Efficiency of Passenger and Freight Transportation Railways in Developing Countries (Data Envelopment Analysis)

كفاءة خدمات السكك الحديدية في نقل الركاب والبضائع في البلدان النامية (التحليل التطويقي للبيانات)

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Abstract:

In this paper, we evaluate the technical efficiency of both freight and passenger transportation railway services in selected developing countries over the time period from 2013 to 2018. We apply the Data envelopment Analysis DEA based on different input-output model configurations under Variable and Constant Return on Scale. The findings suggest the existence of efficiency gaps amongst the investigated railways and most of them are oriented to passenger transportation services rather than freight services. The results also show a moderate dynamic change of technical efficiency during the period of analysis with shifts representing occasional back and forth development for most of the observed railways. Finally, our findings suggest that Algerian Railways Company SNTF should implement substantial inputs restructuring or outputs increase to improve the overall performance of the delivered railways transportation services.

Keywords: *Railways; Benchmarking; Technical Efficiency; Developing Countries, DEA.*

Jel Classification Codes : *D25* ; L92 ; R15

ملخص

تهدف هذه الدراسة إلى تقدير مستوى الكفاءة الفنية لكل من خدمات السكك الحديدية لنقل البضائع ونقل الركاب لعينة من البلدان النامية خلال الفترة الزمنية الممتدة من 2013 إلى 2018. نطبق نموذج التحليل التطويقي للبيانات لتركيبات مختلفة من المدخلات والمخرجات تحت فرضية عائد السلم المتغير والثابت. تشير النتائج إلى وجود فجوات في الكفاءة بين السكك الحديدية المدروسة وان معظمها موجه لخدمات نقل الركاب بدلاً من خدمات الشحن. كما تظهر النتائج تغيرا ديناميكيا طفيفا في الكفاءة الفنية خلال فترة الدراسة بين تطور وانخفاض من حين لآخر لمعظم السكك الحديدية قيد الدراسة.أخيرا، تشير نتائج الدراسة إلى أن تحسين الأداء الكلي لخدمات النقل بالسكك الحديدية المقدمة من طرف الشركة الجزائرية S NTF مرهون بمدى قدرتها على إعادة هيكلة مدخلاتها أو زيادة مستوى خدماتها المقدمة.

الكلمات المفتاحية: *السكك الحديدية، المرجعية، الكفاءةالفنية، البلدان النامية، التحليل التطويقي للبيانات*

تصنيف JEL: *D25 ; L92 ; R15*

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Introduction

The investigation of railways efficiency has become a matter of great interest to governments and railway managers, particularly, those facing budget constraints and operating in competitive markets (De jorge & Suarez, 2003, p. 221). Political decisions makers and railway experts keep looking continuously for better ways to improve railway efficiency for passengers and freight services. Market pressures to keep the costs low while improving rail's level of service and expanding rail capacity combined with the increase demand in railway usage for passenger and freight; make the railway efficiency a very challenging topic (De jorge & Suarez, 2003, p. 221).

In most countries, governments engage huge investments in terms of infrastructures and rolling stock, and pay large subsidies to improve railway infrastructures and passenger transport. In these cases, the focus of the government will be on asking whether those investments and subsidies are spent efficiently or how, through higher efficiency, they could be reduced (Kapetanović, Milenković, Bojović, & Avramović, 2017, p. 404).

The main objective of benchmarking is to compare the products and services generated by an amount of inputs with organizations recognized as leaders in their sector (Doomernik, 2015, p. 137). It intends to find the best practices by comparing the individual performances within a selected peer group. Many indicators have been developed to assess the efficiency and productivity of railways. If we consider the relationship between one single input and output, we refer to Uni-dimensional Ratio analysis RA or Partial Productivity Measures PPM (Doomernik, 2015, p. 138). Although this approach is practical (easy and fast to implement), it lacks in providing meaningful information about effective performance leading to misinterpretation. Even the multi-PPM analysis where more ratios are measured at the same time tends to end up with more dilemmas than solutions (Ozcan, 2008, p. 108). In the other hand, the Multi-dimensional approach deals with multiple inputs and multiple outputs, four indicators can be identified in the literature: Two frontier techniques (Data Envelopment Analysis DEA and Stochastic Frontier Analysis SFA) and two average techniques (Total Factor productivity TFP and Least Square Analysis LSR). The frontier-based techniques are viewed to be advanced and sophisticated analytical schemes in assessing the railways efficiency (Merkert, Smith, & Nash, 2010, p. 36).

It is worth mentioning that research involving railways efficiency and productivity comparisons, have been limited to West European countries or US to greater extent (Hilmola, 2008, p. 258). Some studies favored the parametric approach SFA such as (Coelli &

Perelman, 2000) ; (De jorge & Suarez, 2003) ; (Wetzel, 2008). However , most of studies have dealt with the nonparametric technique DEA such as; (Hilmola, 2007) ; (Hilmola, 2008) ;(Kutlar, Kabasakal, & Sarikaya, 2013) ;(Doomernik, 2015)and (Li & Hilmola, 2019) to mention few.

Amongst the existent literature on efficiency of railways , only few studies have considered both passenger and freight transportation operations. For instance , we can mention (Hilmola, 2008)who investigated the technical efficiency of 30 European railways for both freight and passenger transportation operationsfrom 1994 to 2003 using different inputs-outputs combinations. The authors' findings suggest that most ofthe investigated railways are efficient either in passenger or in freight operations and only few railways can simultaneously perform better in both transportation modes. The authors' results also showed that Central and Eastern European (CEE) railways experienced a technical efficiency collapse during the period and considerable inputs restructuring or outputs increase should be implemented to improve the overall railways performance. In a more recent study (Kapetanović, Milenković, Bojović, & Avramović, 2017)have identified the same findings. The authors examined the determinants of 34 European railways between 2004 and 2013, based on a two–stage analysis and found that few companies outperform their peers in both transportation services. Most of investigated firms are oriented either in freight or in passenger transport services. Finally , the influential study of (Li & Hilmola, 2019) is worth mentioning , the authors performed different DEA model configurations to analyze the efficiency of railways operating in countries members of the Belt and Road Initiative from 2000 to 2016. The authors noticed a slight improvement in the analyzed railways whether they are oriented for freight or passenger transportation operations.

As stated above, the literature on developing countries is quasi inexistent. Hence, we attempt in this study to fill this gap and provide empirical evidence on railway efficiency from the prospective of only economies in development. We address two main research questions :

- ***Question 1:*** *What is the level of current technical efficiency of developing countries railways, its explaining sources and how does it evolve over the time?*
- ***Question 2:*** *In which type of operations railways of developing countries perform better: Passenger or freight transport services?*

With this respect, the following three hypotheses are formulated:

- ***Hypothesis*** H_1*: The technical efficiency varies amongst the observed railways given the scale size and development level of each firm.*

- ***Hypothesis*** $\boldsymbol{H_2}$*: Due to heavy regulations on freight transport operations and high competition in the market especially in shorter distances. Most of railways are oriented on passenger transport services.*
- ***Hypothesis*** $\boldsymbol{H_3}$ *: There are differences in terms of dynamic efficiency changes for each railway in the sample.*

With this regard, the aim of this paper is to measure and identify the best practices of selected railway companies from Central Eastern Europe, South East Asia and Africa. Based on a balance panel data from 2013 to 2018, twenty 20-railway systems are benchmarked against their peers using the actual system characteristics and performance. We conduct a Data Envelopment Analysis DEA under Constant Return on Scale CRS and under Variable Return on Scale VRS to draw the overall technical TE, Pure Technical PTE and Scale SE efficiencies of our selected railways observed. We perform three different models of inputs-outputs selection for passenger and freight transportation taken distinctively as well as jointly to assess the overall performance. We also examine the dynamic changes in railway technical efficiency over the period of analysis and identify the peer benchmark group for each railway.

In this study, we rely on frontier techniques to measure the railway efficiency for its superiority over the traditional KPI indicators such as: traffic density, wagon/coach productivity,..,etc. Berger and Mester (1997) point out that the frontier approaches use a powerful economic optimization mechanism such as the linear programing to benchmark the relative performance of production units. The authors outline two main reasons for using the frontier techniques rather than basic indicators: "The power of frontier analysis is twofold. First, it permits individuals with very little institutional knowledge or experience to select "best practice"unit within the industry, assign numerical efficiency values, broadly identify areas of input overuse and/or output under-production, and relate these results to questions of government policy or academic research interest. Second, in the hands of individuals with sufficient institutional background, frontier analysis permits management to objectively identify areas of best practice within complex service operations, a determination not always possible with traditional benchmarking techniques due to a lack of a powerful optimizing methodology such as linear programming ". [Cited by (Berger & Mester, 1997, p. 897)].

The study has many policy implications for railways managers and policy makers as well. The findings would help the managers of railways to objectively identify the best practices amongst the different railways transportation systems. A determination not always possible when relying on the traditional key performance indicators. Thus, overused inputs can be easily detected, and then reduced which leads to improvements in the overall performance.

On other side, most of railways are state-owned companies and governments engage a lot of money to build railways infrastructures. With this regard, the governments may gain insight into whether the capitals invested and the subsidies are efficiently used. And therefore readjust their policies.

The remainder of the paper is organized as follows: we review the different benchmarking methods and applications to railway efficiency in section 1. We discuss the research methodology in section2. Data, variables and different DEA models adopted in the study are presented in section 3. We discuss the findings in section 4. Finally, the section 6 concludes.

2 . Research Methodology: Data Envelopment Analysis DEA

DEA is a linear programming technique that allows calculating relative efficiency of a business unit. It was developed by Charnes, Cooper and Rhodes in 1978 in order to measure relative efficiency without knowing what variables are more important or what their relationship is. The non-parametric measurement of DEA creates a piecewise linear convex frontier that envelops the input-output of all DMUs in the sample relative to which inputs are minimized or outputs are maximized is. Efficiency scores are then calculated from the frontier generated by a sequence of linear programs. Each DMU is assigned an efficiency score between 0 and 1 with higher score indicating the most efficient DMU (Charnes, Cooper, & Rhodes, 1978, p. 431).

We opt for the DEA approach because of many advantages this non-parametric offer for the analysis. The main reasons is that DEA works relatively well with efficiency analysis involving small samples and it does not require any assumption regarding the distribution of inefficiency and the functional form of the production function (Charnes, Cooper, & Rhodes, 1978, p. 432). In fact, DEA is very suitable for the use in the rail sector, due to the highly regulated and quasi-monopolistic industry structure and where the formal link between input and output is not clear in the first instance (Coelli & Perelman, 2000, p. 1968).

An important advantage of DEA is that the results are based on a relative comparison and that DEA can work with index numbers, ensuring that no sensitive information is provided to others as often desired by companies (Kapetonovic, Milenkovic, Bojovic, & Avramovic, 2017, p. 406). However, DEA suffers of some drawbacks as it remains sensitive to outliers and assumes data to be free of measurement error.

Under the assumption that managers of railways companies have higher control over the inputs rather than outputs which are influenced by different macroeconomic factors exogenously determined by public transport institutions (Merkert, Smith, & Nash, 2010, p. 7), we opt for the an input-output orientation in estimating the technical efficiency. The input-output oriented model measures improves in efficiency through proportional reduction of input quantities without altering produced output quantities. The technical efficiency score for firm i in a sample of *I* firms is estimated through the following optimization CCR –DEA form(Coelli, Rao, O'Donnell, & Battese, 2005, p. 163) :

$$\min_{\theta\lambda} \theta$$
$$\text{st} - q_i + Q\lambda \geq 0 \qquad (1)$$
$$\theta x_i - X\lambda \geq 0$$
$$\lambda \geq 0,$$

Where Q and X stand for input and output matrices. λrepresents the weights for the inputs and outputs which is a *I.1* vector of constants.θrepresents the efficiency score for each firm in the sample, it measures the distance between the observations q_i and x_i and the frontier (where the frontier represents efficient operation. A value of $\theta = 1$ indicates that a firm is efficient and thus, located on the determined frontier. The CRS-DEA model is based on Constant Return on Scale CRS assuming that all observed firms are operating at the optimal scale (Banker, Charnes, & Cooper, 1984, p. 1078). However, it is a common knowledge that railway industry is subject to imperfect competition, budgetary restrictions as well as regulatory constraints on entries and mergers, which may lead to firms not operating at optimal scales (Merkert, Smith, & Nash, 2010, p. 40) . Accordingly, in this paper given the heterogeneity across size and development level of the investigated railways, we also measure a DEA model under Variable Return on Scale VRS assumption. The BCC-DEA model takes the following form (Coelli, Rao, O'Donnell, & Battese, 2005, p. 172) :

$$\min_{\theta\lambda} \theta$$
$$\text{st} - q_i + Q\lambda \geq 0 \qquad (2)$$
$$\theta x_i - X\lambda \geq 0$$
$$I1'\lambda = 1$$
$$\lambda \geq 0,$$

Where *I1* is *I x 1* vector on ones. The restriction *I1'*λ *= 1* represent a further convexity constraint which ensures that inefficient firms are only benchmarked against its peers of the same size. The conduction of both CRS and VRS DEA models enables us extract the Scale Efficiency by decomposing the technical efficiency obtained from the CRS-DEA into two components, one due to "Pure" Technical Efficiency and one due to Scale Efficiency (SE. $TE_{CRS} = TE_{VRS} \text{x} SE$) . If there is a difference in the CRS and VRS TE scores for a particular firm, then this indicates that the firm has scale inefficiency (Coelli, Rao, O'Donnell, & Battese, 2005, p. 172).

3 . Data and Variables

As mentioned above , This study aims at analyzing the technical efficiency levels of the railway companies from selected countries in development based on a balance panel data spread over six years from 2013 to 2018 period. Our data set includes 20 railway companies: 04 railways companies from Africa (Gabon, Algeria, Tunisia, Morocco) ; 09 railway companies from South East Asia SEA (Korea, Pakistan, Malaysia, Vietnam, Iran , Uzbekistan, Azerbaijan, Bangladesh, Georgia, Kazakhstan) and 07 railway companies from Central East Europe CEE (Turkey, Romania, Lithuania, Czech Bosnia and Belarus).

Data were drawn from the official statistics of International Union of Railways RAILISA (RAIL Information System and Analyses). The database covers worldwide data provided by railway companies. Numerous indicators are available for more than 100 railway companies: length of lines and tracks on the infrastructure network, passenger and freight traffic (*e.g.* passenger-kilometers and ton-kilometers), train movements, rolling stock, staff numbers, financial results,..,etc. (UIC, 2013-2018).

It should be noted that the choice of the sample is highly influenced by data availability. In addition, for sake of ensuring comparability between the firms' studies, we prefer focus on railway companies operating in developing countries that share similarities in terms of economic performances and where railway transportation systems are at early stages of development. Since there have been difficulties in obtaining data for some companies, in certain years of the time period observed, they were omitted in the analysis for respective years, We only consider companies that provide both passenger and freight transportation services.

We develop three different DEA-Models, two single-output models (M1 for Passenger transport operations and M2 for Freight transport operations) and one multiple-output model for Overall railway performance:

- **Model M1**: Inputs (Employees + locomotives +passenger cars) - Outputs (Passenger-kilometers achieved).
- **Model M2** : Inputs (Employees + locomotives + wagons) – Outputs (Freight Tons-kilometers achieved)

- **Model M3**: Inputs (Employees + locomotives + passenger cars + wagons) - Outputs (Passenger-kilometers achieved + Tons-kilometers achieved).

Table 1. Summary of inputs and outputs used in the DEA models

Inputs-Outputs Variables	**Definition**
Labor (Input 1)	Mean Annual staff strength. Full time equivalent
Tracks (Input 2)	Number of Diesel and Electric Locomotives
passenger cars (Input 3)	Bodies in Multiple unit and trailers – coaches
Freight (Input 4)	Total number of wagons.
Passenger-kilometers achieved (Output 1)	Domestic + international passenger-kilometer (KM travelled × Nbr of seats available)
Freight Tons- kilometers achieved (Output 2)	Domestic + international Freight Tons- kilometers (KM travelled × freight train cargo)

Source: Prepared by the authors

Table 2. Descriptive Statistics of input-output variables

Country	Railways	Des. stats	Input 1	Input 2	Input 3	Input 4	Input 5	Input 6
Korea	KOR-AIL	Mean	26936	479	2427	11096	23040	9004
		STD	591	24	86	381	613	901
Turkey	TCDD	Mean	24832	645	1406	19227	4329	10554
		STD	715	30	51	371	306	494
Pakistan	PR	Mean	72078	478	1743	16159	24903	8080
		STD	2921	22	11	363	1824	2576
Malaysia	KTM	Mean	3131	125	450	826	2652	1236
		STD	216	7	89	64	210	124
Gabon	SETR-AG	Mean	1157	24	35	538	137	2722
		STD	84	2	10	65	28	423
Vietnam	VN-DSVN	Mean	28701	289	1022	4875	3883	3748
		STD	2288	12	13	284	439	362
Iran	RAI	Mean	9158	892	2113	23686	15019	27379
		STD	504	37	87	1066	1557	4151
Algeria	SNTF	Mean	12718	275	364	10722	1355	965
		STD	751	10	58	622	165	53
Tunisia	SNCFT	Mean	4868	141	129	3477	1225	714
		STD	267	4	6	90	69	120
Morroco	ONCF	Mean	7743	201	570	5480	5160	4454
		STD	138	29	37	68	362	759
Romania	CFR	Mean	1317	12	309	148	868	42
		STD	60	1	10	38	66	4
Lithuania	LG	Mean	459	231	225	8466	402	14629
		STD	34	17	22	459	36	1191
Uzbekistan	UTI	Mean	283	292	788	21819	3973	22936
		STD	10	0	7	984	248	4
Czech	CD	Mean	22673	1502	3923	24928	7405	10848
		STD	640	14	517	1374	466	532
Bosnia	ZFBH	Mean	3466	97	84	2143	22	809
		STD	201	0	37	19	5	47
Belarus	BC	Mean	71442	792	2905	33906	7142	45303
		STD	2620	28	66	4631	997	4156
Azarbejan	AZ	Mean	21160	290	441	15428	525	5976
		STD	1395	40	228	4534	57	1326
Bangladesh	BDR	Mean	26575	278	1491	12813	8760	723
		STD	982	11	36	217	618	160
Georgia	GR	Mean	8729	187	69	12215	557	3962
		STD	2548	24	29	1015	57	1063
Kazakhstan	KTZ	Mean	12725	1846	2486	69122	18507	208646
		STD	2324	85	54	26748	759	15718
Nbr.Obs			120	120	120	120	120	120

Source: Authors' Calculations

4 .Discussion of Results

4.1 Technical Efficiency of Railways in Developing Countries - DEA Results

Table (3) reports the average six years value of technical efficiency for each railway company. The calculated CRS efficiency TE is split into two components, one due to scale inefficiency SE and one due Pure Technical Efficiency PTE (VRS). Considering large scale of results data, Table (3) reports only the PTE efficiency scores for both passenger (Model M1) and freight (Model M2) transportation modes. Beside this, we prefer emphasize our analysis on Pure Efficiency outcomes that reflect the managerial efficiency of some analyzed railways, already disadvantaged by their size regarding the rest of the sample.

The table (3) displays the average technical efficiency score for each observed firm. For instance, the company VN-DSVN (Vietnam) has obtained a technical efficiency score of 0.43 for the passenger model M1. This score suggest that VN-DSVN (Vietnam) could possibly reduce the usage of its inputs (employees, locomotives and passenger cars) by 56,3 % to produce the same bundle of outputs (Passenger-kilometers) in comparison with the best-practice railway companies of the sample, within the same market and the same industry conditions.

It can be seen from table (3) that the different estimated technical efficiency variants (TE,PTE and SE) of the three models vary considerably amongst the railways observed with standard deviation STD around 34,2 % - 18,2 % which suggest confirms our ***hypothesis*** $\boldsymbol{H_1}$. And when looking at the mean value of the estimated efficiency scores in the M1 (0.755) and M2 (0,481)as well as the individual scores, apart from AZ (Azerbaijan), we notice that all the observed railway companies are oriented on passenger transport operations rather than freight operations **(**$\boldsymbol{H_2}$ **confirmed).**

Table 3. DEA results

Country	Company	Model M1	Model M2	Model 3 M3			-
		PTE	PTE	TE	PTE	SE	RTS
Korea	KORAIL	1	0,43	1	1	1	--
Turkey	TCDD	0,28	0,264	0,315	0,315	0,999	-
Pakistan	PR	1	0,028	1	1	1	-
Malaysia	KTM	1	0,506	1	1	1	-
Gabon	SETRAG	1	1	1	1	1	-
Vietnam	VN-DSVN	0,437	0,242	0,488	0,504	0,968	drs
Iran	RAI	1	0,575	1	1	1	-
Algeria	SNTF	0,33	0,098	0,262	0,33	0,795	irs
Tunisia	SNCFT	1	0,233	0,897	1	0,879	irs
Morocco	ONCF	1	0,394	1	1	1	-
Romania	CFR	1	1	1	1	1	-
Lithuania	LG	1	1	1	1	1	-
Uzbekistan	UTI	1	1	1	1	1	-
Czech	CD	0,27	0,194	0,289	0,315	0,918	drs
Bosnia	ZFBH	1	0,331	0,188	1	0,188	irs
Belarus	BC	0,291	0,731	0,602	0,782	0,77	drs
Azerbaijan	AZ	0,139	0,205	0,198	0,206	0,96	irs
Bangladesh	BDR	0,686	0,056	0,682	0,686	0,994	drs
Georgia	GR	1	0,325	0,85	1	0,85	irs
Kazakhstan	KTZ	0,722	1	1	1	1	-
Mean	-	**0,755**	**0,481**	**0,738**	**0,807**	**0,916**	-
STD	-	0,321	0,342	0,317	0,288	0,182	-
Max	-	1	1	1	1	1	-
Min	-	0,139	0,028	0,188	0,206	0,188	-

PTE: Efficiency Score under Variable Return on Scale assumption VRS. **TE:** Efficiency score under Constant Return on Scale assumption CRS. **SE**: Scale efficiency. **RTS**: Return on Scale.
irs: increasing return on scale. **drs**: decreasing return on scale
Source: Authors' calculations using "deaR", a software package in R developed by (Vicente , Rafael , & Bolos, 2020)

From Table (3) it can be drawn out that only four companies [SETRAG (Gabon), CFR (Romania), LG (Lithuania) and UTI (Uzbekistan)] have an efficient index of 1 in both passenger and freight transportation services (Model M3) and most of the companies perform better in terms of passenger transportation compared to the freight transportation. Some companies although they represent a benchmark in the passenger model M1, they show a very poor efficiency in the freight service M3 [e.g. PR (Pakistan), SNCFT (Tunisia), ZFBH (Bosnia) and GR (Georgia)] (H_2 confirmed). This could be explained by the fact that freight transport operations are being heavily regulated and operate in competitive market alongside with the other modes of transport particularly in shorter distances. The exception is made by AZ (Azerbaijan), KTZ (Kazakhstan) and BC (Belarus), the latter has obtained a freight efficiency score (0.73) significantly higher that its passenger efficiency (0.29). The results suggest that only SETRAG (Gabon), UTI (Uzbekistan), FGC (Spain) and LG (Lithuania) represent the benchmark for other companies in both passenger and freight transportation services. The companies SNTF (Algeria), VN-DSVM (Vietnam), AZ (Azerbaijan) and TCDD (Turkey) represent the worst-practices within the sample, with an efficiency score below 30% in average for the two transportation services delivered.

The decomposition of the technical efficiency reveals interesting results about the contribution of the size in efficiency. The analysis enables us asking whether inefficiency is due to mistakes regarding size decisions – to make recommendations on whether the firms should increase/decrease their size, depending on whether they operate under increasing/ decreasing returns to scale (see Table 7 in Appendix).

When looking at the Multi-output DEA Model M3 results, we notice that Efficiency scores either increase slightly or drastically for some companies or decrease for others in contrast with the single-output models M1 and M2. These conflicting results is due to one of DEA drawbacks. In fact, the non-parametric method is highly sensitive to multi-dimensionality problems that occurs when thenumber of inputs-outputs is relatively high compared to the number of DMUs observed leading to some inconsistencies in the results. In effect, for most railway companies, the difference between the CRS and VRS technical efficiency is either inexistent for the aforementioned fully efficient firms or quite moderate for some firms [such as TCDD (Turkey), VN-DSVN (Vietnam) or BDR (Bangladesh)] whose the scale efficiency score is around 0.77-0.99. Accordingly, the chosen size for these firms does not imply a great loss of technical efficiency. For example, despite the low technical efficiency of 0.315scored by TCDD (Turkey), the firm gets a scale efficiency of 0.99 indicating that TCDD is operating at an optimal size of scale. In contrast with ZFBH (Bosnia) in which the lowest scale efficiency figure (0.188) is observed although being fully efficient in terms of pure efficiency which suggest that ZFBH (Bosnia) relies much more on the way to manage the internal organization rather than the choice of an optimal size to reach the best levels of its performance .

4.2 The Evolution of Technical Efficiency over Time

Table (4) displays the evolution of the technical efficiency levels from 2013 to 2018 based on the overall performance model M3 that handles both passenger and freight services.

Table 4. Yearly VRS-DEA results

Country	Railway Company	Eff 2013	Eff 2014	Eff 2015	Eff 2016	Eff 2017	Eff 2018	Mean	STD
Korea	KORAIL	0.98	1.00	1.00	1.00	0.96	1.00	**0.99**	0.02
Turkey	TCDD	0.28	0.34	0.33	0.31	0.31	0.31	**0.31**	0.02
Pakistan	PR	0.81	0.90	0.85	0.88	0.95	1.00	**0.89**	0.06
Malaysia	KTM	1.00	0.99	0.91	0.92	0.95	1.00	**0.96**	0.04
Gabon	SETRAG	0.88	0.94	1.00	1.00	1.00	0.99	**0.97**	0.05
Vietnam	VN-DSVN	0.45	0.45	0.45	0.36	0.40	0.44	**0.42**	0.04
Iran	RAI	1.00	0.98	0.93	0.87	0.89	1.00	**0.94**	0.05
Algeria	SNTF	0.26	0.26	0.28	0.36	0.40	0.41	**0.32**	0.07
Tunisia	SNCFT	0.81	0.81	0.80	0.81	0.79	0.81	**0.81**	0.01
Morocco	ONCF	0.97	0.98	0.99	0.92	0.87	0.75	**0.90**	0.09
Romania	CFR	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**	0.00
Lithuania	LG	0.86	0.91	1.00	0.97	1.00	1.00	**0.95**	0.05
Uzbekistan	UTI	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**	0.00
Czech	CD	0.27	0.27	0.29	0.30	0.33	0.35	**0.30**	0.03
Bosnia	ZFBH	0.57	0.57	0.57	0.33	0.31	0.32	**0.41**	0.12
Belarus	BC	0.52	0.51	0.47	0.49	0.54	0.58	**0.52**	0.04
Azerbaijan	AZ	0.19	0.18	0.15	0.28	0.25	0.26	**0.21**	0.05
Bangladesh	BDR	0.60	0.56	0.60	0.72	0.60	0.60	**0.61**	0.05
Georgia	GR	0.79	0.71	0.43	0.94	1.00	1.00	**0.74**	0.20
Kazakhstan	KTZ	1.00	0.95	0.84	0.86	0.95	1.00	**0.93**	0.06

Source: Authors' calculations using "deaR", a software package in R developed by (Vicente , Rafael , & Bolos, 2020)

The evolution of technical efficiency is different in each case (*Hypothesis H_3 confirmed)*. However, the variability of technical efficiency change is quite moderate for most of investigated railways across the period (the standard deviation for most companies varies between 0 % and 20 %) with the exception of three railway companies that deserve special attention. Indeed, a steady decreasing shift of technical efficiency is observed in ZFBH (Bosnia) from 0.57 in 2015 to 0.32 in 2018. Followed by ONCF (Morocco) from 0.99 in 2015 to 0.75 in 2018, and GR (Georgia) from 0.79 in 2013 to 0.43 in 2015, after that efficiency increases significantly to 0, 94 in 2016 and reach the efficient frontier for the rest of the period. (SNTF) Algeria has witnessed a significant performance progress through the years studied as its efficiency score almost doubled from 0.26 in 2013 to 0.41 in 2018.

Railway Companies like KORAIL (Korea), Malaysia (KTM), VN-DSVN (Vietnam), RAI (Iran), SNCFT (Tunisia), BDR (Bangladesh) and KTZ (Kazakhstan) show a technical efficiency of about the same values for all the years studied, with shifts representing occasional back and forth developments. Finally, we notice that only CFR (Romania), UTI (Uzbekistan) have maintained a fully technical efficient score during the whole period of analysis.

4.3 Peer-benchmark Results

From the peer-benchmark group (see Table 5) can be seen that KORAIL (Korea), SETRAG (Gabon) and (KTZ (Kazakhstan) are the most peer benchmark for the inefficient railways in the sample (five/four times). For instance, The projected point of SNTF (Algeria) lies on the line joining the points of SETRAG (Gabon), PR (Pakistan) and SNCFT (Tunisia) which define its efficient production by a linear combination of these efficient points where the weights in this linear combination is illustrated by the Lambda weight . In this regard, SNTF (Algeria) should consider SETRAG and SNCFT as the main peer benchmark to reach better levels of performances as they get the highest Lambda weight (0.535 and 0.385 respectively).

Table 5. Peer-benchmark Group

Countries	Eff-Vrs	Peer-benchmark Lambda weight	peer count
Korea	1	Korea 1.000	5
Turkey	0,315	Gabon Kazakhstan Pakistan Korea 0.833 0.029 0.003 0.135	0
Pakistan	1	Pakistan 1.000	2
Malaysia	1	Malaysia	2
Gabon	1	Gabon	5
Vietnam	0,504	Gabon Malaysia Korea 0.641 0.180 0.179	0
Iran	1	Iran 1.000	1
Algeria	0,33	Pakistan Gabon Tunisia Morocco 0.013 0.535 0.385 0.067	0
Tunisia	1	Tunisia 1.000	1
Morocco	1	Morocco 1.000	1
Romania	1	Romania 1.000	2
Lithuania	1	Lithuania 1.000	0
Uzbekistan	1	Uzbekistan 1.000	0
Czech	0,315	Kazakhstan Korea Iran Malaysia 0.021 0.070 0.184 0.724	0
Bosnia	1	Bosnia 1.000	0
Belarus	0,782	Gabon Kazakhstan Korea 0.579 0.172 0.249	0
Azerbaijan	0,206	Spain Gabon Kazakhstan 0.025 0.951 0.024	0
Bangladesh	0,686	Spain Korea 0.658 0.342	0
Georgia	1	Georgia 1.000	0
Kazakhstan	1	Kazakhstan 1.000	4

Source: Authors' calculations using "deaR", a software package in R developed by (Vicente , Rafael , & Bolos, 2020).

4.4 How can the Algerian SNTF railway efficiency be improved?

In this study, we apply the BCC-DEA model with an input orientation model under a variable return on scale assumption to assess the technical efficiency of the observed railways company. The Algerian company SNTF obtained a low efficiency score of 33 % (see table 3. M5) which means that SNTF could potentially reduce its inputs by 67 % for producing the same bundle of outputs compared to the best-practice railways companies within the same market and industry conditions. Table 6 displays in details a summary of input slacks.

We notice that SNTF existing inputs are very higher than the efficient objectives. It is suggested that if the company is focusing on a cutting-cost strategy, it should reduce its staff, number of locomotives, number of passenger cars by 66 % and number of freight wagons by 80%. The cutting-cost policies would allow SNTF not only reach a target output of 1186 freight ton kilometers achieved, but also gain substantially in the number of passenger-kilometers by 126% potential improvement. Railways companies of Gabon and Tunisia are likely the best peer-benchmark for SNTF.

Table 6. Target inputs and outputs of the Algerian railway company SNTF

	Input-output orientation. TE = 33%. SE = 79.5%			Output-input orientation TE = 26.8 %. SE = 97.9%		
Variable	**Original values**	**Target values**	**Potent Impro**	**Original values**	**Target values**	**Potent Impro**
Output (Passenger-kilometers achieved)	928	2099	126%	928	34567	273%
Output(Freight Tons-kilometers achieved)	1186	1186	-	1186	4418	273%
Input (number of employees)	12438	4103	-67%	12438	12438,6	-
Input (number Dies and Elec Locomotives)	275	90,7	-67%	275	211,3	-23%
Input(number of passenger cars)	424	139,8	-67%	424	425	-
Input(number of wagons)	11510	2294	-80%	11510	6042	-48%
Peer-benchmark Lambda weight	Gabon 0.535	Tunisia 0.385	Morocco 0.067	Morocco 0.585	Tunisia 0.312	Pakistan 0.09

Source: Authors' calculations using "deaR", a software package in R developed by (Vicente , Rafael , & Bolos, 2020)

It is well known that SNTF like any other public railways company would face big challenges if the managers opt for a drastic cutting-cost strategy, in general such changes are subject to many technical, social or even political constraints (ex : the public transport policy , Unions, topography,…etc.). Accordingly, we assume that SNTF should manage efficiently its actual inputs to deliver a maximum of passenger and freight services. Based on this assumption, we run a BCR-DEA model with an output orientation model and we obtain a low score efficiency of 26.8 %. The results suggest that SNTF is wasting about 73.2 % of potential outputs it could be earned when using the same bundle of inputs compared to the best practices under the same market and industry conditions. The summary of output slacks is presented in Table6. Such as shown, if SNTF uses the best transportation process, the potential gain in passenger and freight services are so considerable (+ 273%). Nevertheless, reaching these efficient objectives is no longer possible without a reduce in the number of locomotives and freight wagons (-23% and -48% respectively). When considering the output-input orientation model, railways companies of Morocco and Tunisia appear to be the best peer-benchmark for SNTF.

5.Conclusion:

This paper has employed a DEA analysis to estimate the technical efficiency of 20 railway companies from countries in development between 2013 and 2018. Our empirical findings reveals the existence of significant gaps across the observed railways and most of them are oriented to passenger transport services rather than freight transport services. Hence it is recommended that some railways should be specialized in either passenger or freight operations. Otherwise, some worst performers would lose their ability to manage efficiently their operations without support packages from governments and international organizations (Hilmola, 2008, p. 273).

In general, the reasons that stand behind the existence of efficiency gaps between the railway companies depend on many factors (Arne , Heiner , & Martin , 2013, p. 5) : regulations and infrastructures constraints that affect the freight and passenger train length. Indeed, government and regulatory institutions can significantly affect the efficiency of railway companies by opening the rail market to competition and providing a consistent and reliable funding for rail infrastructures and operations that improve the quality of public mobility. Similarly, Technology plays a crucial role to enhance railway efficiency through the use of effective maintenance of assets, automation of process, state-of-art technologies of communication..,etc. For better understanding of how county or region-specific factors impact the performances of railways , we suggest conduct a two-stage DEA analysis to empirically identify the determinants of railway efficiency of developing economies in future research.

*The key limitation of our analysis is probably the lack of studies that tackle the efficiency of railways in the context of developing countries, yet, we cannot check the consistency of our research outcomes with other studies. In this regard, we think that further evidence would greatly benefit our understating in this topic from the perspective of economies in development. We suggest expand the DEA based analysis to the boo*tstrap approach or apply another frontier technique such as Stochastic Frontier Analysis.

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7. Appendices

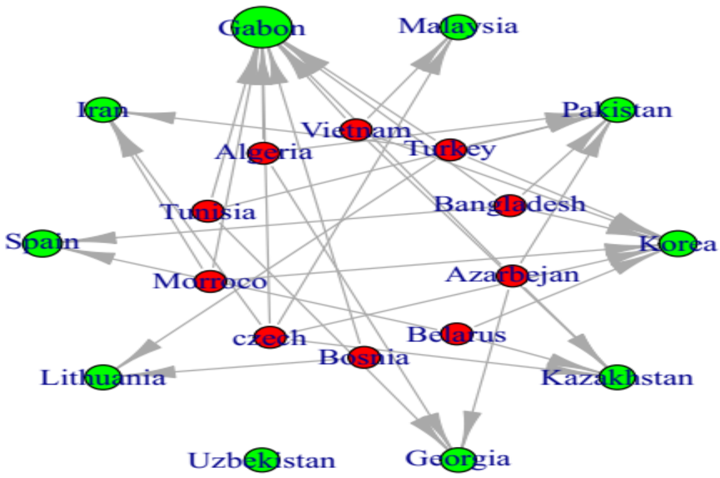
Table7. Return On scale (Model M3)

DMU	eff (2013) rts	eff (2014) rts	Eff (2015) rts	Eff (2016) rts	Eff (2017) rts	eff(2018) rts
Korea	0.98 Drs	1.00 Cst	0.99 Drs	1.00 Cst	0.96 Drs	1.00 Cst
Turkey	0.28 Drs	0.34 Irs	0.33 Irs	0.31 Irs	0.31 Irs	0.31 Irs
Pakistan	0.81 Irs	0.89 Drs	0.85 Irs	0.88 Irs	0.94 Drs	1.00 Cst
Malaysia	1.00 Cst	0.98 Drs	0.91 Irs	0.91 Drs	0.94 Drs	1.00 Cst
Gabon	0.81 Irs	0.86 Irs	1.00 Cst	0.78 Irs	1.00 Cst	0.98 Irs
Vietnam	0.45 Drs	0.44 Drs	0.45 Drs	0.36 Irs	0.39 Drs	0.42 Drs
Iran	1.00 Cst	0.98 Drs	0.93 Irs	0.86 Drs	0.89 Drs	1.00 Cst
Alegria	0.23 Irs	0.23 Irs	0.25 Irs	0.32 Irs	0.36 Irs	0.37 Irs
Tunisia	0.72 Irs	0.72 Irs	0.69 Irs	0.70 Irs	0.68 Irs	0.69 Irs
Morocco	0.97 Irs	0.98 Irs	0.98 Irs	0.91 Irs	0.85 Irs	0.73 Irs
Romania	0.85 Irs	0.87 Irs	0.91 Irs	0.93 Irs	0.98 Irs	1.00 Cst
Lithuania	0.73 Irs	0.83 Irs	0.92 Irs	0.87 Irs	1.00 Cst	1.00 Cst
Uzbekistan	1.00 Cst	1.00 Cst	1.00 Cst	1.00 Cst	1.00 Cst	1.00 Cst
Czech	0.26 Drs	0.26 Drs	0.28 Drs	0.29 Drs	0.31 Drs	0.35 Drs
Bosnia	0.14 Irs	0.15 Irs	0.14 Irs	0.08 Irs	0.06 Irs	0.07 Irs
Belarus	0.51 Drs	0.49 Drs	0.46 Drs	0.47 Drs	0.53 Drs	0.57 Drs
Azarbaijan	0.19 Irs	0.18 Irs	0.15 Irs	0.28 Irs	0.25 Irs	0.25 Irs
Bangladesh	0.59 Irs	0.53 Irs	0.58 Irs	0.70 Irs	0.58 Irs	0.58 Irs
Georgia	0.78 Irs	0.69 Irs	0.42 Irs	0.94 Drs	1.00 Cst	1.00 Cst
Kazakhstan	1.00 Cst	0.93 Drs	0.84 Drs	0.86 Irs	0.95 Drs	1.00 Cst

Irs : increasing return on scale - Drs: decreasing return on scale- Cst : constant return on scale
Note: Irs: for increasing ,Drs: for decreasing , Cst: for constant.

Source: Authors' calculations using "deaR", a software package in R developed by (Vicente , Rafael , & Bolos, 2020).

Fig.1. Network Graph of Railways' Technical Efficiency Scores'



Source: Authors' calculations using "deaR", a software package in R developed by (Vicente , Rafael , & Bolos, 2020)

Note: The green circles in Fig.1 represent the efficient DMUs and the red circles the inefficient ones. The size of the circle aims to convey the idea of how important is the efficient DMU for the set of inefficient DMUs. Lines of direction refer to the set of the peer benchmark group of each DMU.