PROJECT REPORT ON  
  
PUBLIC TRANSPORTATION EFFICIENCY ANALYSIS  
  
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ABSTRACT

* The Transport System of the Recife Metropolitan Area is under change.
* As a subsidy to its change an efficiency analysis is done with the purpose of highlighting characteristics of the efficient systems.
* Twelve transport system from several countries in Europe and seven from Brazil are analyzed: nine from Europe and only one from Brazil were found efficient.
* These system are characterized by very different power structure and tariff structure.
* Efficient ones adopted a more democratic power partition among communalities and established a more broad system of tariffs.
* Among other lessons it is suggested that RMR adopts a structure that allows a more equal partition of the several municipalities comprising the Metro Area including representatives of users groups like workers associations and syndicates.
* Also it should adopt a more flexible tariff systems giving advantages to usual users at the same time that decreases costs and improves the operational efficiency.

INTRODUCTION

* Metropolitan areas have experienced in the last decades an increasing expansion bringing, as a consequence, several socio-economic problems such as an unequal spatial urban development, a high pressure on disposable infrastructure, land and housing shortages and, with emphasis, lack of urban services.
* These problems, in addition to low income and unemployment, expel poorer people to urban peripheries where housing costs are lower.
* But these peripheries are diploid of public services and increase the cost of providing urban infrastructure.
* Public transport, in particular, planned to operate in more density populated areas, offer a lower frequency and quality service, due in part to larger distances and a precarious road system.
* Unorganized urban expansion leads to an unorganized and irrational transport system in which superimposition of routes is one of its characteristics.
* In addition, municipal system if not centrally coordinated results in superimposition and low coordination of routes and irrationality of the whole system.
* Urban expansion, a conurbation phenomenon in which city limits loose expression bring planning difficulties.
* Notwithstanding the difficulties, people require in each area an adequate public transport that allows easy moves to work, shopping, educational, health and cultural centers. Thus, a metropolitan public transport system needs to assure mobility and accessibility through a fast, secure, regular and trustable transport at a reasonable cost.
* Unfortunately it is not easy to assure all these characteristics due to complex institutional arrangements between state and several municipalities.
* Thus, a first step consists of working an agreement among all political institutions involved. In particular, questions such as power division among them, administrative coordination, financing and selection and operation of all concession to operate the several services involved (bus, metro, vans, and so).

EFFICIENCY ANALYSIS

* In general terms, the cost function shows the minimum cost of producing a given quantity of output from the available inputs.
* Costs are therefore expressed as a function of output level and factor prices, i.e.
* C = C(W,Q) (1) where W is a vector of input prices and Q is the level of output (or a vector of output levels if a multiple output technology is described).
* The cost function expressed in equation (1) is deterministic and assumes that operations are performed in an efficient (cost-minimizing) manner, which might not be the case in reality.
* Cost frontiers allow for the possibility of inefficiency in the operations of individual decision-making units
* Ci C w i w i wNi q i q i qMi , ........, , , ,........, ³ 1 2 1 2 (2) where Ci is the total cost for decision-making unit (DMU) i, using N different inputs in the production of M different kinds of output.
* Introducing di as a measure of the inefficiency of decision- making unit i and a random disturbance term i e results in: ( ) Ci C w i w i wNi q i q i qMi di i = , ........, , , ,........, + + e 1 2 1 2 (3)
* In the present case it is assumed that the PTAs use capital, labour and fuel in order to produce passenger trips.3 The total cost for public transport in county i during the year t (Ci,t) is therefore determined by the number of trips made (qi,t), the wages of bus drivers (w1 i,t), the price of diesel fuel (w2 i,t) and the cost of capital (w3 i,t). The cost of capital is defined as the interest rate of ten-year government bonds.
* Nash (1982) and Button (2010) include general discussions on cost relationships in public transport production,
* while Oum and Walters (1996) provide a discussion on cost functions in transportation research.

METHODOLOGY

* In this study, the focus is on bus transportation since it is more flexible compared to rail transportation and widely preferred by the masses in cities. The primary data source of this study comes from the Department of Transportation for the City of Antalya.
* We load the complete boarding data of December 18,2019 which is a standard weekday.
* The boarding data consists of passenger Id, passenger’s boarding stop Id (origin), boarding time, bus Id, route Id (the direction on a particular line) .
* For a particular route, bus stop locations with GPS coordinates required to visualize path on a map, are available from both municipal and commercial websites (such as [www.ulasimburada.com](http://www.ulasimburada.com/)).
* The data set formed consist of 305 lines and 608 routes. A route consist of a sequential list of bus stops in either forward or backward (return) directions.
* Each line has opposite two directions except two lines which are omitted in analysis. On December 18, 2019, a total of 7347 trips (single direction services) were made and with these trips a total of 381962 passengers were carried.
* Efficiency of a transportation system as a whole requires individual busses which are limited in numbers run as efficient as possible while keeping residents happy through easy access to a bus service, quick access to destination, connectivity to 4 Kamer Ozg¨un and et.al ¨ transit network and comfort.
* Our approach in improving transportation system has 2 stages; 1- improve route efficiency, 2- improve customer satisfaction. However, in this study we solely focus on the route efficiency. In a follow up study we aim to include customer satisfaction aspect of the transportation.

Hierarchical Clustering for Bus Stop Similarity

* If routes and bus stops had to be eliminated or redesigned.
* Then it is important to know which routes are close in terms of trip. Bus stops of a route may be used to determine overlapping routes.
* Several similarity measures are available to determine close routes. Among them cosine similarity with inverse term frequency has advantages over others as it favors less frequent matches over frequent ones .
* Cosine similarity based distance matrix is formed where Rows and Columns are Routes and each cell in the matrix has a value between 0 and 1 that represents the cosine angle between the two routes.
* A distance value 0 means perfect match, whereas a distance matrix of 1.0 means routes do not have anything in common.
* During the hierarchical clustering complete linkage method is used to calculate the cluster distances Once distance matrix is formed for routes, it has been used to cluster routes with respect to each other via distances calculated in the prior step.

Time-Location Variance Analysis of Route Boarding

* Time-Location mapping of route boarding provides us to analyze the variation of boarding in both time domain and as well as route bus stop sequences.
* Mapping involves counting boarding in subsequent bus stops for each trip on a route. Such mapping may be visualized using heatmap plot.
* Visually, we can conclude that Route KC06 has the lowest variation both in time and location which is also consistent with the route efficiency of this route. Route LF10 has medium performance but Route CV 39 has the most variation both in location and trip.
* Variance-Area curve obtained by Equation 4 allows us to quantify variation in both time and bus stop dimensions. Such numeric evaluation shown in Figure matches visual experience shown in Figure 6. CV 39 has the highest and KC06 has the lowest variation

Variance-Area Curves for Route Boarding

* Simply put, the between-area variance curves are obtained by calculating the variances of gray scale pixel values while varying rectangular unit areas within the 2-D gray scale matrix.
* This 2-D gray scale matrix is constructed from the heatmap image.
* Although there are many ways to choose rectangular unit areas having equal area sizes , for the purpose of this study, these unit areas are considered squares.
* Let m be the pixel length and n be the pixel width of the entire heatmap matrix.
* The image is first partitioned into unit areas of size A1x1. The between-area variance curve, CB(Ak), is the plot of the coefficients of variation between the varying unit areas Ak×k. Mathematically, this relationship is formulated with Equation.

CB(Ak) = 100 F¯ k vuut 1 mknk Xmk i=1 Xnk j=1 [Fi,j − F¯ k] 2

PROBLEM DEFINITION

* Transport policy in developed countries has for a long time included the need to increase the usage of public transport. The availability of ‘good’ public transport is a major strand in policies to achieve greater usage of public transport and to influence modal shift. However, ‘good’ public transport has many attributes including financial sustainability and the provision of quality services efficiently.
* This paper addresses two related themes relevant to the provision of ‘good’ public transport with particular reference to the provision of urban bus services in the UK. The first theme examines the way in which financial stability, quality and efficiency can be measured by urban transport providers: in this context the paper considers the theoretical and practical issues of applying benchmarking by an urban transport provider. The second theme considers the [economic framework](https://www.sciencedirect.com/topics/social-sciences/economic-framework) in which differences in behaviour of public and private firms and differences in legislative frameworks can be a means of explaining the disparity in attitude by transport providers to the potential benefits of the benchmarking tool.
* Using available benchmarking experience, the paper evaluates the relevance of the theory and identifies key attributes for developing more successful performance measurement for public transport operators in the future. This is important because understanding what is best quality performance and attempting to move towards industry best is one of the most secure ways of ensuring the provision of quality services in a financially stable environment.

MEASURING QUALITY AND EFFICIENCY IN PUBLIC TRANSPORT

There is a plethora of management models and ideas which can be used in a business context to improve business performance[3](https://www.sciencedirect.com/science/article/pii/S0386111214601400). Benchmarking has been a key tool in the business improvement armoury for many years[4](https://www.sciencedirect.com/science/article/pii/S0386111214601400). Benchmarking is a way of measuring how good the business is at what it does, making a quantitative statement as to whether their performance is as good as other businesses and using this information to improve the business process. In short, benchmarking is a tool for searching for industry best practice, leading to improvement in performance. It is an on-going technique for measuring and improving processes against the best that can be identified. It requires data gathering, goal setting and analysis. Benchmarking is concerned with facts in contrast to other key management tools, such as balanced scorecards, which also include more subjective elements relating to business aspirations. Benchmarking can be widely applied and can cover all aspects of measurable activity: in a urban bus context, benchmarking could cover both inputs (internal efficiency) and outputs (revenue and passenger responses).

BENCHMARKING IN THE PUBLIC TRANSPORT SECTOR

One of the earliest interests in performance measurement was noted in the passenger transport sector over twenty years ago with the investigation by the OECD. The OECD Road Research Programme undertook an examination of the key issues to be considered in developing a technically sound approach to evaluation of performance, using various ‘packages’ of indicators. The resulting report outlines a clear conceptual basis for development of system-wide indicators in two categories of interest to this paper: efficiency and effectiveness[7](https://www.sciencedirect.com/science/article/pii/S0386111214601400). Effectiveness is concerned with the results of the service, while efficiency is concerned with the means of achieving these results.  
The report identifies eight groups of users with each having differing needs for performance indicators: public transport managers; municipal managers; policy makers; regional planners; street traffic system managers; central, national and state governments; public transport users; and the research community. Data requirements and sources are identified and the pros and cons of manual versus automatic data collection systems described. The recommended set of performance indicators required for the purposes of (a) service planning, (b) internal assessment, (c) comparison of different operations and (d) more global assessment are outlined. In addition, some applications for each indicator are noted, together with advice of the frequency at which the measure should be reported. However, despite this early work, no evidence of it being put into practice in a sustained way has been identified in the public transport sector.