Multiple Criteria and Multiple Periods Performance Analysis: A Comparison of North African Railways

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Multi-period differences of technical and financial performances are analyzed by comparing five North African railways over the period 1990–2004. A first approach is based on the Malmquist DEA TFP index for measuring the total factors productivity change, decomposed into technical efficiency change and technological changes. A multiple criteria analysis is also performed using the PROMETHEE II method and ARGOS software. These methods provide complementary detailed information, especially by discriminating the technological and management processes by Malmquist and the two dimensions of performance by Promethee, service to the community and enterprise performance, which are often in conflict.

Keywords: case study, multiple criteria decision aid, Promethee, Malmquist dea tfp index, North African Railways, multiple periods performance analysis

INTRODUCTION

Conceived as a vector for strategic economic development, the African railway companies have become a source of exasperation in the economic and financial crises that shake some African States. The analysis of the terrestrial transport policy in most African countries emphasizes an absence of planning such that the configuration of transport infrastructure in Africa produces serious problems for economic and social development coordination and in means of transport as well. Thus, the evaluation and measurement of public utilities presented by Estache and Kouassi, especially in developing countries, became a crucial point in the open and liberal economies. Yet, there is a surprising lack of literature that measures the efficiency of operators in a way that would allow economic regulators to introduce explicit performance incentives in the regulation of operators in African countries.

The total productivity of factors is well known in the economic literature and was the subject of several empirical evaluations, particularly on public services in networks (Coelli and Perelman) (Plane). The analysis of productivity contributes a sound base of information and thinking on the way in which

organizations are managed. From this point of view, this paper aims to measure the performance of North African railways. Within the framework of liberalization and privatization, this measurement can help the regulator understand what is needed in order to improve at the level of network performance (Estache et al.).

The first approach compares network productivity based on the Malmquist index (Estache et al.). Next, we use multiple criteria analysis in order to compare the quoted railway networks according to two general dimensions of performance (technical and economic), aggregating several families of criteria. In this respect, we will use the multiple criteria ranking provided by the method Promethee II (Brans et al.) and included in the ARGOS software (Colson).

BACKGROUND OF THE NORTH AFRICAN RAILWAYS

In Algeria

The Northern African Railways rail network is managed by the National Company of Railroad Transport (Société Nationale des Transports Ferroviaires: SNTF). It consists of 3,973 km of lines of which 2,888 km present a normal gauge (1435 mm) and 1,085 km a narrow spacing (1055 mm). This network is the third longest in Africa after the South African and Egyptian networks. However, it remains insufficient for Algeria's economic needs. Mainly inherited from colonial times, it comprises lines of both normal and narrow gauge. The mining line that connects the mines of Ouenza to the town of Annaba (300 km) is the only electrified line. The network comprises 400 km of double tracks mainly in the north of the country. The network structure follows the development and location of the population, industry, and mining sources. The crossing ways in the stations are short and do not allow long trains, and the signal and communication systems are decayed and do not allow modernization. Algeria intends to open access to the railroad transport system to the private sector under a mode of concession. It is envisaged to stop the monopoly of the SNTF on rail, which is the only transport sector still avoiding competition since road transport was opened to the private sector in 1988 and maritime and air transport in 1998. The general trend of privatization in North Africa provides an opportunity to delegate the exploitation of the national rail network to one or more companies under the concession mode. The opening of railroad transport to competition is justified by the fact that the monopoly of the State involved a constant reduction in the performance of this means of transport and systematic recourse to the Treasury for its financing. The private sector should carry the load of rehabilitation and development of the rail network.

In Libya

The railway mode is not yet existent in Libya because road transport ensures the totality of the carriage of goods and passengers. Two national companies operate in the sector: one for long-distance transport and the other committed to inter-city connections. Transport by taxi is also used for short and average distances.

In Morocco

Railroads in Morocco are managed by the National Office of the Railroads (Office National des Chemins de Fer ONCF), a publicly owned establishment with financial autonomy. ONCF exploits 1,907 km of national network of which 1,003 km are electrified and 370 km have a double track. This network is composed of a principal line connecting Marrakech to the south to Oujda on the Morocco–Algeria border, with ramifications toward Tangier in the north, phosphate mining zones, and some large ports. Since the end of the 1980 s, the ONCF has undertaken a comprehensive program of modernization of the network related to the reorganization of some stations, the renewal of ways, and the installation of telecommunications and signals in order to offer a quality service to its customers.

In Mauritania

In order to transport iron from its place of extraction to its place of transformation and export, the Mauritanian State financed the construction of a 670 km railway line with a single track between the iron fields of Fderik and the port of Nouadhibou. Six convoys of 220 coaches (2000 tons per convoy) have

traversed this since its opening in 1963. It is the longest train in the world at more than 2 km in length. The train crosses an almost uninhabited zone and transports only ore. Maintenance services exist all along the railroad. The equipment is maintained perfectly as the iron trade is unacceptable to stop the trade of iron as it is the country's primary source of income. This network is owned and operated by the Mauritanian public Enterprise SNIM (Société Nationale Industrielle Minière). The train also accommodates several coaches intended for passenger transport.

Due to the lack of reliable available data, an analysis of the Mauritanian network is not included in this study.

In Tunisia

The overall length of the network is 2,196 km of which nearly 1,862 km are currently in use. The network presents a majority of metric gauge (1,687 km), except for the Tunis–Ghardimaou (trans-Maghreb) line at 471 km length whose branches (116 km) present normal gauge. Owing to the fact that the majority of the lines converge toward Tunis, this difference in gauge does not seem to constitute, for the moment, a major handicap. However, if the Maghrebian network were to develop (toward Libya), then the difference in gauge could constitute a serious problem. The structure of the network is conceived to ensure a good service road. In addition, the agricultural zones in the country's northeast and center, and all the frontier mining zones are connected to the large clusters of activity and ports located on the littoral zone.

The railway activity is managed by two public operators: The publicly owned National Company of the Tunisian Railroads (Société Nationale des Chemins de Fer Tunisiens: SNCFT) and the Company of the Leger Subway of Tunis (Société du Métro Léger de Tunis: SMLT), which operates the large urban subway system in Tunis. This 135 km of railway line presents double tracks and only 65 km are electrified.

In Egypt

The first railway built in Africa was in Egypt in 1853. The idea of building a railway dates back to 1833, when Mohamed Ali consulted his Scottish chief engineer, T. Gallway, about building a road between Suez and Ain Shames to become the link between Europe and India. Mohamed Ali initiated the project and bought the rails in order to start building the road and the stations. However, France was able to prevent this from happening because the French government wanted to substitute this project with building a canal between the Red and the Mediterranean Seas. Mohamed Ali found himself shattered between the two ideas, so he refused to carry out any of them. When Mohamed Ali died in 1849, England wrote to his successor, Abass Helmy I, asking him to build a railway in Egypt. He agreed and signed a contract with Robert Stephenson on the 12th of June 1851. The contract asserted that the work should start in September of the same year and that Stephenson should be responsible for all matters of the project. The first railway route in Egypt was built in 1854 between Alexandria and Kafer Eassa, and it reached Cairo in 1856. In 1858, the route between Cairo and Suez was built, but was removed in 1878 after digging the Suez Canal. A new route was built in 1867 to connect Cairo with southern Egypt and Imbaba Bridge was built in 1891 to enable the trains to pass over the Nile near Cairo. From this point on, the railway has become one of the most important means of transportation in Egypt. You can use the railway to go as far as Matrouh (Libya frontier) in the west and as far as Aswan in the north. Passengers can depend on the railway service to travel all over Egypt. The railway activity is operated by public enterprise Egyptian National Railways (ENR) with 4 974 mean line kilometers.

A COMPARISON OF PRODUCTIVITIES OF THE RAILWAYS' NETWORKS BASED ON THE MALMQUIST INDEX

Table 1 presents differences in the sizes of the railways as expressed in line kilometers. According to these figures, Egypt has the largest with 4,974 line km followed by Algeria (4,124), Tunisia (2,133), and Morocco (1,905). We can explain this difference by the area of each country and by the goals of colonization. We shall see that the ranking by productivity does not reflect the size ranking of networks.

TABLE 1
SIZE OF RAILWAYS EXPRESSED IN LINE KILOMETERS (*)

	ALGERIA SNTF	EGYPT ENR	MOROCCO ONCF	TUNISIA SNCFT
Mean Line Km	4124	4974	1905	2133
Ranks	2nd	1st	4th	3rd

* Source: UIC (Union internationale des chemins de fer)

Methodology of the Malmquist Index Analysis

We begin our analysis by having recourse to the Malmquist index (Färe et al.). One can read a description of this index in "A Primer on Efficiency Measurement for Utilities and Transport Regulators" (Coelli et al.):

> *"The Malmquist index of productivity measures the variation of productivity (TFP) between two observations, by calculating the ratio of the distances from each data (network) compared to a common technology (the efficient frontier of production). The Malmquist index of variation of TFP (directed in input) between period 0 (the basic period) and period 1 (by using the technology of period 1 as technology of reference) is defined by:*

$$TFP_1/TFP_0 = D_1 (Y_0, X_0) / D_1 (Y_1, X_1), \quad (1)$$

> *where the notation Dt (Xs, Ys) represents the distance between the observation of the period S and the technology of the period T, and XS and YS are, respectively, the input and the output in period S.*
>
> *A value of this ratio in (1) higher than 1 will mean an improvement of the TFP."*

Our study relies on the physical data of four North African railway networks (Algeria, Egypt, Morocco, and Tunisia) over a 15 year period (1990–2004). This method allows us to know the origins of the positive or negative evolutions of the total productivity of the operators differentiated into technological change and change of efficiency: the latter often reflects management improvements within each network while the former reflects innovation (e.g., new investments). In this same quoted reference and using Färe et al. [10]), we read that the Malmquist productivity index is defined as the geometric mean of two indices, namely, an index evaluated in connection with technology of period 1 and another in connection with the technology of period 0. We obtain then:

$$TFP_1/TFP_0 = [D_1 (Y_0, X_0)/D_1 (Y_1, X_1) * D_0 (Y_0, X_0)/D_0 (Y_1, X_1)]^{0.5} \quad (2)$$

We can also transform (2) in (3):

$$TFP_1/TFP_0 = D_0(Y_0,X_0)/ D_1(Y_1,X_1) [D_1 (Y_0,X_0)/D_0(Y_0,X_0) * D_1(Y_1,X_1) /D_0(Y_1,X_1)]^{0.5} \quad (3)$$

The ratio outside the brackets of (3) measures the change in the input-oriented measure of technical efficiency between periods 0 and 1. The remaining part of the index in the equation is a measure of technical change, i.e., the geometric mean of the technical change between the two periods, evaluated with the observations of periods 0 and 1.

Presentation of Data and Choice of Variables

Table 2 gathers all the data available for the analysis concerning the railways operators in the four North African countries during 1990–2004.

As output, we chose "passenger-kilometers" (P-km) and «ton-kilometers» (T-km) (A. M. Mbangala). We could have chosen, for example, the sales turnover that reflects the sold production of the operators. However, several problems remain regarding the availability of reliable data and the diversity of the countable standards in each country encouraged us to avoid this kind of output.

Equipment (total number of coaches and wagons) and railway employees are the input variables. We notice the absence of Sudan and Mauritania in this presentation due to a lack of data reliability.

TABLE 2
INPUTS AND OUTPUTS (*) OF THE MALMQUIST DEA TFP INDEX ANALYSIS

		Outputs	***Inputs***		
Railways	**Year**	**T-km**	**P-km**	**Equipment**	**Manpower**
Algeria	1990	2178000	2990851	10650	18200
	1991	2716736	3192091	10930	18104
	1992	2529701	2903505	6893	18187
	1993	2304584	3009728	10653	17497
	1994	2278800	2234011	10894	16780
	1995	2121000	1797000	10950	16600
	1996	2301430	1826113	10911	16269
	1997	2301430	1826113	10845	16269
	1998	2174000	1163000	10806	14400
	1999	2033000	1163251	10796	14385
	2000	1979714	1141646	10573	12510
	2001	1990000	981000	10558	12300
	2002	2247000	955000	10488	11400
	2003	2040892	963517	10483	11420
	2004	1947135	949872	10466	11139
Morocco	1990	5107346	2237276	10477	13716
	1991	4526170	2345462	9022	14002
	1992	5001100	2232718	9079	14157
	1993	4419089	1903566	8897	14349
	1994	4679216	1881191	8623	14385
	1995	4621201	1530892	8443	13782
	1996	4757208	1686398	7561	12639
	1997	4834688	1855934	7265	12016
	1998	4757000	1875000	7121	11600
	1999	4794499	1880000	7016	10905
	2000	4576000	1956000	6700	10308
	2001	4622000	2019000	6417	10200
	2002	4974000	2145000	6421	9800
	2003	5146525	2374169	6282	9487
	2004	5563323	2644583	6037	9207

Egypt	1990	3028979	38533000	17054	88000
	1991	3276000	41151000	16717	88000
	1992	3211511	42589000	15906	88000
	1993	3141129	46338000	14143	71653
	1994	3621000	44293000	14437	72890
	1995	4072577	48242000	14800	74123
	1996	4117000	50465000	14947	74015
	1997	3969000	52926000	16276	71684
	1998	4265000	55000000	16200	71062
	1999	3464000	59638000	16242	71000
	2000	4000000	63060000	16123	70900
	2001	4217000	66008000	15889	70750
	2002	4188000	39083000	14661	70500
	2003	4104000	46185000	15028	70200
	2004	4321000	52682000	15101	70000

* Sources: Algeria: Société Nationale des Transports Ferroviaires (SNTF); Morocco: Office National des Chemins de fer (ONCF); Egypt: Egyptian National Railways (ENR); Tunisia: Société Nationale des Chemins de Fer Tunisiens (SNCFT); UIC: l'Union internationale des chemins de fer

Presentation and Analysis of the Results

From Table 3, "MALMQUIST INDEX SUMMARY OF ANNUAL MEANS," we conclude that the total growth annual rate is 3.2% over the period 1990–2004. We have converted the indices to growth rates. The decomposition of this rate shows that this growth comes primarily from the column "technological progress," which reflects the development of the investment level in the railways sector. This change is mainly due to the investment in equipment. Technological progress takes part at a rate of 4.4% in the growth. The remaining effect is negative (1.2%) issued from the column "change of the technical efficiency" that assesses the evolution of the management in this sector. We can therefore conclude that North African railways are very inefficient much like a majority of state-owned enterprises (SOEs) in developing countries.

TABLE 3
MEAN PRODUCTIVITY CHANGES OF THE NORTH AFRICAN RAILWAYS 1990–2004

MALMQUIST INDEX SUMMARY OF ANNUAL MEANS (converted to growths rates)[1]

Year	Efficiency change	Technological change	Total factors productivity change
1991/1990	+3.3%	+1.1%	+4.4%
1992	+2.3%	+6.9%	+9.4%
1993	-2.6%	-1.2%	-3.7%
1994	-0.2%	+2.5%	+2.3%
1995	-2.9%	+2.5%	-0.4%
1996	-3.4%	+10.3%	+6.6%
1997	-2.8%	+6%	+3.1%
1998	-2.3%	+2.9%	+0.6%
1999	-5.9%	+5.5%	-0.8%
2000	+5.8%	+3.7%	+9.7%
2001	+3.2%	+3.7%	+7.0%
2002	+1.5%	-3.0%	-1.5%
2003	-6.3%	+9.9%	+3.0%
2004/2003	-6.0%	+12.5%	+5.7%
Mean	**-1.2%**	**+4.4%**	**+3.2%**

TABLE 4
PRODUCTIVITY CHANGES OF THE NORTH AFRICA RAILWAYS 1990–2004 BY COUNTRY

MALMQUIST INDEX SUMMARY OF NETWORKS MEANS (converted in growths rates)

Sector	Efficiency change	Technological change	Total factors productivity change
Algeria	-4.6%	+4.9%	+0.1%
Egypt	0.0%	+3.8%	+3.8%
Morocco	0.0%	+4.1%	+4.1%
Tunisia	-0.3%	+5.0%	+4.7%
Mean	**-1.2%**	**+4.4%**	**+3.2%**

* Note that all Malmquist index averages are geometric means

The second table, "MALMQUIST INDEX SUMMARY OF NETWORK MEANS," indicates for each year the networks that contributed more (or less) than others to the improvement of productivity. We can confirm that Tunisia comes at the head of the ranking with a rate of 4.7% to the total growth rate followed by Morocco (4.1%), Egypt (3.8%), and Algeria (0.1%). We can notice for all operators that the rates of the technological column are higher than those of the effectiveness column, confirming that the annual total growth rate results mainly from the technical progress and reflecting investment in the railway sector. The average efficiency change is negative due probably to weakness in management.

According to the average growth in productivity (Table 4), we can rank the countries' railway performance as follows:

Tunisia: 1st (+4.7%); Morocco: 2nd (+4.1%); Egypt: 3rd (+3.8%); Algeria: 4th (0.1%)

We can also compare this ranking to the first ranking made by size (Table 1). Network size cannot give a good evaluation of companies' productivity (Table 5).

TABLE 5
COMPARED RANKINGS OF THE NORTH AFRICA RAILWAYS FROM 1990 TO 2004 BY SIZE AND PRODUCTIVITY (MALMQUIST INDEX)

Ranks	1st	2nd	3rd	4th
Size ranking	Egypt	Algeria	Tunisia	Morocco
Malmquist index ranking	Tunisia	Morocco	Egypt	Algeria

A COMPARISON OF PERFORMANCES OF THE RAILWAYS NETWORKS WITH PROMETHEE II

Data and Ratios Presentation

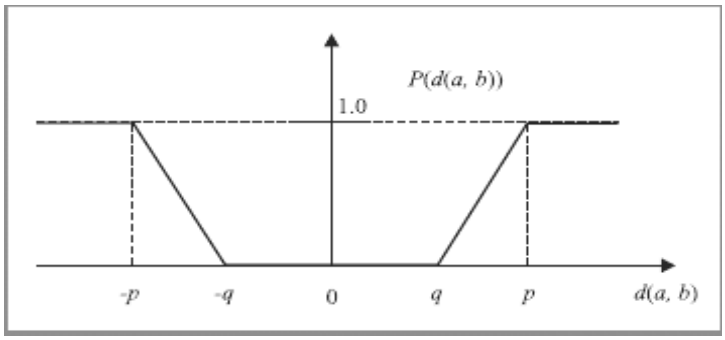
Data concerning the railway operators in the four North African countries during the period 1990–2004 are gathered in Table 6 hereafter while in Table 7 we compute ratios free of the rates of money changes and inflation.

Recalling the Promethee II Method[2]

Multiple criteria methods are well known in the literature. One of the best-known methods is the second release of Promethee by Brans et al. The Promethee II method is an outranking multiple criteria device that provides a preorder of items by making pair wise comparisons of these items (railway sectors = networks, in our case) first for each criterion and then for all criteria. The final ranking is obtained according to the decreasing order of the preference flows of the items. Among the six kinds proposed by the method, we used only one kind of criterion: the pseudo-criterion with a linear preference between the two thresholds (Fig. 1).

The linear pseudo-criterion used in Promethee is as follows:

FIGURE 1
PSEUDO-CRITERION WITH A LINEAR PREFERENCE BETWEEN THE TWO THRESHOLDS



P(d) = 0 if |d| ≤ q, there is indifference;
$P(d) = 1$ if $|d| > p$, there is a strong preference;
$P(d)=(|d|-q)/(p-q)$ else, there is a weak preference.

Let a and b stand for two items and let *d(a,b)* be the difference of their evaluations on a criterion *c*. We assume that a positive *d(a,b)* corresponds to a preference for *a* over *b*. The preference function *P(d(a,b))* is assumed to take the value 1 as soon as the preference is strong (= clearly stated), i.e., when $|d| > p$, the preference threshold, and is assumed to take the value 0 when an indifference between *a* and *b* is decided because their evaluation difference does not reach the threshold q. Between these two decisions, a weak preference is expressed and *P* linearly increases with *d*. Thus, this criterion states that *a* is surely preferred to *b* when *P(d(a,b))* = 1. For the sake of simplicity, let us write $Pc(a,b) \equiv Pc(d(a,b))$: the preference function for the criterion c.

The method defines then a multi-criteria preference index as the weighted average of the preference functions Pc for all criteria. In our application, we considered that the three criteria of each point of view had the same weights. The index Phi(a,b) is computed by the next equation:

$$Phi(a,b) = [P1(a,b)+P2(a,b)+P3(a,b)]\ /3. \quad (4)$$

This index is called the (multi-criteria) preference flow of a over b. We are more confident that a is preferred to b according to all criteria of the considered family when the flow value is closer to 1. Of course, a is surely preferred to b when the unanimity of criteria is in favor of a and then Phi(a,b) = 1. At this stage, Promethee proposes plotting a graph on the set K of considered items with its nodes being all of the compared items: a,b,c, . . . of K. The arcs joining two items are valued by Phi(a,b) and Phi(b,a) for a pair (a,b). Then, the method computes two flows for an item a:

$$Phi^{+}(a) = \sum_{b \in K} Phi(a,b)\text{: the leaving flow } Phi^{-}(a) = \sum_{b \in K} Phi(b,a)\text{: the entering flow.} \quad (5)$$

One interprets the leaving flow as a multi-criteria force of preference of a on the other items in K, and the entering flow as a multi-criteria preference weakness of a.

In Promethee II, a balance of flows is completed, delivering a net preference flow for each item a on all the other items and for all criteria of the family:

$$Phi(a) = [Phi+(a)] - [Phi-(a)]\text{: the net flow in favor of } a. \quad (6)$$

Usually, by ranking the net flows in decreasing order, we obtain the preference ranking of the items: positive flows associated with the dominating items and negative ones associated with dominated ones. Note that unlike the classical method Promethee, we did not divide the flows by (n−1) with n being the number of

items in Eq. (5); our simplification was done in order to point out the maximum number of possible dominances.

Methodology of the Multi-Criteria Analysis at Three Levels

To analyze the performance of the railways sector (networks) in the four North African countries by a multi-criteria method, we based our analysis on two dimensions of performance of public companies: effectiveness of public service and efficiency of those in terms of using resources. We borrow this methodology from Colson and Mbangala.

These authors constituted a hierarchy at three levels of selected criteria. Here, we have initially incorporated three or four basic criteria to constitute a coherent family. The four families are then gathered into two dimensions of analysis (also called "assessment functions"). Table 6 presents this hierarchy and the preference, and the indifference thresholds of the adopted 14 pseudo-criteria. According to the first dimension, described as technical, we aim to collect performance data of the sector from the users' point of view. This first dimension is a general performance function that measures the importance of (public) service to the user and to the country by the railway sector (four criteria per family). The second dimension evaluates the economic health of the sector (three criteria per family) by means of two families: railways economic performance and the firm's global performance.

We adopted only one type of criterion: the linear pseudo-criterion (with two thresholds of decision) because this type fits well with less reliable data than usual and avoids a strong preference for a small variance. The first threshold (q) is the limit between a decision of indifference between two actions (networks) and a decision of weak preference.

For the calculation of multi-criterion preference flows of all sectors, we used ARGOS software (Colson), which has the advantage of being able to treat directly two levels of hierarchy of criteria. Recall, however, that the multi-criteria flows are not reduced in an interval [0,1] in this software as it was in the original Promethee method. Table 6 synthesizes the criteria and the families with their thresholds. The second column indicates the thresholds q that mark the end of an indifference between two operators due to the weakness of the differences in evaluation between these two operators on a same criterion; a third column indicates the thresholds p and a last column shows the preferable direction (max or min) for each criterion.

TABLE 6
VENTILATION OF THE CRITERIA ACCORDING TO THE FAMILIES AND DIMENSIONS WITH THE THRESHOLDS AND THE CRITERION DIRECTION

FUNCTIONS, FAMILIES AND CRITERIA PER FAMILY	Threshold q	Threshold p	Criterion direction
1- Technical assessment function			
Freight traffic			
TKm/Traffic Units: Freight traffic part in TU	1.5	4	Max
TKm/cars: Freight cars employment	20	50	Max
TKm/Total Freight: Mean haulage length	1.5	4	Max
TKm/Lines Km: Freight traffic density	15	35	Max
Passenger traffic			
PKm/Traffic Units: Passenger traffic part in TU	1.5	4	Max
PKm/Cars: Passenger Cars employment	100	250	Max
PKm/Passengers: Mean journey length	0.5	1.5	Max
PKm/Lines Km: Passenger traffic density	50	150	Max

2- Economics assessment function			
Railways Economics performance			
Traffic Units/GDP: Rail economic intensity	50	150	Max
PKm/Inhabitants: population-oriented service	50	150	Max
Lines Km/Area: Network geographical density	0.1	0.3	Max
Firm's Global performance			
Traffic Units/locos: Locos employment	20	50	Max
Traffic Units/Manpower: Manpower productivity	10	25	Max
Traffic Units/Lines: Network Density	70	170	Max

TABLE 7
MULTI-CRITERIA DATA REPRESENTING THE RAILWAY NETWORKS OF FOUR COUNTRIES OF NORTH AFRICA (*)

Railway	Years	Traffic Units	T-km				Cars	Total freight			Lines Km	Passengers	P-km	Cars
Algeri	1990	5168851	217800	9985	12372965	5131	53664000	2990851	665	45,1	25,3	238174	241	18200
	1991	5908827	271673	1029	11958107	4047	57841000	3192091	637	44,6	25,9	238174	238	18104
	1992	5433206	252970	6259	11132763	4047	58422000	2903505	634	45,4	26,5	238174	231	18187
	1993	5314312	230458	1002	9700000	3945	59590440	3009728	632	44,5	27,2	238174	227	17497
	1994	4512811	227880	1032	9488542	3945	50241000	2234011	572	44,1	27,7	238174	216	16780
	1995	3918000	212100	1032	8600000	4246	44200000	1797000	628	45,7	28,3	238174	221	16600
	1996	4127543	230143	1042	8870878	4532	44522424	1826113	487	47,6	28,8	238174	242	16269
	1997	4127543	230143	1036	7900000	5021	44522424	1826113	481	48,1	29,2	238174	275	16269
	1998	3337000	217400	1033	8300000	4573	34100000	1163000	470	50,6	29,6	238174	246	14400
	1999	3196251	203300	1033	7800000	4268	34181887	1163251	465	52,2	30	238174	246	14385
	2000	3121360	197971	1011	7793351	3973	28324204	1141646	455	53,5	30,5	238174	246	12510
	2001	2971000	199000	1010	7800000	3831	28800000	981000	451	54,8	30,9	238174	219	12300
	2002	3202000	224700	1004	9300000	3855	28900000	955000	441	57,1	31,4	238174	197	11400
	2003	3004409	204089	1004	8167765	2888	27528637	963517	436	61	31,9	238174	205	11420
	2004	2897007	194713	1002	8297367	3572	27258196	949872	440	64,1	32,4	238174	207	11139
Railway	**Years**	**Traffic Units**	**T-km**				**Cars**	**Total freight**			**Lines Km**	**Passengers**	**P-km**	**Cars**
Egypt	1990	4156197	302897	1350	10930000	4751	462931524	3853300	3554	65,7	55,7	100145	927	88000
	1991	4442700	327600	1324	10200000	4751	468157297	4115100	3477	66,4	56,8	100145	829	88000
	1992	4580051	321151	1300	10900000	4769	693000000	4258900	2906	69,4	57,9	100145	820	88000
	1993	4947912	314112	1114	10272000	4903	680800000	4633800	2996	71,4	59	100145	831	71653
	1994	4791400	362100	1146	11566000	4903	668201000	4429300	2969	74,2	60,1	100145	840	72890
	1995	5231457	407257	1167	12240000	4810	442000000	4824200	3129	77,7	61,2	100145	984	74123
	1996	5458200	411700	1167	12795000	4925	109000000	5046500	3274	81,6	62,4	100145	825	74015
	1997	5689500	396900	1262	12000000	4925	121600000	5292600	3656	86	63,6	100145	779	71684
	1998	5926500	426500	1272	12224000	5060	131400000	5500000	3476	91,4	64,8	100145	892	71062
	1999	6310200	346400	1276	10830000	5024	139790000	5963800	3476	97	66	100145	873	71000
	2000	6706000	400000	1295	12027000	5105	139790000	6306000	3165	102	67,3	100145	732	70900
	2001	7022500	421700	1272	12036000	5179	148350000	6600800	3165	106	68,6	100145	692	70750
	2002	4327100	418800	1159	11903000	5215	451000000	3908300	3069	109	69,9	100145	687	70500
	2003	5028900	410400	1195	11237000	5150	451000000	4618500	3069	113	71,3	100145	680	70200
	2004	5700300	432100	1203	11814000	5150	451049961	5268200	3069	117	72,6	100145	680	70000

Railway	Years	Traffic Units	Cars	Total	Lines	Passenger	P-km	Cars	GDP	Inhabitan	Area	Loco	Manpowe
Morocco	1990	7344622	9898	29048603	1893	11997328	223727	579	26,7	23,9	44655	248	13716
	1991	6871632	8404	25965663	1893	12042115	234546	618	28,6	24,4	44655	258	14002
	1992	7233818	8459	28360106	1907	11369047	223271	620	27,4	24,9	44655	257	14157
	1993	6322655	8355	25504000	1907	9525000	190356	542	27,1	25,5	44655	248	14349
	1994	6560407	8061	27303995	1907	9881017	188119	562	29,9	26	44655	237	14385
	1995	6152093	7863	26911000	1907	8393253	153089	580	28	26,3	44655	244	13782
	1996	6443606	7129	27329000	1907	9364694	168639	432	31,4	26,6	44655	130	12639
	1997	6690622	6893	28818000	1907	11518884	185593	372	30,7	26,9	44655	227	12016
	1998	6632000	6749	27076088	1907	11890000	187500	372	33	27,2	44655	226	11600
	1999	6674499	6644	27948000	1907	12165000	188000	372	33	27,5	44655	226	10905
	2000	6532000	6406	27129000	1907	13086000	195600	294	33,3	27,8	44655	225	10308
	2001	6641000	6123	27493000	1907	13570000	201900	294	35,4	28,2	44655	206	10200
	2002	7119000	6133	29945000	1907	14685000	214500	288	36,6	28,5	44655	205	9800
	2003	7520694	5994	30402000	1907	16515724	237416	288	38,6	28,8	44655	202	9487
	2004	8207906	5707	32715000	1907	18543000	264458	330	40,2	29,8	44655	202	9207
Railway	**Years**	**Traffic Units**	**Cars**	**Total**	**Lines**	**Passenger**	**P-km**	**Cars**	**GDP**	**Inhabitan**	**Area**	**Loco**	**Manpowe**
Tunisia	1990	2877880	5007	9865000	1961	28594000	101900	336	12,3	8,15	16361	189	9636
	1991	2839000	5007	9800000	1961	28600000	101900	182	12,7	8,32	16361	199	9600
	1992	3093000	5109	10709000	2162	30654000	107800	207	13,7	8,48	16361	195	9061
	1993	3069000	5244	10600000	2162	28200000	105700	206	14	8,65	16361	189	8687
	1994	3263000	5220	11630000	2162	28268000	103800	206	14,5	8,81	16361	189	8252
	1995	3313000	5097	12159000	2162	27660000	996000	203	14,8	8,95	16361	211	8364
	1996	3317000	4989	12262000	2168	28841000	988000	206	15,9	9,09	16361	211	8299
	1997	3434000	4879	12311000	2168	31447000	109600	209	16,7	9,21	16361	378	8124
	1998	3494000	5121	12300000	1820	31500000	113600	221	17,5	9,33	16361	189	8200
	1999	2829435	4642	12219976	2142	32200000	119245	261	18,6	9,45	16361	189	6719
	2000	3221500	4011	12200000	2152	32200000	119250	261	19,5	9,56	16361	189	6634
	2001	3539000	4642	12200000	2207	32200000	125700	261	20,4	9,67	16361	61	6075
	2002	3554000	4447	12200000	2325	36900000	128100	261	20,8	9,78	16361	68	5737
	2003	3417000	4447	11500000	2162	35700000	124300	261	21,9	9,83	16361	194	5554
	2004	3376193	3903	10891928	2281	35700000	129400	261	23,2	9,93	16361	184	5507

* Source: Algeria: Société Nationale des Transports Ferroviaires (SNTF); Morocco: Office National des Chemins de fer (ONCF); Egypt: Egyptian National Railways (ENR); Tunisia: Société Nationale des Chemins de Fer Tunisiens (SNCFT); UIC: l'Union internationale des chemins de fer.

TABLE 8A
PROMETHEE II PREFERENCE FLOWS OF GENERAL PERFORMANCE FUNCTIONS FOR RAILWAYS IN FOUR NORTH AFRICAN COUNTRIES (*)

	Algeria		Egypt		Morocco		Tunisia		
	Technical Performances	Economic Performances	Technical Performances	Economic Performances	Technical Performances	Economic Performances	Technical Performances	Economic Performances	Balances
1990	-19.7	-31	17.5	35	17.5	5	-15.3	-9	0
1991	-15.4	-22.5	15.4	38	12	-0.5	-12	-15	0
1992	-11.6	-30.5	14	37.5	12.4	0	-14.8	-7	0
1993	-20.5	-29.2	20	40	12	-2.7	-11.5	-8.1	0
1994	-23.4	-38.8	20	40	11.9	-1	-8.5	-0.2	0
1995	-25.6	-40	16.8	40	15.8	0	-7	0	0
1996	-25.6	-40	16.8	40	15.8	0	-7	0	0
1997	-29.5	-37.5	16	40	17	2.2	-3.5	-4.7	0
1998	-30.4	-44.9	16	40	19.5	2.5	-5.1	2.4	0
1999	-31	-42.5	16	40	25	5	-10	-2.5	0
2000	-30	-43	16	40	22.5	4.5	-8.5	-1.5	0
2001	-31	-45	16.5	40	22.4	-0.2	-7.9	5.2	0
2002	-32.5	-45	20	32.5	22	5	-9.5	7.5	0
2003	-32.5	-38.5	20	35	22	0	-9.5	3.5	0
2004	-32.5	-44.5	20	35	21.5	10	-9	-0.5	0
Total	**-391.2**	**-572.9**	**261**	**573**	**269.3**	**29.8**	**-139.1**	**-29.9**	**0**

* Source: Calculation by Karim SABRI from ARGOS software results.

TABLE 8B
PROMETHEE II PREFERENCE FLOWS OF PERFORMANCE BY FAMILIES OF CRITERIA FOR RAILWAYS IN FOUR NORTH AFRICAN COUNTRIES (*)

	Algeria					**Egypt**									**Tunisia**					
	Freight	**Passengers**	**Economic**	**Performance**	**TOTAL**	**Freight**	**Passengers**	**Economic**	**Performance**	**TOTAL**	**Freight**	**Passengers**	**Economic**	**Performance**	**TOTAL**	**Freight**	**Passengers**	**Economic**	**Performance**	**TOTAL**	**Balances**
90	-17.5	-2.2	-15	-16	**-50.7**	-7.5	25	17.5	17.5	**52.5**	17.5	0	-7.5	12.5	**22.5**	7.5	-22.8	5	-14	**-24.3**	0
91	-10.4	-5	-15	-7.5	**-37.9**	-9.6	25	17.5	20.5	**53.4**	15	-3	-7.5	7	**11.5**	5	-17	5	-20	**-27**	0
92	-7.6	-4	-17.5	-13	**-42.1**	-10	24	17.5	20	**51.5**	17.4	-5	-7.5	7.5	**12.4**	0.2	-15	7.5	-14.5	**-21.8**	0
93	-15	-5.5	-16.6	-12.6	**-49.7**	-5	25	17.5	22.5	**60**	17	-5	-7.7	5	**9.3**	3	-14.5	6.8	-14.9	**-19.6**	0
94	-15	-8.4	-20.2	-18.6	**-62.2**	-5	25	17.5	22.5	**60**	16	-4.1	-8.5	7.5	**10.9**	4	-12.5	11.2	-11.4	**-8.7**	0
95	-15	-10.6	-20	-20	**-65.6**	-5	21.8	17.5	22.5	**56.8**	17	-1.2	-7.5	7.5	**15.8**	3	-10	10	-10	**-7**	0
96	-15	-10.6	-20	-20	**-65.6**	-5	21.8	17.5	22.5	**56.8**	17	-1.2	-7.5	7.5	**15.8**	3	-10	10	-10	**-7**	0
97	-15	-14.5	-20	-17.5	**-67**	-5	21	17.5	22.5	**56**	17	0	-5.3	7.5	**19.2**	3	-6.5	7.8	-12.5	**-8.2**	0
98	-13	-17.4	-22.5	-22.4	**-75.3**	-5	21	17.5	22.5	**56**	17	2.5	-5	7.5	**22**	1	-6.1	10	-7.6	**-2.7**	0
99	-10	-21	-22.5	-20	**-73.5**	-5	21	17.5	22.5	**56**	20	5	-2.5	7.5	**30**	-5	-5	7.5	-10	**-12.5**	0
00	-12.5	-17.5	-22.5	-20.5	**-73**	-5	21	17.5	22.5	**56**	17.5	5	-2.5	7	**27**	0	-8.5	7.5	-9	**-10**	0
01	-10	-21	-22.5	-22.5	**-76**	-5	21.5	17.5	22.5	**56.5**	16	6.4	-2.7	2.5	**22.2**	-1	-6.9	7.7	-2.5	**-2.7**	0
02	-7.5	-25	-22.5	-22.5	**-77.5**	-5	25	17.5	15	**52.5**	14.5	7.5	-2.5	7.5	**27**	-2	-7.5	7.5	0	**-2**	0
03	-7.5	-25	-22.5	-16	**-71**	-5	25	17.5	17.5	**55**	14.5	7.5	-2.5	2.5	**22**	-2	-7.5	7.5	-4	**-6**	0
04	-7.5	-25	-22.5	-22	**-77**	-5	25	17.5	17.5	**55**	14	7.5	-2.5	12.5	**31.5**	-1.5	-7.5	7.5	-8	**-9.5**	0
T	**-178.5**	**-212.7**	**-301.8**	**-271.1**	***-964.1***	**-87.1**	**348.1**	**262.5**	**310.5**	***834***	**247.4**	**21.9**	**-79.2**	**109**	***299.1***	**18.2**	**-157.3**	**118.5**	**-148.4**	***-169***	0

* Source: Calculation by Karim SABRI from ARGOS software results.

Interpretation of the Results of the Multi-Period and Multi-Criteria Rankings

According to Table 6, we achieved three levels of analysis of the performances of railway sectors in North Africa for every year 1990–2004.

At the upper level, we obtained Table 8a, which is the aggregation of preference flows of Table 8b, i.e., the four applications of Promethee II, to the data of Table 7 for each family of criteria, taking into account the ventilation and the thresholds of Table 6.

Each cell of Table 8b contains a multi-criteria net preference flow indicating how much the corresponding country sector dominates the other ones in this family, if it is positive. A negative flow indicates how much the sector is dominated by the others in its family.

For instance, in 1990 and 2004, the Egyptian sector alone dominates the three other sectors on the criterion passengers; it also dominates them on the criterion performance and economic. But we notice that the Morocco sector dominates in freight for all years.

The horizontal total additions yield to zero because those of the dominated ones exactly compensate the flows of the dominating sectors.

The general rankings according to each of these two dimensions and together are, therefore:

Technical performances (TP): Morocco 1st (269.3), Egypt 2nd (261), Tunisia 3rd (−139.1), Algeria 4th (−391.2).

Economic performances (EP): Egypt 1st (573), Morocco 2nd (29.8), Tunisia 3rd (−29.9), Algeria 4th (−572.9).

Together: Egypt 1st (834), Morocco 2nd (299.1), Tunisia 3rd (−169), Algeria 4th (−964.1)

Table 9 summarizes the networks' rankings according to the three considered dimensions.

TABLE 9
RANKINGS OF FOUR NETWORKS BY TECHNICAL (TP) AND ECONOMIC (EP) PERFORMANCES AND TOGETHER

	Algeria		**Egypt**		**Morocco**		**Tunisia**	
Function	TP	EP	TP	EP	TP	EP	TP	EP
Ranking	4th	4th	2nd	1st	1st	2nd	3rd	3rd
General Ranking	4th		1st		2nd		3rd	

TABLE 10
RANKINGS OF THE FOUR NETWORKS ACCORDING TO THE SIZE, THE MALMQUIST INDEX, AND TO THE PROMETHEE II METHOD

Ranks	1st	2nd	3rd	4th
Size ranking	Egypt	Algeria	Tunisia	Morocco
Malmquist index ranking	Tunisia	Morocco	Egypt	Algeria
Promethee II ranking	Egypt	Morocco	Tunisia	Algeria

Finally, we observe that the Egyptian railway sector is the sector having a positive preference flow for the two dimensions for all the period. We recall, however, and confirm that the size of the network cannot provide a good evaluation of the company's performance even if the Egyptian network remains at the first position according to Promethee ranking, but not for the productivity comparison.

CONCLUSION

We notice that the positions of Morocco (2nd) and Algeria (4th) are the same according to the two methods of multidimensional analysis, whereas Tunisia is at the top according to the Malmquist index and Egypt takes the head in Promethee II. Similar to another study made about telecom performances by Colson et al., we could conclude here using their own words:

"Anyway, the two methods of analysis are indeed different in scope and used data and they give complementary information. While the Malmquist index analysis can separate the effects of technological and management changes, the 3-levels multiple criteria method can score the preference flows via two levels of aggregation and highlights the two dimensions of service and enterprise performance, useful to fully evaluate a utility sector …."

In general, we can confirm that all the networks analyzed in this paper, much like with the majority of the public companies in the developing countries, need to apply much more effort in order to improve their performance, mainly in management. For J. Nellis, many African state-owned enterprises (SOEs), particularly those working in infrastructure, have a long history of poor performance. The reasons for the heavy African reliance on SOEs and their unsatisfactory performance are several. The failure of the African States in this respect has given rise to a reform approach that relies much more heavily on private sector participation and ownership (Nellis).

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ENDNOTES

1. Let us recall that indexes are f.i. for the last line 0.988 and 1.044, producing by multiplication: 1.032; thus, 3.2% of growth decomposed into −1.2% and 4.4%. The figures of the last column can be obtained sometimes by an addition as an approximation.
2. The Promethee method we use is a simplification of the general method exposed by Brans et al.

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