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The urban transport companies in Spain: analysis of efficiency with data envelopment analysis

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Abstract

Purpose – This paper aims to define the efficiency achieved by urban transport companies in Spain concerning the resources they use, considering the type of management used for implementation, public-private, and size.

Design/methodology/approach – This study consisted of an analysis of the efficiency of 229 public-private urban transport operators during the period 2012–2021 using Data Envelopment Analysis, the Malmquist Index and inference estimators to determine productivity, efficiency change into Pure Technical Efficiency Change (PTECH), and scale efficiency change.

Findings – Based on the efficiency analysis, the authors concluded that of the 229 companies studied, more than 35 were inefficient in all analysed periods. Considering the sample used, direct management is considered significantly more efficient. It cannot be concluded that the size of these companies influences their efficiency, as the data show unequal development behaviours in the studied years.

Originality/value – This study provides arguments on whether there is a significant difference between the two types of management in the urban transport sector. It also includes firm size as a study variable, which has not been previously considered in other studies related to urban transport efficiency. Efficiency should be a crucial factor in determining funding allocation in this sector, as it encourages operators to optimize and improve their services.

Keywords Efficiency, Urban transport, Data envelopment analysis

Paper type Research paper

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1. Introduction

Urban transport services are considered essential strategic sectors both for the overall development of the economy and for being a tool that ensures mobility and sustainability in cities. The bus is the most used surface transport to achieve that goal (European Commission, 2001; Fitzová *et al.*, 2018). The changes in displacement derived from the pandemic and the emergence of new modes of transport have affected its use (Aloi *et al.*, 2020; Awad-Núñez *et al.*, 2021), making necessary a significant investment by public operators to improve its attractiveness in a highly subsidized sector (Fitzová *et al.*, 2018).

In this sense, measuring efficiency and calculating its performance is one of the most reviewed concepts in the literature (De Borger *et al.*, 2002; Holmgren, 2013; Pina and Torres, 2001; Sampaio *et al.*, 2008). Measurement cannot be linked to a single concept of efficiency, and there is no clear consensus on what factors favourably influence when assessing efficiency.

For this reason, the main objective of this work is to measure the efficiency of transportation companies in the study period, considering the size of the company and the type of management (public, direct-private or indirect).

To achieve the stated objectives, we have used the non-parametric method, Data Envelopment Analysis (from now on DEA) and the Malmquist index (MPI), as they are the most widely used techniques in the analysis of efficiency in this field (De Borger *et al.*, 2002; Jordá Lope, 2012; Pina and Torres, 2001). We have incorporated a variable that has been little analysed in studies of efficiency in the sector, such as the size of the companies, which, however, the general literature suggests is significant according to sectors (Al Yami *et al.*, 2021; Halkos and Tzeremes, 2007), instead of the size of the city where the service is provided, which is an exogenous variable and, on some occasions, independent of the type of company and the supply offered. Similar to other analyses, the type of management is included as a variable affecting transport efficiency (Campos-Alba *et al.*, 2020; Georgiadis *et al.*, 2014; Nolan, 1996; Pina and Torres, 2001).

The paper is structured as follows: Section 2 reviews what the literature says about the importance of urban and suburban transportation, the efficiency in the sector, and the methodology used to analyse efficiency, ending with the hypotheses to be tested in our work. Section 3 explains the methods used to calculate efficiency, the sample and the variables used. Section 4 analyzes the analysis results and ends in Section 5 with the study discussion and the main conclusions.

As a result of our research, we can observe ample room for improvement in urban transport companies. On the one hand, there is a significant difference between direct and indirect management, the former being more efficient. On the other hand, although there is a considerable efficiency evolution between companies, it cannot be concluded that the size of these companies affects their efficiency, as the data show unequal evolution behaviours in the years of study.

Our study enhances the literature's contribution regarding efficiency, considering that we analyse by size and employ variables not utilized hitherto. Moreover, the sample size is more significant, adding robustness to our findings. By exploring novel dimensions and incorporating a more extensive dataset, our research expands the understanding of efficiency dynamics, offering valuable insights for future studies in this domain. In this sense, our work allows us to know how the events of the last ten years have affected efficiency in the sector, as well as define the criteria for achieving efficient transportation. Considering that efficiency should be a crucial factor in determining the allocation of financing in the sector since many countries are reformulating their current transportation systems for more efficient modes, as is the case with the United Kingdom (Vickerman, 2021) as it encourages operators to optimize and enhance their services (Li *et al.*, 2020). Likewise, the study applies to many companies offering services by analysing the Spanish national scope, not limiting the conclusions to a regional scope (Pina and Torres, 2001; Roy and Yvrande-Billon, 2007). In this way, the conclusions are relevant for concessionary companies and public administrations related to the urban transport sector in Spain.

2. Literature review

2.1 The importance of the urban transportation system

In recent years, many researchers have studied transportation due to its significance in the economic and social development of cities and as one of the activities that generate environmental impact, both in terms of energy consumption and emissions (Epicoco and Falagario, 2022; Zhao *et al.*, 2020).

Considering the development of urban transport as one of the main lines of action followed by the European Union to achieve more efficient and sustainable mobility.

That line has guided the transportation policies of the member countries, as they generally have a similar transportation infrastructure (Cavoli, 2015; Stead, 2008). And the decisions adopted by international organizations and in most industrialized countries (Epicoco and Falagario, 2022).

The use of urban transport in cities minimizes air pollution, noise pollution and urban congestion (Anguita *et al.*, 2014; Basagaña *et al.*, 2018; Gutiérrez *et al.*, 2021) and facilitates social and territorial inclusion processes (Glaeser *et al.*, 2008; Gómez-Ortega *et al.*, 2023; Lopes Toledo and Lèbre La Rovere, 2018; Oviedo and Attard, 2022; Schilardi, 2014; Susnienė, 2012).

In the case of Spain, these lines have materialized in the Spanish Sustainable Mobility Strategy (2009) and Law 2/2011 of 4 March on Sustainable Economy, establishing the need to improve the urban transport system to address mobility efficiently.

Within this transport system, a priority role is given to urban surface transport, the bus. The importance of bus transport was demonstrated by the COVID-19 pandemic, which ensured mobility in a completely paralysed society (Gutiérrez *et al.*, 2021; Manzira *et al.*, 2022).

Even though it is considered a primary mode of transport, the pandemic also harmed it, as it was associated with a high risk of contagion (Beck *et al.*, 2021; Tirachini and Cats, 2020), reducing its use by up to 80% compared to the years before the pandemic (Aloi *et al.*, 2020; Awad-Núñez *et al.*, 2021).

In this context, the significant effort of companies to enhance their appeal is linked to the incorporation of new technologies, both to reduce their impact and to meet the needs of users (Paulsen *et al.*, 2021; Drabicki *et al.*, 2021; Nehk *et al.*, 2021; Newman and Kenworthy, 2011; Webb, 2019) in the face of the promotion of other sustainable transport modes, such as scooters and electric vehicles, (Nehk *et al.*, 2021; Newman and Kenworthy, 2011; Webb, 2019.

These measures require a significant investment in a highly subsidized service (Fitzová *et al.*, 2018; Holmgren, 2018; Martín Urbano *et al.*, 2012).

Subsidies in countries like Germany, France, and Italy (López and De Rus, 1995; Pina and Torres, 2001; Rhodes *et al.*, 2012) and the country of this study, Spain., are carried out by the municipal government and formulae used are direct management through municipal trading companies, and indirect administration, where private companies provide the service through a concession.

In Spain, municipal commercial companies (Related to the public sector) are used most in large cities (De Rus, 1990). In small cities, private companies usually offer the service under concession (De Rus, 1990). In recent years, according to the work of Campos-Alba *et al.* (2020), new service provision formulae have emerged through mixed management contracts or inter-municipal cooperation, the latter being the least frequent.

In this context, the funding they receive comes from three types of administrations: the General State Administration, either with finalist subsidies or through programme contracts; from the Autonomous Communities, with no stable commitment on their part; and from the local administration, which is responsible for most of the subsidies for these companies when the rest of the funding does not cover the costs of the service (Observatorio de Costes y Financiación del Transporte Urbano Colectivo, 2022).

The funding received by the General Administration is usually scarce and unstable. The criterion for allocating resources, except for companies with a contract programme, is not linked to a regulatory framework (Delgado Jalón *et al.*, 2019). Criteria for allocation focus on balancing company results rather than rewarding effective management (Falcón *et al.*, 2015; López and De Rus, 1995). In addition, transport in Madrid and Barcelona typically receives most of this funding (Ruiz Montañez, 2017).

These characteristics, together with the public service vocation of these companies and the significant investment required to guarantee more sustainable mobility, mean that they have lines and frequencies that are not economically justified (Pina and Torres, 2001), with fares with high social component and high costs.

This situation, therefore, does not guarantee efficient resource management (Martín Urbano *et al.*, 2012) and does not allow for the development of equal sustainable mobility for all cities (Delgado Jalón *et al.*, 2019). It is necessary to reformulate the financing model that allows the development of a more efficient and effective system (Balboa La Chica *et al.*, 2014; Ruiz Montañez, 2014), rewarding those that have a better use of their factors and not those that obtain a more fabulous service (De Rus *et al.*, 2003; Ruiz Montañez, 2017).

This makes measuring the efficiency and calculating the performance of these companies a necessity because the criteria that define an efficient transportation system can determine its structure (Holmgren, 2018; Vickerman, 2021).

2.2 The efficiency of urban transport

In the urban transport sector and given the importance of performance measurement in this sector (Holmgren, 2018), the study of efficiency has been widely studied in the literature (De Borger *et al.*, 2002; Holmgren, 2018; Karlaftis and Tsamboulas, 2012; Odeck, 2008; Roy and Yvrande-Billon, 2007) De Borger *et al.* (De Borger *et al.*, 2002) indicate that despite the four main objectives that frame this type of company, such as equity, financial balance, macroeconomic stabilization and efficiency, it is the achievement of the latter that is considered essential in the development of the activity.

Efficiency is defined generically as achieving the highest possible output with a given level of resources or generating a given output level with the least possible use of resources. Efficiency is directly related to the production function, which represents the quantity of factors necessary to produce goods or services (Castelló and Giralt, 2008; Holmgren, 2018).

There are differences in how we define the service measurement, and there is no clear consensus when we talk about transport (De Borger *et al.*, 2002). Urban transport service can be measured by both service supply and service demand (outputs). The most common indicators for defining supply refer to kilometres per vehicle, per seat or hours per vehicle. Demand is usually analysed regarding kilometres per passenger, passenger trips, or revenue (Holmgren, 2018; Sampaio *et al.*, 2008).

To measure the service (output), it is essential to define the combination of resources (inputs) that makes it possible to achieve it since the calculation of efficiency is conditioned both by the ratio of inputs and outputs and by the method used to obtain it (Castelló and Giralt, 2008; Karlaftis and Tsamboulas, 2012). In practice, the choice of inputs and outputs is often defined by the accessibility of the data and the method chosen (Holmgren, 2018).

As far as inputs are concerned, although there are a large number of resources and combinations of resources that can be used (Brons *et al.*, 2005; Jordá Lope, 2012; Karlaftis and Tsamboulas, 2012), they are traditionally based on indicators that measure: capital, labour and energy of the firm (De Borger *et al.*, 2002; De Rus *et al.*, 2003; Li *et al.*, 2020; Sampaio *et al.*, 2008).

Sampaio *et al.* (2008) indicate that, in general terms, capital can be represented by the number of vehicles, labour refers to the labour force represented by both the number of employees and the cost of employees, and the energy of the company refers to the number of litres of diesel consumed per year.

However, efficiency is also determined by the organization or size of the market, the design of contracts and the way companies are managed (De Borger *et al.*, 2002; Pérez-López *et al.*, 2015; Prior *et al.*, 2019) and there is no single conclusion in this regard.

When talking about the form of company management, studies refer to determining which type of private or public management is more efficient when providing the service due to the high degree of outsourcing that the public service is experiencing in general. In the case of transport, there is no consensus that private companies are more efficient than public companies (Campos-Alba *et al.*, 2020; Karlaftis and Tsamboulas, 2012; Pina and Torres, 2001; Roy and Yvrande-Billon, 2007; Viton, 1997). The work of Pina and Torres (2001) evaluates the efficiency of public and private companies that provide urban transport services in the most important cities of Barcelona. Their main conclusion is that, with the data obtained, no relevant factors indicate that private management is more efficient than public management. However, the study by Roy and Yvrande-Billon (2007) on 135 different urban transport networks in France during the period 1955–2002 shows that the efficiency of private managers is higher than that of public ones.

However, the size of the firms, which, despite being a significant variable from the point of view of efficiency in other sectors (Al Yami *et al.*, 2021; Halkos and Tzeremes, 2007), has not been analysed in the case of transport where greater importance is given to the organization of the market or the size of the market where they provide their service. The literature generally indicates that firms are more significant when they operate in less densely populated areas (Georgiadis *et al.*, 2020; Odeck and Alkadi, 2001; Vigren, 2016).

Finally, there are more diverse studies due to more cases regarding the relationship between efficiency and the design of contracts or how the service is financed. For example, the work by Nolan (1996), using a sample of 29 medium-sized companies in the USA, indicates that federal subsidies negatively impact the efficiency of the service. Roy and Yvrande-Billon (2007) analyse the impact of contractual forms in general and, in particular, in the French transport sector, where they determine that operators whose Cost is fully reimbursed by local authorities are less efficient than those that receive a fixed price, assuming that operators are efficient when they assume part of the risk of their service.

Among the methods used to measure efficiency as a determinant for its valuation (Karlaftis and Tsamboulas, 2012), the most commonly used techniques are related to both econometrics and mathematical programmes (Fried *et al.*, 1993), with frontier methods standing out and within this the DEA (Brons *et al.*, 2005; De Borger *et al.*, 2002; Holmgren, 2018; Venkatesh and Kushwaha, 2018). The review by Brons *et al.* (2005) highlights that 89% of the studies analysed on transport efficiency use this method.

Nevertheless, it is necessary to take account that the limitation of the DEA methodology lies in the fact that it compares units that are ideally homogeneous in their type of management. However, the differences in sizes of transport companies require particular management measures in each case, difficult for other companies to emulate.

2.3 Hypotheses

Considering the importance of transport and the need to ensure efficient management of resources (Martín Urbano *et al.*, 2012), the evaluation of efficiency becomes a fundamental indicator as a gauge of the transport system (Balboa La Chica *et al.*, 2014; Ruiz Montañez, 2014). For this reason, this paper aims to answer the following hypotheses:

H1. The efficiency of transport companies is determined by the type of management (public or private) of urban transport companies.

In this sense, the measurement of efficiency according to the type of management has been widely studied in the literature both in Spain (Campos-Alba *et al.*, 2020; Pina and Torres, 2001) and abroad (Karlaftis and Tsamboulas, 2012; Roy and Yvrande-Billon, 2007; Viton, 1997). Since there is no clear consensus on whether private or public management is more efficient, our work aims to contribute, thanks to the sample analysed, to provide arguments as to whether there is a significant difference between the two types of management in the urban transport sector.

H2. The size of the company providing urban transport services influences its efficiency.

As can be seen in the literature review, there is much debate on how the size and density of the population served by transport companies influences their efficiency (Georgiadis *et al.*, 2014; Odeck and Alkadi, 2001; Vigren, 2016) but there are no studies that analyse the importance of firm size with firm efficiency, even though it is considered a relevant variable when analysing other types of sectors (Al Yami *et al.*, 2021; Halkos and Tzeremes, 2007; Sánchez Robles *et al.*, 2022). For this reason, our work aims to provide an answer to this hypothesis.

3. Methodology, sample and data

3.1 Methodology

Data Envelopment Analysis is a linear programming method to measure the relative efficiency of organization units that present the same objectives and targets. This technique was first developed by Charnes *et al.* (1976) based on preliminary work by Farrell (1957).

Decision-making units (DMUs) in DEA are the analysis units to be considered, and in the present study, each transportation company represents a unique DMU. The main idea is to construct a model company defined by the input and output combinations of the companies in the sample and the identification of the efficiency frontier. All the companies in the frontier will be those performing efficiently for the input and output variables selected in the production model. Companies out of the frontier will be inefficient units, and their relative inefficiency value can be calculated.

DEA aims to find the best input and output variable weights for each DMU to maximize its efficiency value. Let m be the number of DMUs in the sample, n the number of input variables, and r the number of output variables considered in the production model. The efficiency value for each DMU can be calculated by solving the following linear model:

$$max\, E_j = \frac{\sum_r u_r y_{rj}}{\sum_i v_i x_{ij}}$$

$$s.t. \begin{cases} 0 \leq \dfrac{\sum_r u_r y_{rj}}{\sum_i v_i x_{ij}} \leq 1\, \forall j = 1, \ldots, n \\ u_r, v_i \geq 0\, \forall r = 1, \ldots, s;\ i = 1, \ldots, m \end{cases} \qquad \text{Model (1)}$$

Where x_{ij} is the input variable i amount for DMU j, y_{rj} is the output variable r amount for DMU j, v_i is the weight value for input variable i and u_r is the weight value for output r.

The maximum efficiency score for a given DMU i can be acquired when the corresponding efficiency value E_i is one, and efficient units will constitute the reference set for inefficient units. This model allows to determine the variables and the intensity to act for each inefficient unit to achieve efficiency—the model defined in eq. (1) is known as the Constant Return Scale (CRS), where an increase in the input volume produces a proportional increase in the output volume. Banker *et al.* extended this model to consider scale performance in DMUs. This model is known as Variable Return to Scale (VRS), where an increase in the number of inputs causes a proportional increase in the outputs depending on the performance scale of a given DMU. The efficiency value E_{VRS} calculated utilizing a VRS DEA model is called "Technical pure efficiency", and the ratio between this one and the efficiency obtained using the CCR model (known as global efficiency E_{CCR}) is called "scale efficiency" (SE):

$$SE = (E_{VRS}/E_{CCR})$$

When the scale efficiency is one, the corresponding DMU operates at the most productive scale size. Besides, when the scale efficiency is less than one, the corresponding DMU can work in a descendent or ascending return scale. In descendent return to scale, an increase in the input volume causes a shorter output increase for the DMU, to which the increase is obtained in a proportional relationship. The opposite results for a DMU operating in ascending return to scale.

Färe and Grosskopf (1992) developed the Malmquist Productivity Index (MPI), which enables us to evaluate the performance of each unit of production concerning the best practice in several years. The MPI defined by Färe and Grosskopf (1992) is an input-oriented productivity index computed as the geometric mean of the two Malmquist indices developed by Caves *et al.* (1982), referring to the technologies at periods t and $t+1$:

$$MI^{(t,t+1)} = \sqrt{\frac{D_i^t(y^{t+1},x^{t+1})D_i^{t+1}(y^{t+1},x^{t+1})}{D_i^t(y^t,x^t)D_i^{t+1}(y^t,x^t)}} \tag{1}$$

Where $MI^{(t,t+1)}$ is the input-oriented Malmquist index, and y represents the output vector that can be produced using the input vector x.

The input-oriented distance functions represent the measurement of the technical efficiency in the t and $+1$ periods. $D_i^t(y^t,x^t)$ and $D_i^{t+1}(y^{t+1},x^{t+1})$. The input-oriented distance $D_i^t(y^{t+1},x^{t+1})$ Shows the efficiency measure using the observation at period $t+1$ relative to the frontier technology at period t. The input-oriented distance function $D_i^{t+1}(y^t,x^t)$ Shows the efficiency measure using observation at period t relative to the frontier technology at period t $+ 1$. For a more detailed explanation of the methodology, see Coelli *et al.* (2005).

Productivity improvements are shown in values of the Malmquist Index that are more significant than 1 and show that lower amounts of input are required to obtain a given output level. A Malmquist Index of less than 1 shows a reduction in productivity.

Färe and Grosskopf (1992) suggested a decomposition of the DEA MPI into two mutually exclusive indexes intending to differentiate the origin of the changes in productivity. These components are obtained by rewriting the index in (1) as follows:

$$MI^{(t,t+1)} = \frac{D_i^{t+1}(y^{t+1},x^{t+1})}{D_i^t(y^t,x^t)}\sqrt{\frac{D_i^t(y^{t+1},x^{t+1})D_i^t(y^t,x^t)}{D_i^{t+1}(y^{t+1},x^{t+1})D_i^{t+1}(y^t,x^t)}} \tag{2}$$

The ratio outside the square root measures the efficiency change (EFCH) between periods t and $t+1$. The ratios inside the square root (TECH) measure the shift in the frontier between periods t and $t+1$. Grifell-Tatjé and Lovell (1995) suggested a decomposition of efficiency change (EFCH) into Pure Technical Efficiency Change (PTECH) and Scale Efficiency Change (SECH), calculating two new distance measures assuming the return-to-scale-technology variable for the two time periods t: $D_{VRS}^t(y^t,x^t)$ and $t+1$: $D_{VRS}^{t+1}(y^{t+1},x^{t+1})$.

Considering this decomposition of the change in technical efficiency, we can rewrite the Malmquist Index as MI = (TECH) x (PTECH) x (SEFCH). This decomposition is helpful since it enables us to differentiate the factors under the control of the urban transport company, as is the case of the Pure Efficiency Change, from the factors not under the control of a particular company: technology and scale efficiency change.

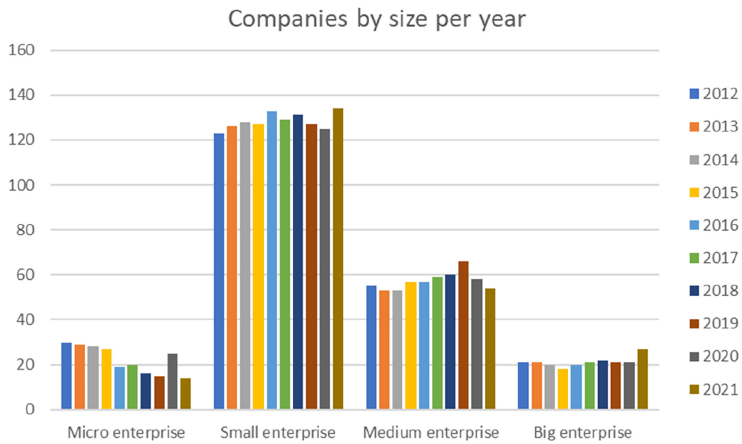
The method used to have a homogeneous sample has been identifying atypical data, that is, decision units that present extreme data compared to the rest. The outliers are challenging to identify since a multidimensional vector of inputs and outputs is considered for each reference unit. Outliers may be caused by several factors, such as unusual characteristics concerning the rest of the sample (Chen *et al.*, 2010) or non-reference group membership (Johnson and McGinnis, 2008). DEA estimates are pretty sensitive to the outlier presence as the method considers extreme observations to identify the unit performance (Sexton *et al.*, 1986). Several methods have been proposed in the literature for outlier detection (Banker and Chang, 2006; Bellini, 2012; Chen *et al.*, 2010; Johnson and McGinnis, 2008; Simar, 2003). In this work, the method proposed by Bellini (2012) has been considered. That allows the outlier detection inside and outside the production frontier.

3.2 Sample

The sample includes 229 passenger transport companies in Spain classified under CNAE [1] code 4,931, "urban and suburban land passenger transport", according to the ORBIS [2] database between 2012 and 2021. ORBIS being an international database with reliable and comprehensive financial data, enables obtaining a comprehensive sample of urban transport companies. Therefore, the companies in this section can do urban transport services exclusively or sometimes include interurban transport lines both of public and private nature. However, there is no additional information to obtain segmented economic details.

The sample period covers ten years, starting the study in the period when the White Paper "Roadmap to a Single European Transport Area: Towards a Competitive and Sustainable Transport Policy" (European Commission, 2001) was published, where the role of transport begins to be important in the development of sustainable measures until 2021, being the last year for which information on these companies is available.

According to the European Union Commission, the company's size can be defined by the number of employees, revenue, or total assets. In this study, the number of employees will be used to classify the size of the entities. The results obtained are shown in Figure 1:



Source(s): Authors' own work

Figure 1.
Number of companies according to size per year

Depending on the year, we can see that some companies vary in segment according to size. In 2021, more than 58% of the companies were catalogued as small.

In terms of management type, the results according to the sample obtained are as follows [3]:

Concerning type of management, Table 1 shows indirect management is the most commonly used form of urban transport service provision, with only 15 providing the service through direct management.

The relationship between size and type of management can be seen in Figures 2 and 3:

As we can observe in Figures 2 and 3, there are no microenterprises with direct control within the type of management. 99.24% of the small and 94.44% of the medium-sized companies use indirect management to provide their services. Immediate management is more present in the large ones, with 40.77%.

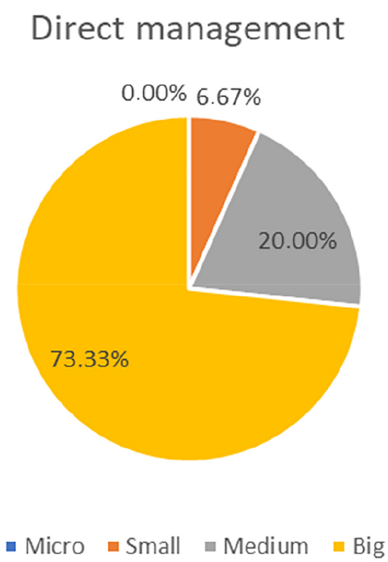
3.3 Variables

The selection of inputs and outputs that have been considered in the analysis of the efficiency of the urban transport companies in the sample is based on the following reasons: On the one hand, variables generally accepted for the calculation of efficiency in previous national and international works (Bellini, 2012; Jordá Lope, 2012; Karlaftis, 2004; Li *et al.*, 2020; Pina and Torres, 2006) and, on the other hand, the availability of reliable data for all sample units that could be collected through the information offered by the UE database.

Table 1. Number of companies by type of management

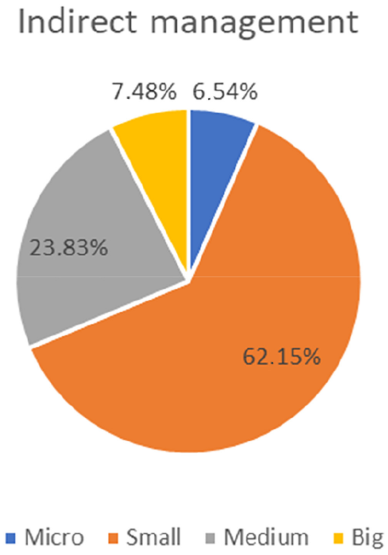
Management type	Number of companies
DIRECT	15
INDIRECT	214
Total	*229*

Source(s): Self-elaboration based on data obtained from UE



Source(s): Authors' own work

Figure 2. Size of companies under direct management



Source(s): Authors' own work

Figure 3. Size of indirect management companies

3.3.1 Inputs. Concerning the resources that enable the realization of service provision, based on the grouping of indicators measuring capital, labour, and energy (De Borger *et al.*, 2002; De Rus *et al.*, 2003; Fielding *et al.*, 1985; Li *et al.*, 2020; Sampaio *et al.*, 2008), the model has focused on depreciation and amortization expenses as an indicator of rolling stock expenses, employee cost to measure personnel resources and procurement cost as a measure of energy consumption, the Cost of supplies that companies generate is used.

3.3.2 Outputs. Regarding how to measure the urban transport service, we have chosen to use the added value of the service, [4] understood as the contribution that the company makes to the region where it provides its service (Asociación Española de Contabilidad y Administración de empresas, 2022). It is considered an indicator of the company's economic performance.

Adding value to measure efficiency has been employed in various sectors, such as agriculture (Delgado Eraso *et al.*, 2023) and energy overall (Shao *et al.*, 2019). However, transportation studies primarily focus on logistics (Noguera, 2018; Ramírez Huerta, 2023) or energy consumption (Zhu and Gao, 2019). This is because it is regarded as a significant gauge of the impact of the service provided by the company and its quality. In addition, it facilitates the information provided by the company (Román Cáceres and Ladrón de Guevara Figueroa, 2013).

In this studio, the output variable used to measure efficiency in the companies considered in this work is defined according to the following expression:

$$\text{Value added} = \text{Depreciation and amortization expenses} + \text{Procurement costs} + \text{Cost of employees.}$$

4. Results

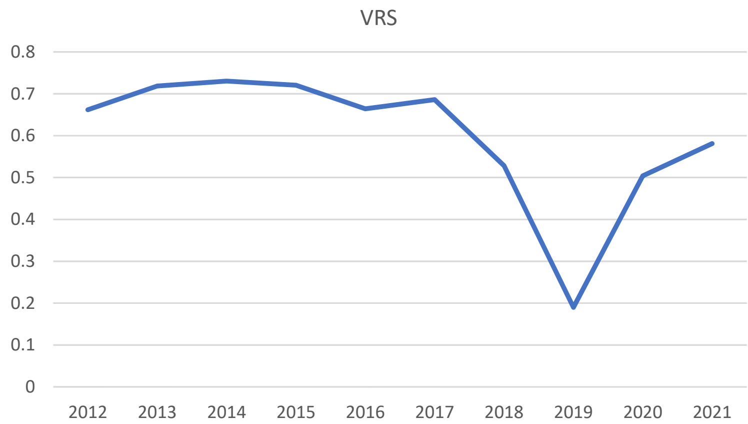
Following the work proposed by Bellini (2012), for each reference year, three transportation enterprises have been identified as outliers out of the 95% bi-variated boxplot resulting from the minimum and maximum distances to the super efficiency scores reached by each DMU:

Empresa Municipal de Transportes de Madrid SA; Transports de Barcelona SA and Avanza Spain SL.

Figure 4 presents the average efficiency values for 229 transportation companies in Spanish municipalities considering an input-oriented VRS model in the period under consideration. The DEA model in our study revealed that 18 of these were efficient in 2012. This represents 7.8% of the companies in the sample, with average efficiency $\overline{E}_{2012} = 0.662$. The number of efficient units during the period under study increased slightly, up to 22 companies (9.6% of the sample) in 2013; 35 companies (15.3% of the sample) in 2014; decreases in 29 companies (12.6% of the sample) in 2015; in 24 companies (10.5% of the sample) in 2016; in 23 companies (10% of the sample) in 2017; increases again in 25 companies (10.9% of the sample) in 2018; whereas in 2019 a considerable drop in efficiency is observed up to 13 companies (5.6% of the sample) recover in 2020 up to 20 companies (8.7% of the sample) and 2021 with 26 companies (11.3% of the sample) (Figure 4). The average efficiency in 2013 ($\overline{E}_{2013} = 0.7187$); 2014 ($\overline{E}_{2014} = 0.7302$); 2015 ($\overline{E}_{2015} = 0.7204$); 2016 ($\overline{E}_{2016} = 0.664$); 2017 ($\overline{E}_{2017} = 0.686$); 2018 ($\overline{E}_{2018} = 0.528$); 2019 ($\overline{E}_{2019} = 0.190$); 2020 ($\overline{E}_{2020} = 0.504$), and 2021 ($\overline{E}_{2021} = 0.581$) confirm this trend efficiency in the period studied (see Figure 5).

Figure 6 shows a box plot of efficiency values for each DMU by type of management in the sample period. Efficiency oscillates under other types of management in the sample period as overall efficiency. We highlight the changes in variation within the type of management. We can observe a weird behaviour 2019 under indirect management and the consequent efficiency drop. Overall, efficiency under direct management surpasses efficiency under indirect management. However, there is a significant difference in the number of DMUs under consideration under different management types, which may lead to different results in the percentage of efficiency DMUs.

Using a one-factor design, we investigated significant differences by management type, considering principal effects and the efficiency score during the sample period 2013–2021. The associated ANOVA table shows significant differences by management type, with greater efficiency under direct management for each year in the considered sample period (p_{2012}-value≈0; p_{2013}-value≈0; p_{2014}-value = 0.005; p_{2015}-value≈0; p_{2016}-value≈0; p_{2017}-value≈0; p_{2018}-value≈0; p_{2019}-value≈0; p_{2020}-value≈0; p_{2021}-value≈0).



Source(s): Authors' own work

Figure 4.
Average efficiency for the DMU with a VRS DEA model input oriented

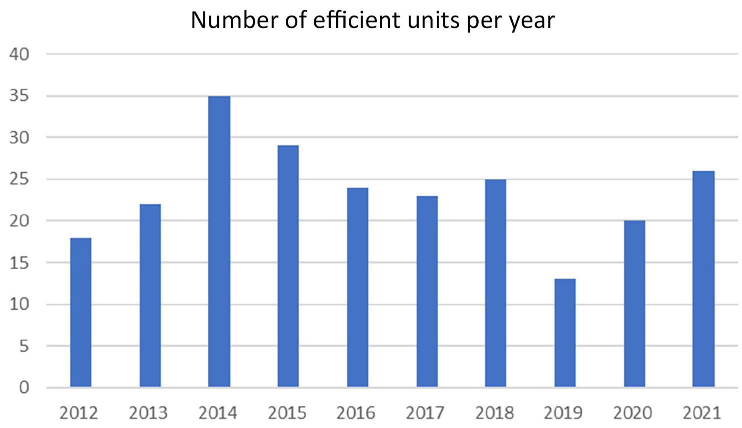


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Figure 5.
Number of efficiency DMU units per year

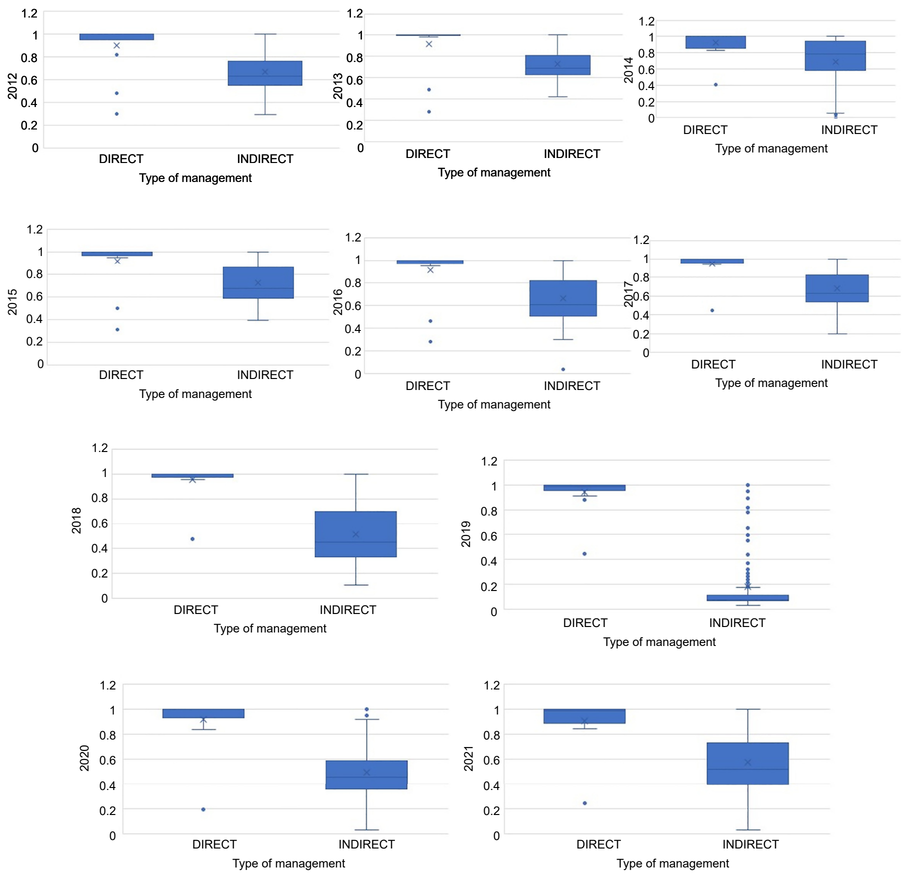

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Figure 6.
Box plot of efficiency values for each DMU

The studio within the company size has been avoided as the VRS model has been considered (see Table 2).

Table 3 shows productivity, technology, efficiency, pure efficiency and scale efficiency changes for the 2012–2021 sample period. The table indicates the gradual productivity increase from 2012 to 2016, mainly attributed to technical productivity improving "best practices". There was an increase in productivity from 59 companies in 2013, with respect to

Period	Summary	Malmquist index	Technical change	Efficiency change	Pure efficiency	Scale efficiency
2012/13	Progress	59	134	149	149	124
	No change	0	0	11	11	11
	Decline	165	90	67	67	92
	Mean	0.940	1.026	1.104	1.103	1
2013/14	Progress	140	136	102	101	88
	No change	0	0	13	13	13
	Decline	88	92	114	115	128
	Mean	1.004	1.030	1.026	1.026	0.999
2014/15	Progress	190	137	89	91	124
	No change	0	0	21	19	18
	Decline	37	90	119	119	87
	Mean	1.046	1.040	0.993	0.993	1.000
2015/16	Progress	178	108	51	52	61
	No change	0	0	18	19	18
	Decline	48	118	160	158	150
	Mean	1.115	1.037	0.934	0.934	1
2016/2017	Progress	58	99	132	132	138
	No change	0	0	15	15	15
	Decline	169	128	82	82	76
	Mean	0.955	1.094	1.144	1.144	1
2017/2018	Progress	184	79	38	38	131
	No change	0	0	16	16	16
	Decline	39	144	175	175	82
	Mean	1.465	1.001	0.778	0.777	1.001
2018/2019	Progress	221	127	5	5	46
	No change	0	0	10	10	10
	Decline	5	99	214	214	173
	Mean	4.891	1.082	0.314	0.318	0.993
2019/2020	Progress	9	84	204	204	184
	No change	0	0	9	9	9
	Decline	219	144	16	16	364
	Mean	0.406	1.713	5.04	4.984	1.008
2020/2021	Progress	140	145	135	136	88
	No change	0	0	13	12	12
	Decline	80	75	81	81	129
	Mean	1.102	1.493	1.433	1.447	0.996

Source(s): Authors' own work

Table 2.
Relationships between basic inputs and intermediate outputs: summary of changes in malmquist index, technical change and efficiency change

Anova table Dependent variable: Malmquist index Origin	Squared sum type III	gl	Quadratic average	F	Sig
Corrected model	3559.78[a]	35	101.71	134.44	0.000
Intercept	2147.63	1	2147.63	2838.85	0.000
Year	988.50	8	123.56	163.33	<0.001
Size	27.66	3	9.22	12.19	<0.001
Year * Size	354.28	24	14.76	19.51	<0.001
Error	1509.24	1995	0.76		
Total	9246.77	2031			
Total corrected	5069.02	2030			

Note(s): [a]R squared = 0.702 (R squared adjusted = 0.697)
Source(s): Authors' own work

Table 3. Table for three-way factor ANOVA for Malmquist indexes

2012, to 178 from 2016 to 2015. A slight decrease in productivity in 2017 concerning 2016, attributed to a recession in "best practices" recover in the next period. Pure and scale efficiency experience the same effect but are more moderate than technical efficiency.

This fall recovered gradually in 2017–2018, with minor fluctuations in technical productivity and an abrupt increase from 2018 to 2019 mainly attributed to the improvement in "best practices". There was a fast drop in efficiency change in 2019–2020 and a slight recovery in 2020–2021. Pure efficiency experienced a gradual increase between 2012 and 2017, followed by a notable decrease in 2017 and 2019 and an abrupt increase between 2019 and 2021. Besides, scale efficiency experiences a slight fluctuation with no notable changes in the period considered.

A three-way factor ANOVA was conducted to explore differences in efficiency changes considering the type of management, company size and reference year. Year and company size resulted in significant factors in Malmquist productivity indexes (see Table 3) whereas type of management resulted in a non-significant factor (p-value = 0.155). Larger Malmquist values were found in 2018 and 2019, concerning the rest and smaller values in 2020. Furthermore, big companies presented larger Malmquist values, whereas huge and microenterprises presented smaller average indices (see Figures 7 and 8). The Levene test

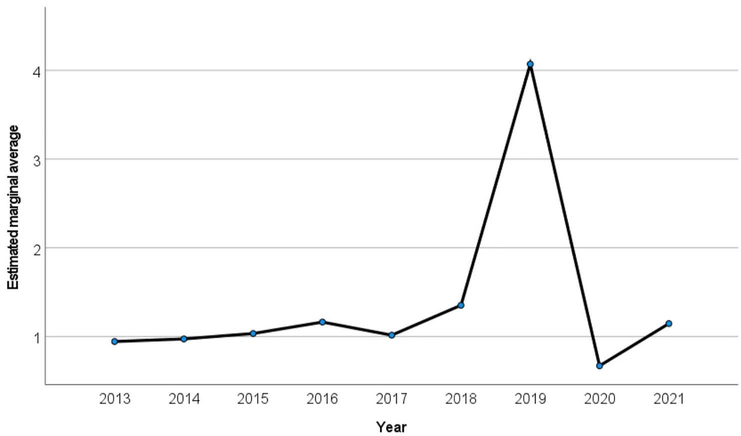

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Figure 7. Malmquist marginal average by year

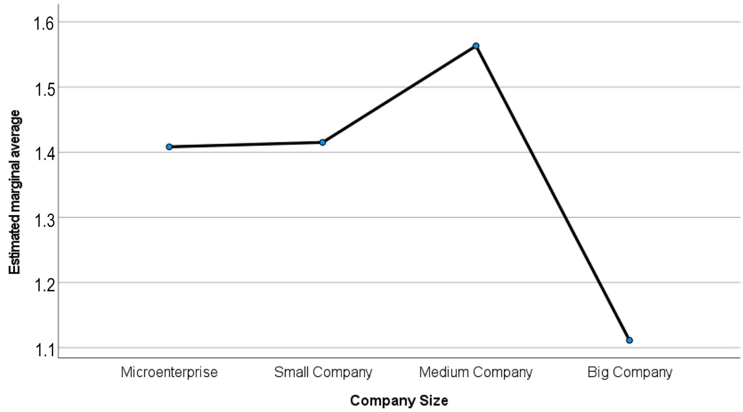

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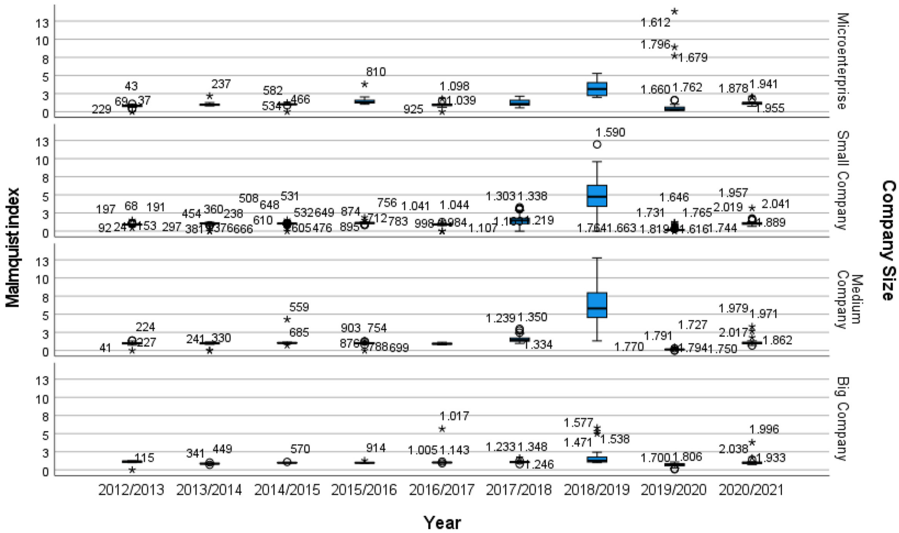
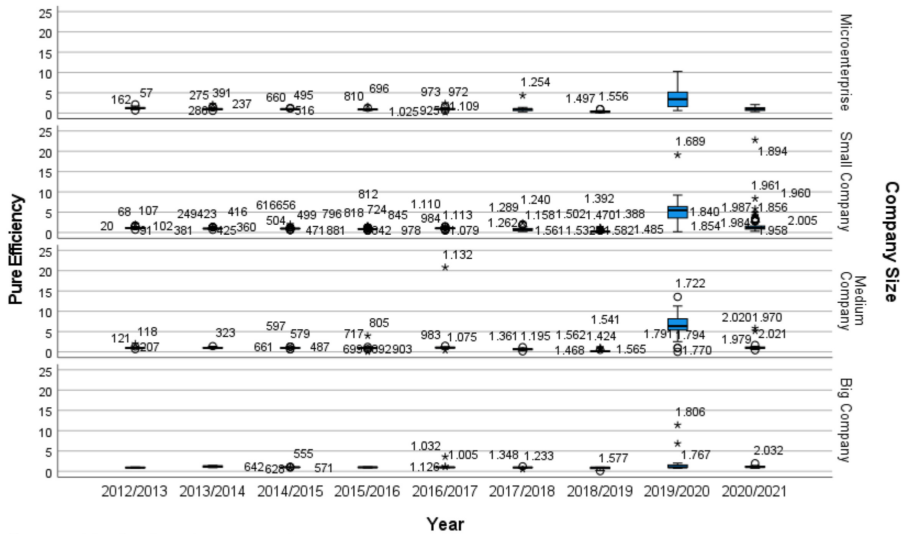
Figure 8.
Malmquist marginal average by company size

rejected the hypothesis of homogeneity in variance for the selected periods for Malmquist, pure, scale and technical efficiency scores. The differences in average and variability by reference year and management type can be highlighted, as the variability increase in 2018/2019 concerning the remaining periods is more pronounced. Microenterprise companies experienced a notable increase in productivity in 2015/2016. In contrast, the previous periods maintained productivity with minor variations, except the 2019/2020 period experienced a notable increase in variability (see Figures 9 and 10). All companies experienced a significant increase in productivity in 2017/2018 and 2018/2019, followed by a notable decrease in 2019/2020, being more accused for big and medium-sized companies and recovering slightly in 2020/2021 (see Table 4). Confidence intervals for parameter estimations have been computed using jackknife estimates consistent with heteroskedasticity robust standard error and t



Source(s): Authors' own work

Figure 9.
Boxplot for pure efficiency scores by company size and type of management



Source(s): Authors' own work

Figure 10. Boxplot for pure efficiency scores by company size and type of management

statistics. No significant changes were observed in technical efficiencies, efficiency and pure efficiency scores when considered solely as factors. However, pure efficiency scores presented smaller average values for huge companies and higher average values for all companies in 2020, as expected (see Figure 9), being statistically significant (see Table 5). Even more, technical efficiency scores were statistically significantly higher for microenterprises (p-value <0.001).

5. Implications, discussion and conclusions

Urban transport is considered a fundamental tool for the sustainable development of cities from an economic, social and environmental point of view. It guarantees mobility and accessibility for citizens with a lower impact on the emission of polluting gases and energy consumption than other modes, such as private vehicles. The way transport is financed, and its challenges have become more relevant with recent events such as the Covid-19 and new modal shifts. In this context, the efficiency of the companies is considered a fundamental factor as a way of measuring the management of the resources that these companies carry out.

When measuring efficiency, the inputs used are those generally accepted for the calculation of efficiency in previous national and international works, indicators that measure capital, labour, and energy and, on the other hand, the availability of reliable data for all the sampling units that have been collected through the information offered by the EU database. While to measure the transport service, the added value of the service has been used.

Considering the relationship between the inputs and outputs obtained, the following has been analysed: the efficiency of urban transport companies providing services in Spanish municipalities from 2012 to 2021.

Based on the efficiency analysis conducted, it can be concluded that out of the 229 companies studied, more than 35 were found inefficient in all the periods analysed. This determination was based on the parameters used to evaluate efficiency. The analysis revealed that the companies' costs within the sample displayed significant variations despite falling within the same size category.

Reference year	Company size	Average ± Standard deviation	95% confidence average interval
2012/2013	Microenterprise	0.78 ± 0.23	[0.69; 0.87]
	Small Company	0.91 ± 0.09	[0.89; 0.93]
	Medium Company	1 ± 0.19	[0.95; 1.05]
	Big Company	1.08 ± 0.26	[0.96; 1.2]
2013/2014	Microenterprise	1.02 ± 0.25	[0.92; 1.11]
	Small Company	1.03 ± 0.16	[1.01; 1.06]
	Medium Company	0.98 ± 0.22	[0.92; 1.04]
	Big Company	0.87 ± 0.08	[0.83; 0.9]
2014/2015	Microenterprise	1 ± 0.21	[0.92; 1.08]
	Small Company	1.04 ± 0.13	[1.01; 1.06]
	Medium Company	1.1 ± 0.44	[0.99; 1.22]
	Big Company	1 ± 0.04	[0.98; 1.02]
2015/2016	Microenterprise	1.53 ± 0.65	[1.2; 1.86]
	Small Company	1.13 ± 0.11	[1.11; 1.14]
	Medium Company	1.01 ± 0.16	[0.97; 1.05]
	Big Company	0.99 ± 0.08	[0.95; 1.03]
2016/2017	Microenterprise	0.96 ± 0.34	[0.8; 1.12]
	Small Company	0.92 ± 0.16	[0.89; 0.95]
	Medium Company	0.93 ± 0.07	[0.91; 0.95]
	Big Company	1.25 ± 1.04	[0.77; 1.74]
2017/2018	Microenterprise	1.24 ± 0.48	[0.99; 1.5]
	Small Company	1.51 ± 0.59	[1.4; 1.61]
	Medium Company	1.57 ± 0.42	[1.46; 1.68]
	Big Company	1.09 ± 0.16	[1.02; 1.17]
2018/2019	Microenterprise	3.26 ± 1.08	[2.66; 3.86]
	Small Company	4.89 ± 2.27	[4.49; 5.29]
	Medium Company	6.21 ± 2.43	[5.6; 6.81]
	Big Company	1.93 ± 1.53	[1.21; 2.64]
2019/2020	Microenterprise	1.6 ± 3.38	[0.21; 3]
	Small Company	0.24 ± 0.2	[0.2; 0.28]
	Medium Company	0.15 ± 0.07	[0.13; 0.17]
	Big Company	0.69 ± 0.28	[0.56; 0.82]
2020/2021	Microenterprise	1.29 ± 0.41	[1.04; 1.53]
	Small Company	1.08 ± 0.26	[1.03; 1.12]
	Medium Company	1.12 ± 0.42	[1; 1.24]
	Big Company	1.1 ± 0.58	[0.87; 1.34]

Source(s): Authors' own work

Table 4.
Descriptive statistics for malmquist index by management type and reference year

Dependent variable: Pure efficiency

Origin	Squared sum type III	gl	Quadratic average	F	Sig
Corrected model	8017.41[a]	36	222.71	177.21	0.000
Intercept	31.28	3	10.43	8.29	<0.001
Year	1452.77	8	181.59	144.49	<0.001
Size	375.86	24	15.66	12.46	<0.001
Year * Size	2542.36	2023	1.26		
Error	10559.77	2059			

Note(s): [a]R squared = 0.759 (R squared adjusted = 0.755)
Source(s): Authors' own work

Table 5.
Table for three-way factor ANOVA for pure efficiency scores

In contrast, the analysis also revealed that only three companies demonstrated efficiency consistently across all the years analysed. These companies fall into the category of big companies, two of which are directly managed (Empresa Municipal de Transporte de Madrid y Transports de Barcelona). And the other one is indirectly controlled (Corporación Municipal de Jerez, S.A). These companies could effectively manage their costs and perform optimally according to the parameters employed in the analysis.

As for the analysis of the management types, the results indicate a significant difference between private and public management, with direct management presenting the highest average efficiency in the periods analysed. Direct management represents only 6.5% of the entire sector.

Regarding the size of companies, it should be noted that most are considered medium-sized or small and, in most cases, use private management. The big companies operate in Spain's large municipalities, with more than 40% directly managed.

Concerning efficiency according to size, unequal behaviour can also be observed. Considering the Malquist index in general terms, there is an increase in efficiency in all the periods analysed, with a significant increase in 2018–2019, a situation that may be due to the general increase in the added value of large companies. In 2019–2020, there was a significant decrease in the efficiency of these companies due to the fact that the non-utilization of the fleet reduces the cost of fuel but keeps the rest of the company's costs unchanged. In 2020–2021, a slight recovery can be seen in all the companies analysed, but without reaching pre-pandemic levels.

With these results, we can conclude that concerning the hypothesis and taking into account the sample used, direct management is considered significantly more efficient, and concerning hypothesis 2, it cannot be concluded that the size of these companies affects their efficiency, as the data show unequal evolution behaviours in the years of study.

From the transportation companies' management standpoint, achieving added value and service efficiency should be considered critical indicators in managerial processes. The circumstances leading some companies to present lower efficiency results, as indicated by the data collected, can be considered by Spanish companies to conduct temporal and spatial comparisons, aiming to comprehend the evolution and differences with the overall sector averages. Such an endeavour would involve an exploration of the specific causes of the efficiency obtained by the company, with a view to modifying policies that might be generating inefficiencies.

According to data provided by various studies (Cavoli, 2015; Stead, 2008), policies, structures, and service quality in many European Union countries can be understood as essentially similar. This leads us to assume that the conclusions drawn from this article may apply to other member countries, a possibility that could be explored in further analyses.

In summary, this work contributes to research on efficiency in the transportation sector, providing a comprehensive review of a broad sample and conclusively confirming the first of the hypotheses formulated. A comprehensive review of a broad sample sets the groundwork for a nuanced understanding of efficiency dynamics.

We acknowledge that the conducted study could be expanded by incorporating operational variables, such as the total number of passengers, distance travelled, or the quantity of fleet vehicles. However, due to limitations in information sources, obtaining such data was not feasible. Although proxy variables were employed to address this situation, this limitation may introduce bias into the results obtained from the applied DEA.

In future lines of research, it is interesting to include external factors such as population density or the GDP of the cities where the companies operate (Georgiadis *et al.*, 2014) or operational variables.

In conclusion, we can state that the efficiency of the companies was conditional on the type of management and population segment to which they provided service.

Based on these results, considering the significant influence of public funding in these companies, we propose the measurement and utilization of efficiency as a reference when defining criteria for a new financing law, which should formulate its directives toward implementing a programme contracts financing type and analyses of company needs, with priority factors population size and the geography where the companies operate.

Notes

1. National classification of economic activities (Clasificación Nacional de Actividades Económicas)
2. https://www.bvdinfo.com/en-gb/our-products/data/international/orbis
3. The management type is constant for all the years analysed.
4. According to the Orbis database this is defined as Profit for the year + Amortization + Taxes + Interest paid + Personnel costs

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