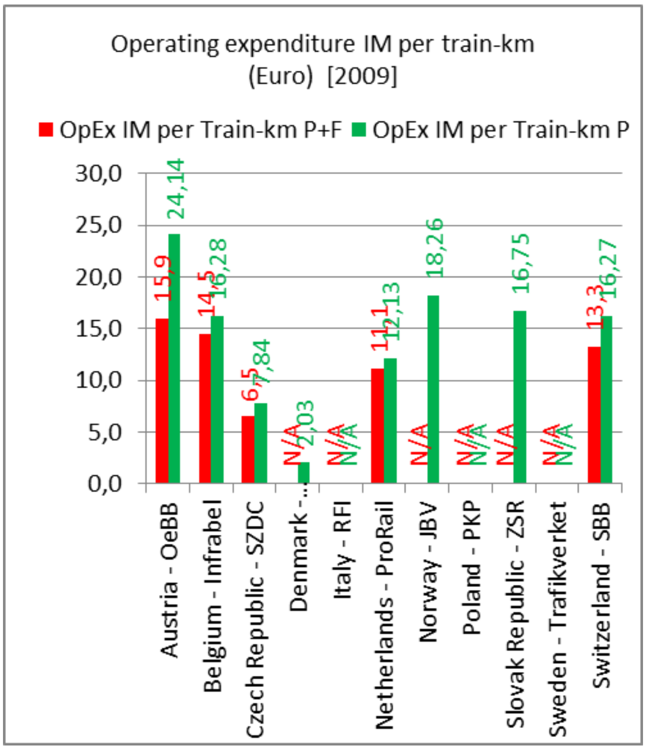


Figure 17 – Operating expenditure of infrastructure manager per train-km in mid-size railway networks in Europe 2009

considerably higher specific costs per train-km than for all trains, especially in case of networks with a high percentage of cargo-train-km. The operating expenses for infrastructure management in 2009 grow clearly with the number of train-km realized while its correlation is satisfactory (Fig. 18).

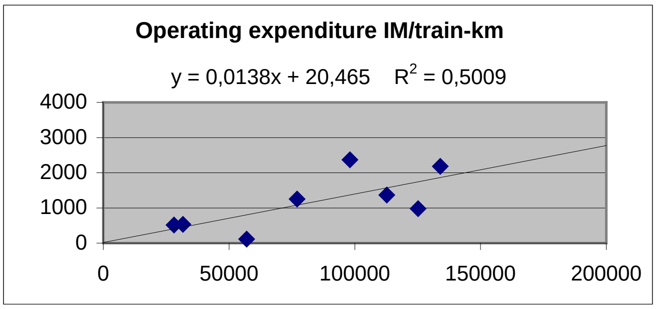


Figure 18 –Scatter plot of operating expenditure of infrastructure manager per train-km in mid-size railway networks in Europe 2009

A better indicator for the distribution of the operating costs for infrastructure management between passenger and cargo trains would be the costs per gross-tonne hauled. Unfortunately, this important data is not reported by most of the infrastructure managers.

The total operating costs of the incumbent passenger train operator and infrastructure management per staff member in 2009 are shown in Fig. 19. The operating costs of the incumbent cargo operator here are excluded to enable a better comparison with those networks, whose cargo operators are private companies and do not publish their specific operating costs. The total train passenger train and network operating costs per staff in 2009 are highest for Dutch Railways NS and ProRail with € 0.29 per staff member.

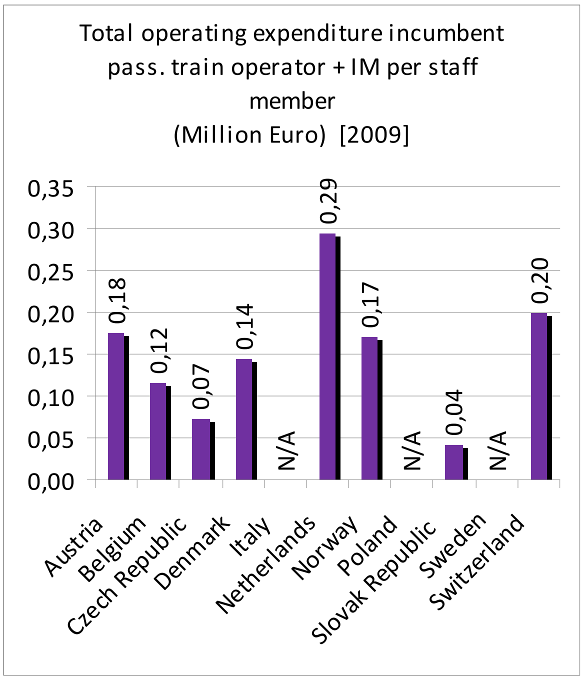


Figure 19 – Total operating expenditure of incumbent passenger train operator and infrastructure management in mid-size railway networks in Europe 2009

As ProRail has subcontracted all infrastructure maintenance works, its operating costs are accounted for its own administration and engineering staff only and lead to relatively high costs per staff. In this case, the efficiency indicator of operating cost per staff member cannot be used for benchmarking with other railway undertakings and infrastructure managers. Furthermore, the cost allocation for property (station buildings and ground) that does not directly belong to the railway infrastructure may differ from country to country.

The total operating expenses of the main passenger transport operator and infrastructure management in 2009 increase clearly with the number of train-km performed, while both are strongly correlated (Fig. 20).

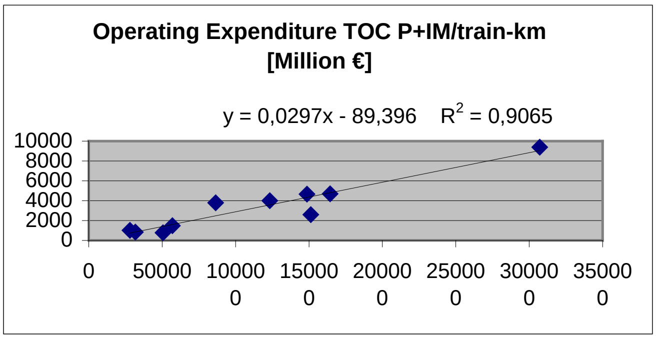


Figure 20 –Scatter plot of total operating expenditure of incumbent passenger train operator and infrastructure management per train-km in mid-size railway networks in Europe 2009

5. CONCLUSIONS

The performance analysis of 11 mid-size European railway networks and undertakings by means of parametric system and regression analysis of key performance indicators for effectiveness and efficiency of only the year 2009 is too limited for a general judgment of the networks and undertakings. The more so, as the analysis reveals structural shortcomings in the current database of UIC especially regarding freight transport and regional passenger transport by private operating companies, as well as the transparency of the operating cost allocation by some integrated railway undertakings for infrastructure management, passenger transport and freight transport. Anyhow, the system and regression analysis of the passenger train operations and infrastructure management performance generate new insights into the interdependence of the relevant inputs and outputs. Further benchmark analysis research based on an extended empirical basis including private train operators, large networks and data over longer time periods (5 to 10 years) is recommended.

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