Transportation Research Part A 93 (2016) 1–12

Contents lists available at ScienceDirect

Transportation Research Part A

journal homepage: www.elsevier.com/locate/tra

# An application of the directional distance function with the number of accidents as an undesirable output to measure the technical efficiency of state road transport in India

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ARTICLE INFO

*Article history:*
Received 29 July 2015
Received in revised form 15 June 2016
Accepted 10 August 2016

*JEL classification:*
D24
R41

*Keywords:*
Technical efficiency
Road transport
Accident
Directional distance function
Tobit
Zero-truncated negative binomial

ABSTRACT

By using the directional distance function (DDF) of data envelopment analysis (DEA), this study measures the technical efficiency of 37 Indian state road transport undertakings (SRTUs) for the year 2012–13. We employ the DDF as a tool for analyzing a joint production function with both desirable and undesirable outputs (i.e., the number of accidents). A comparison between the results with and without accidents shows that several SRTUs have experienced significant changes in their efficiency scores as well as in their rankings after accounting for the undesirable output. This indicates the importance of including the number of accidents – a safety standard – as representative of the undesirable output in computing the efficiency scores of SRTUs. The results of the Tobit model indicate that SRTUs with greater vehicle productivity are more efficient under both conventional DEA and DDF approaches. We also employed zero-truncated negative binomial model to assess the factors influencing the number of road accident experienced by the Indian SRTUs and found that the accident count was significantly influenced by fleet utilization and vehicle productivity.



## 1. Introduction

In India, road transport is one of the most important means of moving both goods and passengers across the country. Though India has the second largest rail network in the world, roadways are the main motorized surface to cater to the hilly, rural, and remote areas with poor railway connectivity. Of the total land passenger requirements in India, 85.2% are presently met by road transport, while the remaining 14.8% are carried by railways (GoI, 2014). Passenger services are handled by operators in both the private and public sectors. The State Road Transport Undertakings (SRTUs), public sector road transporters owned by the respective state governments, play the most important role in passenger transit among the other available public sector operators.

SRTUs are a public utility service provider with the social objective of providing transportation services to more remote parts of the country, hence, it is essential to assess the efficiency of these SRTUs for proper pricing policies and human resource planning, as well as for securing increased investment from the government. Furthermore, as public road passenger transport is a "service business," besides maximizing desirable output (the number of passengers that travel and total

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http://dx.doi.org/10.1016/j.tra.2016.08.012
0965-8564/

revenue), the technical efficiency of SRTUs may also be measured in terms of minimizing undesirable output (the number of accidents encountered by the respective SRTU). Accounting for the undesirable output (i.e., accidents) seems important for precisely two reasons: first, it is a parameter that can capture the extent of the safety measures followed by the respective SRTU, and second, there are considerable social costs associated with such accidents.

The existing literature (see Jarboui et al., 2012 and Daraio et al., 2016 for a detailed review) has only explored how technically efficient the SRTUs are in terms of minimizing input or maximizing output. Significant exceptions are noted in the efficiency measurements of public sector transporters by Pina and Torres (2001) and Agarwal et al. (2011) using Data Envelopment Analysis (DEA). However, while Pina and Torres (2001) included the accident rate as an output in the production function, Agarwal et al. (2011) considered the number of accidents per million kilometers as input rather than interpreting accidents as an indicator of undesirable output. We aim to close this gap by measuring the efficiency of 37 Indian SRTUs in terms of both desirable and undesirable outputs. Through this integrated approach to the consideration of accidents, this work is expected to portray a comparatively different picture regarding the efficiency of SRTUs. This work should be of interest to the public sector transport operators in their efforts to balance their economic objectives with safety. Here, we employ the directional distance function as a tool for analyzing a joint production function with both desirable and undesirable output. Moreover, we also attempt to identify the factors affecting the efficiency of the sample SRTUs and influencing the number of accidents.

The contribution of this study is fourfold. First, with respect to the more general value, we show that the technical efficiency scores as well as rankings of the sample SRTUs vary greatly with the inclusion of undesirable output, i.e., the number of accidents, in our analysis. Second, with respect to the methodology, we believe this to be the first study to employ the directional distance function (DDF) capturing both desirable and undesirable output in the context of measuring the efficiency of road transport operators. Third, the results of the Tobit model indicate that SRTUs with greater vehicle productivity are more efficient under both conventional DEA and DDF approaches. Finally, the outcome of zero-truncated negative binomial model shows that the accident counts of the SRTUs are significantly influenced by fleet utilization and vehicle productivity.

The remainder of this article is arranged as follows: Section 2 briefly reviews the relevant literature. In Section 3, we explain the methodology and describe the data used for the analysis. Section 4 presents the results and the discussion of the findings. Section 5 offers a conclusion for the article.

## 2. Literature review

In the earliest study on this topic, Tomazinis (1977) specified a set of indicators to measure the efficiency of public transport operators. Later on, Fielding et al. (1978, 1985a, 1985b) offered an exhaustive number of indicators that can be used to evaluate the performance of public transit systems. A possible drawback of the above works is that they proposed such a large variety of performance indicators that generally fail to produce consistent results (Benjamin and Obeng, 1990). Furthermore, unlike the manufacturing industry in which output can be stored for future use, the output of a transport system is time sensitive. This realization leads to the conclusion that a smaller number of reliable indicators would be more effective for generating consistent results. Thus, the variables used as the inputs and outputs for the service production process of a transport system should reflect both the objectives of the study and the actual service delivery as accurately and precisely as possible (Jarboui et al., 2012).

Studies conducted to assess the efficiency of road transport operators, including those in both the public and private sectors around the world, can be classified into two broad domains: non-parametric studies that measure efficiency with Data Envelopment Analysis (DEA), and parametric studies that make use of Stochastic Frontier Analysis (SFA). Adopting the non-parametric approach, Odeck and Alkadi (2001) applied DEA to measure the efficiency of 47 road transport companies in Norway for the year 1994 by using the number of seats, fuel consumption, driving hours, and the number of staff members employed as inputs to produce seat-kilometers as the output. On average, bus companies exhibited increasing returns to scale in their production of seat-kilometers. However, the study was only conducted on 47 large operators against 171 companies that were operational during the corresponding period, and the results of the study therefore fall short of generalizability. In our study, we have included all 37 SRTUs rather than selecting decision making units (DMUs) on an *ad hoc* basis, which makes our results more generalizable and pertinent for formulating more effective policies.

Pina and Torres (2001) employed DEA to compare the efficiency of public and private bus operators in Spain. They considered fuel used per 100 km, cost per traveler, and subsidy per traveler as inputs, and bus-kilometers per employee, bus-kilometers per bus, bus-kilometers per inhabitant, and accident rates as output. The analysis revealed that privately-owned bus services were no different from their public counterparts in terms of efficiency. In another study, Cowie (2002) assessed whether the merger of bus operators can result in improvement of efficiency. The number of employees and fleet size were taken as inputs in the DEA for producing vehicle kilometers. Working with 58 British public transport (bus) companies from 1990 to 1997, they found that efficiency improvement was not a result of scale economies, and was instead due to improved internal efficiency, such as better management of operations and working practices. However, as the merger was not evenly spread over the sample DMUs, instead concentrated among three operators, one of which had purchased 28 bus companies, the results may have been biased. Along the same lines, Boame (2004) analyzed the efficiency of 30 Canadian transit systems during the period ranging from 1990 to 1999. He employed the number of active fleets, fuel