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Understanding the determinants of demand for public transport: Evidence from suburban rail operations in five divisions of Indian Railways

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ABSTRACT

This paper analyses suburban rail fare elasticity and compares the results across five suburban divisional operations of the Indian Railways in three cities viz., Chennai, Kolkata and Mumbai. The three cities chosen have a highly varying modal share of public transport trips and thus offer interesting insights into the attitudes of trip makers towards the changes in operational variables such as fares, service levels. This paper contributes towards understanding of the determinants of demand for public transport in a developing country and applies econometric methods involving *static* and *dynamic* modelling methodologies. This research addresses the question of smaller sample sizes which constrain the use of standard regression approaches and applies a *bootstrapping* method which substitutes for traditional assumptions on distributions and asymptotic results. It was found that the suburban rail demand is *inelastic* to fare which indicates that the revenue would increase with an increase in fare. Finally, the paper illustrates the use of computed elasticities by estimating the demand for suburban rail in Kolkata.

1. Introduction

Since Transport Research Laboratory (TRL) published their report on *Demand for Public Transport* edited by Webster and Bly (1980), there has been an extensive research activity to understand the determinants of demand for public transport including the effect of fares, quality of service, income levels, car ownership rate, vehicle-kilometres. It is noted that the analysis of demand with respect to various factors largely remained in focus within a small group of countries having well-developed transport systems e.g. Australia, Finland, France, Netherlands, Norway, UK, USA (Bresson et al., 2003, Paulley et al., 2006). However, in the developing countries there is hardly any evidence of such research work in the past barring a few recent attempts. Currently, a number of cities in developing countries e.g. Mumbai, Delhi, Hyderabad, Bengaluru (India), Philippines (Manila), Dhaka (Bangladesh) and Jakarta (Indonesia) have all initiated metro rail systems which are in different stages of planning/execution. Notably, some of these metro rail projects involve agencies other than the governments under the public/private partnerships. Whosoever builds/owns/operates the infrastructure it will be essential to ensure the economic viability of the project but if it involves private investment it will be necessary to estimate the financial viability too, either way require a good understanding of the determinants of demand. Aside from the regulatory structure, design of the new infrastructure will also depend on the estimates of demand while arriving at a suitable specification for the system being planned.

The aim of this paper is to understand the passengers' response to fare changes in suburban railway systems with the ultimate objective of improving fare policies and managing the suburban transport system better. The main hypothesis is that the demand is related to and is explained by operational variables such as fares and service frequencies. While the demand is represented in terms of *pass-km*, fares are represented as yield i.e. *revenue /pass-km* and the frequency of operations is represented by *vehicle-km* as a proxy. The paper hypothesises further that the demand is also related to socio-economic variables such as population and per-capita income levels besides the availability of alternative modes e.g. personal vehicles and their operating costs. Following from the literature, the paper investigates linearised relationships between the explained variable i.e. the demand and the explanatory variables including operational and socio-economic variables. The method relies on historic data obtained from Indian Railways, but as the data sets are limited to a 30- year period, this paper uses bootstrapping method to overcome the limitation of fewer degrees

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of freedom associated with the estimation.

The paper is set out in six sections including the introduction. Section 2 reviews the elasticities of public transport demand. Section 3 specifies the methods used in estimating elasticity. Section 4 describes the case of suburban rail operations in India in Chennai, Kolkata(E), Kolkata(SE), Mumbai(C) and Mumbai(W). Section 5 discusses the computed estimates of elasticity and considers their policy implications. Section 6 concludes the paper.

2. Review of public transport elasticities

Elasticity is defined as '*responsiveness of demand to changes in the factors of demand*' (Balcombe et al., 2004). The first comprehensive review of elasticities of public transport was done by Webster and Bly (1980) whose rule of thumb of −0.3 was widely acknowledged and used until the end of 1980s. The second major review by Goodwin (1992) looked at 50-odd demand elasticities for bus journeys mainly in the UK and found that the average elasticity was −0.4. Goodwin also found that the bigger cities had greater elasticities an assertion that is widely rejected now. Oum et al., (1992), estimated a range of public transport elasticities from −0.01 to −0.78, with most of the values falling between −0.1 and −0.6 and concluded that the demand for public transit is rather inelastic. Preston (1998) analysed data from 89 European cities and found the elasticity to vary by the size of the city. His finding that larger cities have smaller elasticities and that the smaller cities (less than 0.5 million population) have bigger elasticities, has been largely substantiated by theories and empirical evidences. He suggested an elasticity value of −0.5 for smaller cities and −0.34 for bigger cities. Nijkamp and Pepping (1998) analysed 12 studies on public transport elasticities from European countries and they also found a wide range of values from −0.15 in the UK to −0.8 in the Netherlands. The other studies refined the methodologies and used highly disaggregated data to estimate elasticities. Massot (1994) used survey data of 2750 individuals over 12 years and 35 cities in France. He has highlighted the importance of understanding the sensitivity towards travel time which was found to be twice as important as fares. Hensher (1998) studied direct and cross fare elasticities in Sydney Metropolitan Area based on stated, revealed preference data sets and made a distinction between elasticity for different modes and different types of tickets.

2.1. Studies on rail demand elasticity

Besides public transport, there have been specific studies on rail demand elasticity. Owen and Phillips (1987) studied intercity rail demand elasticity in the UK. Oum et al. (1992) studied intra-city rail elasticity and found peak fare elasticity between −0.20 and −0.40, off-peak fare elasticity of less than −1.0 and all day elasticity between −0.1 and −0.70. Dargay and Hanly (2002) studied suburban rail elasticity in the UK and outside of the UK (short run UK −0.50 to −0.09 and −0.37 to −0.09 outside UK). Hague Consulting Group undertook a major study of rail demand elasticity in Sydney which besides estimating the fare elasticity of rail demand, estimated service level and service quality elasticities (Douglas and Karpouzis, 2009). Wardman (2006) studied the influence of external factors and estimated fare, income, and Gross Domestic Product (GDP) elasticity. Paulley et al. (2006) note a short run suburban rail fare elasticity of −0.5. Worsley (2012) compiled estimates of fare elasticities from several studies based on flows that had seen significant increases in fares and found a range of fare elasticities from −5.0 (London Travel Card) to −1.2 (Leisure trips from the rest of the country to London).

Table 1
Elasticities in Tran-Santiago, Chile.Source: De Grange et al. (2013)

Travel alternative	Multinomial Logit	Hierarchical Logit	Mixed Logit
Metro off-peak (own)	−0.193	−0.233	−0.186
Metro peak (own)	−0.588	−0.557	−0.579
Bus off-peak (own)	−0.340	−0.349	−0.354
Bus peak (own)	−0.284	−0.268	−0.309
Metro off-peak & peak (cross)	0.159	0.141	0.211
Metro and Bus off-peak (cross)	0.114	0.134	0.137
Metro & Bus peak (cross)	0.250	0.236	0.218

2.2. Elasticities of public transport in developing countries

In contrast to the experience noted from the developed world, there are far fewer studies estimating elasticities of public transport in developing countries and more so on railways. De Grange et al. (2013) studied integrated fare elasticity in Tran-Santiago, Chile, using discrete choice modelling in which they employed Multinomial Logit, Hierarchical Logit and Mixed Logit models. Elasticities estimated by them are presented in Table 1.

In a doctoral thesis on public bus transport elasticities in India Deb (2008) mentions no evidence of any earlier study on elasticity either in developing countries or in India. Deb's work may be considered as one of the few existing evidences, which is based on a 10-year intercity bus transport data from 22 states of India. He found the elasticity value to vary between −0.354 and −0.523 for public bus transport (Table 2).

A White Paper on Indian Railways (IR, 2009), however, mentions an aggregate GDP elasticity of 0.79, which is a simple arithmetic calculation of change in GDP over change in Indian Railway's earnings. There are many problems with this value. Firstly it is an aggregate value for the entire railway including earnings from freight operations. Secondly, it is a GDP elasticity and not a fare elasticity, and thirdly it is not about suburban transport systems. Then there are a few others e.g. Bharill and Rangaraj (2008) who have analysed the elasticity of rail fares in India but they have focussed solely on specific intercity rail operations. There is thus a substantial gap between the developed and developing world with regard to studies on elasticity which is summarised as in the following. The studies in developing countries-(i) were aggregate of the public transport system including bus and rail operations; (ii) did not consider passenger railway operations exclusively in their studies; and (iii) never took up the subject of suburban railways on their own. Our paper thus focuses on the suburban rail operations from five divisions of the Indian Railways.

Table 2
Price and income elasticity in Indian public bus transport system.Source: Deb (2008)

	Fixed Effects	Random Effects	PCSE[a]	Corrected LSDV[b]	
				Short run	Long run
Price	−0.460***	−0.354***	−0.359***	−0.374***	−0.523***
Income	−0.020	−0.065	0.061	−0.027	−0.038
Service quality	0.834***	0.818***	0.754***	0.676***	0.957***

*** Significant at 99.9% confidence level.
[a] Panel Corrected Standard Errors.
[b] Least Squares Dummy Variables.