Measuring and improving public bus transport performance in largest Morocco's cities

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Abstract

The aim of this paper is twofold. Firstly, it measures the relative performance of six operators in the largest Morocco's cities for the year of 2013. Secondly, it identifies the potential performance improvements for the under-performing companies. To this end, Data Envelopment Analysis (DEA) methodology is applied for comparing operators according to three performance dimensions namely; Production efficiency, operational effectiveness and overall performance. The D.E.A results revealed that company operating in Casablanca city was the most efficient of the sample. In addition, the companies operating in Casablanca and Marrakech cities are classified, respectively, as the best performing of the sample in terms of operational effectiveness and overall performance. Also, based on the overall performance measure, the research outcomes identify the percentage that an underperforming operator needs to increase its outputs or reduce its inputs in order to achieve best performance.

Keywords

Production efficiency, Operational effectiveness, Overall performance, Data Envelopment Analysis, Public Bus transport.

Introduction

The performance measurement of public bus transport services is a crucial tool for transport operators. It generally allows them to verify whether the service is provided efficiently and effectively, to identify areas where performance improvement may be needed, to ensure that community and users are satisfied; and to support decision-making bodies, such as transport authorities and funding institutions (etc...), to make decision about where, when, and how service should be provided.

To gain significance, performance measures needs to be compared to something else in order to monitor progress and detect areas of performance improvements. Benchmarking is considered as the most effective technique to reach this aim by providing bus operator's with the opportunity to compare performance against other companies operating in different geographical contexts.

Among methods that have been widely used as a tool for analyzing and benchmarking performance in the public transport sector is Data Envelopment Analysis (D.E.A) method. This latter is a non-parametric technique whose purpose is to measure the relative efficiency of a set of organizational units transforming several inputs (resources) into several outputs (services). Application of DEA informs on the best performing units as well as on the improvement which is required by all the other entities in order to reach them (Georgios et al, 2014). This approach is widely applied because of some advantages namely it doesn't impose any particular functional form for the production frontier and it can handle multiple inputs and multiple outputs. DEA is suitable method for assessing comparative performance of decision-making units (DMUs).

In the Moroccan context, the studies measuring and benchmarking the performance of public bus transport services are very few. The few attempts are made, generally, by non-governmental organizations (e.g. CoMun, 2014, 2015) and international institutions (e.g. World Bank, 2015; Banque mondiale & CETE de Lyon, 2006). These reports used performance ratios approach which do not give a complete picture of performance and may vary in different senses. Moreover, these ratios are insufficient to qualify the relative performance of operators and identify the needed potentials improvements.

By using D.E.A approach, the objective of this paper is toweled; Firstly, it measures the relative performance of six operators in the largest Morocco's cities for the year of 2013. Secondly, it identifies potential performance improvements for each under-performing operator. The remainder of this paper is organized as follows. Firstly, the performance concepts and DEA applications are reviewed as well as the organization of public bus transport in Morocco is presented. Then, the methodological approach used is discussed. Next, data and DEA models specification are exposed. Finally, results are discussed and concluding remarks are outlined.

1. Background:

1.2 Performance concepts and DEA applications in public bus transport

The public transport literature generally distinguishes two dimensions of performance, namely efficiency and effectiveness (Wayne & Pamela, 1981). Efficiency is the relationship between the inputs (resources) and the outputs (production) of what is called "productive" or "technical" efficiency in the economic literature. On the other hand, effectiveness refers to the use of products to achieve goals or the consumption of services (Xuehao et al, 1992). Due to the non-storable characteristics of public transport services, these two measures should be considered separately in the evaluation of public transport systems (Xuehao et al, 1992; Hatry, 1980).

To accommodate non-storable characteristics, Fielding G.J et al. (1985(a)) has proposed three performance measures that reflect efficiency and effectiveness dimensions. The Cost-efficiency is defined as the ratio of service inputs (Labor, Capital, and Fuel) to service outputs (Bus-Hours, Bus-km, Seat-km). The Service-effectiveness is defined as the ratio of service consumption (passengers, passenger-km, operating revenue...) to service outputs. The cost-effectiveness is defined as the ratio of service consumption to service input. However, if input factor prices are not available, it would be more appropriate to use the terms of production efficiency, service effectiveness, and operational effectiveness instead of cost-efficiency, service effectiveness and cost-effectiveness respectively (Yu MM & Chen LH, 2016).

Several studies have used both efficiency and effectiveness measures to evaluate, through the DEA method, the performance of public transport. These studies used different DEA models with different input-output approaches. Some authors only measured efficiency and effectiveness through two separate DEA models (e.g., Xuehao et al, 1992; Yaser et al, 2012; Mulley & Patrick, 2013), others added a third DEA model measuring Overall performance as a combination of the two measures (e.g., Karlaftis, 2004; Tsamboulas, 2006; Georgios et al, 2014).

Two methods of using input-output variables were adopted in these studies; the first is to use separate sets of input and output variables (e.g. Xuehao et al, 1992; Lawrance & Erwin, 2003). The second is to use the same inputs but separate output variables (e.g., Karlaftis, 2004; Yaser et al, 2012; Tsamboulas, 2006; Mulley & Patrick, 2013; Georgios et al, 2014).

In addition, these studies focused on different geographical contexts. For instance, Xuehao et al. (1992), Karlaftis (2004) and Tsamboulas (2006) have analyzed the performance of public transport systems in the United States and Europe respectively. Mulley & Patrick (2013) and Lawrance & Erwin (2003) have carried out an international comparison of the railway systems performance while Yaser et al, (2012) and Georgios et al., (2014) have focused only on benchmarking the performance of bus routes in Thessaloniki, (Greece) and Al Ain (United Arab Emirates) respectively.

In the Moroccan context, no study, to our knowledge, has been performed to analysis the performance of public bus operators by applying the DEA method. Therefore, by applying Data Envelopment Analysis approach, the objective of this paper, as stated in introduction, is twofold. Firstly, evaluate and compare the production efficiency, operational effectiveness and overall performance of six operators of public bus transport in largest cities. Secondly, identify potential performance improvements for each under-performing operator.

1.2. The organization of public bus transport in Morocco and sample description

The municipalities (Cities), alone or in the framework of inter-municipal cooperation, are in charge of urban public transport, with the support and supervision of the central government. Indeed, the Organic Law N° 113-14 attributes to the municipality a general competence in the management and equipping of local public services, including urban public transport. In addition, the central government supports and supervises the municipalities through the Ministry of the Interior which is the Ministry responsible for the sector. It is responsible for the support and supervision of urban transport activities in urban areas, in addition to the design, implementation and monitoring of specific measures taken at the State level to promote the sector.

Since the 1980s, the authorities have called on the private sector to strengthen bus transport networks in some cities due to the inability of public operators (the autonomous municipal companies of transport) to meet the growing demand and due to their financial imbalance. This recourse was often done through the concession of lines to be served by different operators, which resulted in the presence of several operators in the same territory. However, since the promulgation of Law N° 54-05 on the delegated management of Public services in 2006, the contract is awarded to a single operator covering the territory of a municipality or even several municipalities.

At present, public bus services are provided exclusively by private operators, with the exception of Safi city which uses an autonomous municipal company of transport and the agglomerations of Rabat Salé-Témara and surrounding centers which have called upon a local public company to replace a failing private operator.

The number of delegated management contracts for public urban bus transport, in the course of execution, is 40; of which 17 have been concluded since 2006, covering 260 municipalities. The companies in charge of the sector achieved a turnover of 1 790 MAD (in Million Moroccan Dirham (MAD) and employed a workforce of 12 950 in 2013. They have committed to make investments of 5 680 MAD from the start of the delegated management contract until 2013 (Public finance court, 2014).

In this study, due to the unavailability of data for all city operators, we will focus only on operators in six major cities. The urban population of these cities represents nearly 50% of the total urban population in all

Moroccan cities in 2013. Table 1 provide some information's about the six cities and their operators.

Table1. Information's about the six cities and their operators in 2013.

Cities	Agadir	Casablanca	Fez	Marrakech	Rabat-Salé	Tangier
Population size	828 000	3 358 000	1 106 000	1 195 000	1 805 000	750 000
Urbanized area (km²)	138	195	78	100	100	77
Total length of urban network (km)	272	795	540	207	573	251
Urban lines	22	70	53	20	55	26
Delegating authority	Agadir City + (8 other municipalities)	Casablanca City + 10 other Municipalities	Fez City	Marrakech City	IMCE named "Al Assima"	Tangier City
Delegate company	Private operator				Public operator	Private operator
Monitoring body	MC+ PCS	Inoperative MC + PCS	PCS	MC+ PCS	Inoperative PCS	MC+ PCS
Contract regime	Delegated management			Concession agreement	Public management	Delegated management
Start	September, 2010	November, 2004	September, 2012	February, 1999	2012	June, 2014
Duration (years)	15	15	15	15+5	For a Transitory period	10
MC=Monitoring Committee; PCS = Permanent control service; IMCE = Inter-municipal cooperation entity Source : (CoMun, 2014, 2015)						

2. Data Enveloppement analysis (D.E.A) approach:

Based on the efficiency concept initiated by Farrell M.J (1957), Data Envelopment Analysis, developed by Charnes et al., (1978) and Banker et al., (1984), is used to evaluate the relative efficiency of organizational units that transform resources (inputs) into services (outputs). These units are called Decisions Making Unites (DMUs). The DEA technique involves the use of linear programming methods to construct a non-parametric piecewise surface (or frontier) over the data. The efficiency measures are then calculated relative to this surface (Coelli et al., 2005). DMUs located at the frontier have a score of 1 (or 100%) while those below the frontier score have less than 1 (or 100%) and therefore have a scope for improvement of their performance. Note that no DMU can be greater than the efficiency frontier because it is not possible to obtain a score greater than 1 (100%). DMUs at the frontier serve as peers (or benchmarks) for inefficient DMUs. These peers are associated with observable best practices. The DEA method is therefore a benchmarking technique.

The two basic models of the DEA method most used in the literature are CCR and BCC. The CCR model developed by Charnes et al., (1978) assumed constant returns to scale (a model also named Constant Returns to Scale-CRS-) whereas the BCC model, developed by Banker et al., (1984), assumed variables returns to scale (model also named variable returns to scale -VRS-)

In addition, a DEA model (CCR or BCC) can be oriented towards inputs or outputs. In an inputs-oriented approach, the DEA model minimizes inputs for a given level of outputs. In an outputs-oriented approach, the DEA model maximizes outputs for a given level of inputs.

On another note, the use of the VRS model can lead to biased performance estimates because this model tends to increase scores and is not robust and stable in the observation of outliers (Tsamboulas, 2006). Moreover, the CRS model proved to be more restrictive than the VRS model (Cooper et al., 2006). It is more appropriate for analyzing the performance of road networks (Fancello et al., 2014). As a result, the CRS model is adopted in this paper.

2.1. Mathematical formulas of CCR-DEA model

Considering a set of n DMUs, each DMU uses a number m of inputs and a number s of outputs, x_{io} is the amount of the input i used by the DMU o and y_{ro} is the amount of the output r produced by the DMU o. Following the CRS model with an output orientation, the relative efficiency score of the DMU o is obtained by solving the following linear programming model (according to the notation of (Zhu J, 2014)):

$$\text{Maximise } \emptyset_o + \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right)$$

Subject to:

$$\sum_{j=1}^{n} \lambda_j y_{rj} - s_r^+ = \emptyset y_{ro} \qquad i = 1,2, \dots m$$
$$\sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = x_{io} \qquad r = 1,2, \dots s$$
$$\lambda_j \geq 0 \qquad j = 1,2, \dots, n$$

Where:

- $1/\emptyset_o$ is the efficiency score of DMU o that using m inputs to produce s outputs
- s_r^+ Outputs slacks;
- s_i^- Inputs slacks;
- λ_j represents the weight associated with the outputs and inputs of the DMU o.
- ε is a non-Archimedean value

The interpretation of results of this model can be summarized as:

- DMU o is efficient if and if only $1/\emptyset_o = 1$ and $s_r^+, s_i^- = 0 \; \forall_j = 1, \dots, n; r = 1, \dots, s; i = 1, \dots, m$
- If $1/\emptyset_o = 1$, then the DMU under evaluation is a frontier point. i.e., there is no other DMUs that are operating more efficiently than this DMU. Otherwise, if ($\frac{1}{\emptyset} < 1$), then the DMU under evaluation is inefficient. i.e., this DMU can either increase its output levels or decrease its input levels.

- The left-hand-side of the envelopment models is usually called the "Reference Set", and the right-hand-side represents a specific DMU under evaluation. The non-zero optimal λ_j^* represents the benchmarks for a specific DMU under evaluation.
- The target levels for inputs and outputs could be obtained, respectively, as: $x_{i0}^* = x_{i0} - s_i^{-*}$ et $y_{rj}^* = \Phi^* y_{ro} + s_i^{+*}$

2.2 The potential performance improvements

Inefficient operators can improve their performance by adjusting the level of their outputs and inputs. One of the important results of the DEA technique is the proposition of these adjustments that operators should make if they want to be (100%) efficient (or efficiency score equal to 1).

In the CRS output-oriented Model, the outputs slacks indicate the need for further augmentations in corresponding outputs whereas inputs slacks signals any additional reductions of inputs which could be reduced by the efficient levels of outputs.

The DEA method defines not only the levels of input-output slacks but also the levels of input-output targets which are the projected values on the frontier. In a DEA model with output orientation, the levels of inputs-outputs targets are defined by the following formula:

$$y_{ro}^* = \Phi^* y_{ro} + s_i^{+*}; \; r = 1,2, \dots s.$$
$$x_{i0}^* = x_{i0} - s_i^{-*}; \; i = 1,2, \dots m.$$

Where,

x_{i0}^* is the input target i for the DMU o,

y^*_{ro} is the output target r for the DMU o;
x_{io} is the actual input i for the DMU o,
y_{ro} is the actual output r for the DMU o,
ϕ^* is the efficiency score for the DMU o;
s_i^{-*} is the optimal input slacks et s_i^{+*} is the optimal output slacks.

Potential improvements indicate the percentage that a DMU needs to increase its outputs or reduce its inputs to become 100% efficient (or to achieve an efficiency score of 1).
The percentage of output augmentation and input reduction for the i-th DMU is calculated as follow:

$$\text{\% of output augmentation : } = \left(\frac{y^*_{ro}-y_{ro}}{y_{ro}}\right) * 100$$

$$\text{\% of input reduction : } = \left(\frac{x^*_{io}-x_{io}}{x_{io}}\right) * 100$$

3. Data and DEA model specifications

3.1 Inputs/Outputs variables and DEA models specification

With respect to inputs variables, the most frequently used, in the bus transport literature, are those reflecting Capital, Labor and Energy. Capital is measured by the total number of Bus fleet. Labor is measured by the total number of employees and energy is measured by the total litters of consumed fuel. On the outputs side, vehicle kilometres or seat kilometres (representing production process), passenger kilometres or number of passengers (reflecting consumption process) are the most commonly-used outputs (Borger et al., 2002).

In this study, we selected these variables primarily based on their relevance in the literature and the availability of data. Due to the unavailability of energy and Labor data, we used only two variables reflecting the capital: the size of bus fleet (total number of buses) and the operating network (total length of urban bus network). These inputs are used for the three measures (production efficiency, operational effectiveness and global performance). As for outputs, the bus-km is used as output to measure the production efficiency in the DEA model 1, total passengers is used to measure the operational effectiveness in the DEA model 2.

As the DEA technique has the ability to process multiple inputs and outputs to generate a global measure for benchmarking. Global performance, which is a combination of production efficiency and operational effectiveness (Karlaftis, 2004; Tsamboulas, 2006; Georgios et al, 2014), could be measured using both Bus-km and total passengers as outputs and the total number of buses and the length of the bus network as the inputs in the DEA model 3.

The inputs selected in this study are predefined in the specifications and in the contracts established with the delegating authorities. Operator managers seek to maximize service delivery rather than minimizing the quantities of these inputs. Therefore, the output-oriented approach in the three DEA models is chosen.

Table 1 presents the three DEA models and their corresponding input-output variables. Table 2 provides a summary description of the data in 2013.

Table 2.D.E.A Models

Models	**DEA Model**	**Performance dimensions**	**Input variables**	**Output variables**
DEA Model 1		Production efficiency	-Total number of Bus fleet	Bus-km
DEA Model 2	CRS output-oriented Model	Operational effectiveness	-Total length of urban bus network (km)	Total passengers
DEA Model 3		Overall performance		Bus-km ; Total passengers

Table 3.Summary description of data in 2013

Variables	**Inputs**		**Outputs**	
	Total number of Bus fleet (Bus)	Total length of urban bus network (Km)	Bus–km (in millions Km)	Total passengers (in Millions of Persons)
Mean	313.5	439.67	16321.33	56537.50
SD	257.98	233.22	13678.81	44047.97
Min	77	207	4202	16165
Max	674	795	39915	142042

It is important to mention that the number of transported passengers in 2013 is only available for the operators of Rabat-salé and tangier cities. The other operators have data that vary between 2008 (Marrakech), 2010 (Fez, Casablanca) and 2012 (Agadir). For the purpose of comparison, we will consider all data for 2013.

4. Results and discussion

4.1 Analysis of three performance dimensions

Efficiency, effectiveness and overall performance scores are calculated using the DEAP software (developed by Coelli (1996). Table 4 illustrates the distribution of the scores assigned to the 3 DEA models (1, 2 and 3).

In terms of production efficiency, the analysis revealed that the operator serving bus transportation in Casablanca City is the most efficient of the sample, which means that this operator was able to achieve the highest level of kilometres travelled by Bus (Bus-km) given the resources at its disposal (the number of Buses and network length). This may be explained by the fact that this operator has mastered over time its production process (it has been operational since 2004). In contrast, the operator of Fez city is the least efficient with a score of 0.765. This may be explained by the fact that this operator has just taken over from the former public operator (the Autonomous Urban Transport Authority of Fez) in September 2012 and therefore it has not yet mastered its production process (2012-2013, one year of service).

As for the operational effectiveness, the companies' serving bus transport in Marrakech and Casablanca cities are the most effective of the sample, which means that these two operators were able to attract the most passengers given the resources at their disposal (the number of Buses and network length). This may be explained by the fact that these two operators have been able, over time, to adapt their offers on demand. They have been operational since 1999 and 2004 respectively. On the contrary, the company offering the bus service in Rabat-Salé City is the least effective with a score of 0.532. This may be explained by the fact that this public operator has just taken place instead of a failing private operator in 2012 and therefore it has not yet been able to adapt to customer demand (2012-2013, one year of service).

In terms of overall performance, operators in Casablanca and Marrakech cities are still the best performers of the sample. This is due to the fact that these two operators are the oldest and therefore have been able to control their production and consumption processes respectively.

In general, the performance scores of the sample are moderate. The average score of efficiency, effectiveness and overall performance is 0.688, 0.791 and 0.89, respectively. The poor performance of operators may be explained by structural deficiencies in the urban transport sector, namely under-investment in infrastructures (roads, rolling stock, etc.), poor management of Traffic and parking, a lack of financial, social and environmental sustainability and poor institutional coordination at the local level (World Bank, 2015).

4.2 The potential performance improvements

The overall performance scores showed that four out of six operators are underperforming. These operators can improve their performance by adjusting the level of their outputs and inputs while comparing their references. One of the important results of the DEA technique is the proposition of these adjustments that underperforming operators would have to make if they want to be (100%) well performing (or the performance score is equal to unity).

Table 4 provides the target values of the inputs and outputs derived from the CRS-DEA model to measure the overall performance. To explain the results, take the case of a single operator, for example, the worst performer of the sample (operator of Fez city). The overall performance score of this operator is 0.782, which implies that this operator could become efficient if all his outputs are proportionally increased by 20% ((1/(0.782(φ))-1), and 1/φ is the overall performance scores of an outputs-oriented model reported by the DEAP software). However, even with this proportional increase required in all outputs, this operator would not achieve best performance. In order to project this operator on the efficiency frontier, other "slack" adjustments are necessary because non-zero input-output slacks appear for this operator.

Table 4. Potential performance improvements

	Target output values		Target input values		% of outputs augmentation		% of inputs reduction	
	Y1	Y2	X1	X2	Y1	Y2	X1	X2
Agadir	11070.628	47087.488	171	272	2155 (24.17%)	6997 (17.45%)	0	0
Fez	15942.417	65711.308	245	377.651	3478 (27.91%)	14337 (27.91%)	0	162 (30.06%)
Rabat-Salé	28768.925	102377.442	432.453	573	3546 (14.06%)	47947 (88.09%)	242 (35.84%)	0
Tangier	5064.485	19482.959	77	110.65	862 (20.53%)	3318 (20.53%)	0	140 (55.92%)
Y1=Bus-km ; Y2= Passengers ; X1= Total Bus ; X2= Bus Network Length Source: Author's Calculations								

The company operating in Fez city has to make three adjustments to become best performer. First, it should increase all its outputs by 20%. Second, it should increase the number of Bus-kms and total passengers by 27.91% respectively. However, despite the increase in its output, it still does not perform well. No other output can be increased. Thus, the operator should also reduce his bus network length by 30.06%. The first adjustment is known as a radial adjustment, whiles the second and third types of adjustments are known as slack adjustments. A similar interpretation can be used for other underperforming operators.

Finally, it is interesting to note that operator managers should be aware that some of these performance improvement options (and target values) may not be practical. They can choose to implement only some of these potential improvements (especially the increase in outputs) because the quantities of inputs selected in this study are predefined in the specifications and in contracts established with delegating authorities. Their change must be the subject of a prior agreement between the operator and the delegating authority.

Conclusion

In this paper, we conducted a comparative analysis of the performance of six public bus transport operators in major Moroccan cities for the year of 2013. To this end, Data Envelopment Analysis method was used to evaluate and compare performance along three dimensions, namely production efficiency, operational effectiveness and overall performance.

The D.E.A results revealed that company operating in Casablanca city was the most efficient in the sample. As for the operational effectiveness, the companies of Casablanca and Marrakech cities are the most effective of the sample. Finally, these two operators are ranked first, in the sample, in terms of overall performance.

Based on the overall performance measure, the search results also identify potential performance improvements for each underperforming operator. This result provides practical information to operators or delegating authorities on the percentage that an operator needs to increase its outputs or reduce its inputs in order to achieve 100% performance (or to achieve an overall performance score equal to 1).

The major contribution of this research is to capture a preliminary image on the performance of public bus transport in major Moroccan cities using limited available data. The results allows operators to compare their performance against other operators in different geographical contexts. However; one of the limitations of this study is that performance measurement were done without taking into account the environment in which these companies operate. Future research will focus on determining the external factors that affect the estimated performance.

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