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Economic Characteristics of the Urban Bus Transit Industry: A Comparative Analysis of Three Regulated Metropolitan Bus Corporations in India.

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Working Paper No. 54

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ABSTRACT

The present scenario with respect to bus transit corporations in major metropolitan cities in India, presents a paradoxical situation. Despite the critical role played by bus transit systems in catering to ever mounting demands of urban commuters, services have deteriorated. Rising levels of deficits appears to be a persistent problem. The principal purpose of this research work was to make an analytical assessment of deficiencies in bus transit operations by scrutinising the behaviour of 'costs' and a host of 'economic effects'. Towards this end, three major regulated urban bus transit systems providing 'conventional' type, fixed-route fixed-schedule mass transit services in the cities of Bombay, Madras and Delhi have been selected as case studies. Given diverse operating conditions, attempts have been made to empirically estimate 'cost functions' separately for each of these bus transit corporations on the basis of monthly time series data. A sound theoretical and quantitative framework is an integral part of the cost function analysis towards ensuring greater accuracy of results. On the whole, the empirical analysis revealed vital measures that could be taken for efficient operation of bus services. This paper summarises various facets of the study.

1. Introduction

The genesis of this research work has it's roots in the 'urban transport crisis' being witnessed by larger metropolitan cities in the developing world, wherein cost advantages accruing from 'agglomeration economies' has resulted in spatially concentrated economic growth, accompanied by equally phenomenal urban growth both demographic and spatial. Such formidable levels of urban growth exerts insurmountable pressure on infrastructural facilities and other amenities endangering conditions for urban existence. This is evident from the conditions in the urban transport sector. Rapid increase in population speedily enhances demand for transport infrastructure and services, making it almost impossible to meet the same at adequate magnitudes and levels of service, while the spatial spread of the city, characterised by spatial separation of functions across the urban area, accentuates mobility requirements and journey lengths. Financial resource constraints are such that capacity expansion can never keep pace with the increase in demand. The end result today, is a situation where a whole gamut of motorised and non-motorised modes scramble for limited road space under extremely congested conditions, oblivious of the adverse repercussions on energy use, environmental quality and safety.

An efficient public transport system based predominantly on the bus mode could no doubt mitigate the severity of these problems to a considerable extent. 'Buses and minibuses provide the cheapest and most flexible way of meeting a wide range of demands throughout the city and can cope with the heaviest of demands by bus priority measures such as exclusive bus lanes running in dense corridors' (World Bank, 1986). The role of bus transport in cities of the developing world may be stressed on 'equity' considerations as well. For the poor this may be the only means of motorised transport for gaining accessibility to new employment opportunities, education and health centres. Provision of demand-responsive and better quality of service in terms of frequency and speed could tilt patronage in favour of the bus mode which has a higher carrying capacity and economises on the use of road space as compared to private modes of travel. This would arrest the current trend indicating increasing ownership and use of private motorised modes, especially two-wheelers, which have accentuated congestion levels in 'Third World' cities. If bus services are provided by a well maintained fleet of buses based on fuel-efficient technology then pollution levels could also be checked.

Amidst growing resource constraints fixed track systems may be a remote possibility. Even where feasible, these may be justified only for a few large cities and within these, along very limited routes. This is because, such projects have high capital and operating cost requirements involving substantial foreign exchange, limiting the scale in which these can be built. Thus, such alternatives can make only a limited contribution to solving the urban transport problem. (Hamer et al., 1987). In any case, even if the major cities of the developing world build and operate such capital intensive mass transit systems along limited corridors, some time in future, bus transit services would continue to assume significance in terms of fulfilling the requirements of 'feeder services' as well as catering to commuting requirements in areas where the fixed track rapid transit system cannot penetrate. A 'well-run' bus transit system would have sufficient vitality to reorient its routing and scheduling pattern in order to complement the newly introduced rapid transit system wherever required, thereby forming an integrated public transit system in the future scenario.

Under these circumstances, there seems to be an ardent need to exploit the 'beneficial externalities' of bus transit operations more fully to serve as some kind of a panacea to the urban transport crisis in cities of the developing world. Thus, it is our contention that the provision of improved bus transit services would form an integral part of the 'environmentally sustainable transport policy' being advocated today. (Dalvi, 1996; Leinbach, 1995; Banister, 1991; Hamer et al 1987).

However, bus services in most of the developing world cities have deteriorated. These are inadequate, unreliable, uncomfortable, and overall output has in fact declined forcing users to shift to more costly modes of transport or even walk long distances.(Midley, 1994). An important reason for this state of affairs is that this sector (which is largely regulated in the developing world), has failed to generate internal resources so necessary to expand services and enhance the quality of service. This is partly because severe constraints have been placed on pricing of services on socio-economic grounds, while subsidies have been adhoc and inadequate, have not been linked to any measure of performance and have removed incentives to reduce costs or increase revenues. Consequently, there is a tendency to curtail investments in services, standards deteriorate and expansion is stunted (Patankar, 1988). Under these circumstances, it may not be difficult to envisage poor management standards, laxity in maintenance, obsolete technology, dearth of technically trained personnel, over-staffing especially in public sector undertakings where union pressures are strong. Further, 'bus priority measures' are rare and operation under congested conditions results in higher operating costs through higher fuel consumption and greater wear and tear of vehicles (Vasconcellos et al., 1995). Driving under congested conditions greatly enhances emissions associated with long idling times and repeated accelerations (Younes, 1993).

In the Indian context, these declining trends with respect to bus transit services have been further aggravated due to improper planning directed towards solving the overall urban transport crisis. The main approach has been to create new capacity as a sequel to capacity shortages instead of realistic anticipation of future demand. This is partly because meagre attempts have been made to integrate physical planning with overall investment planning at the city level (Mohan, 1992). Mere expansion of capacities has benefited the minority who have access to private modes. Such policies have implicitly subsidised these modes by the extent of social and environmental damage external to their use. Failure of public policy to internalise these external costs unquestionably makes the use of private modes artificially cheap distorting competition between private modes and public transport (Pucher, 1995).

At the national level plan priorities and allocations have been biased towards 'freight' traffic which is perceived of as being more directly connected with economic activity and development needs. Therefore, 'passenger' traffic: inter-urban, intra-urban as well as rural, has deteriorated due to relative neglect (Report of the National Transport Policy Committee, 1980, pp. 2-3). Proposals put forth in the 'Five Year Plans' have been too general with little manifestation of the acuteness of the urban transport crisis.[1]

Against this backdrop, the importance of a 'sustainable transport development strategy' (Dalvi, 1996), assumes critical significance especially in the cities of the developing world.

[1] Some of these proposals are the construction of by-passes around congested towns, setting up of 'self-contained residence-cum-work places', rationalization of the fare structure, energy conservation, modernisation, and so on.

The intention is to reduce adverse effects of private modes and more important to improve the urban environment as a place to live in, reduce trip lengths by land use planning, switch to soft modes (walking and cycling) and public transport (Banister, 1991), making efficient use of existing infrastructure and resources. In keeping with this strategy, particularly the notion that public transport will be a key element of this approach, the objective of this research work is to delve into the 'economic characteristics' of three major regulated urban bus transit systems providing 'conventional' type of mass transit services in the cities of Delhi, Bombay and Madras. These are, the 'Bombay Electricity Supply and Transport Undertaking' (B.E.S.T.) operating in Bombay, the 'Pallavan Transport Corporation' (P.T.C.) operating in Madras and the 'Delhi Transport Corporation' (D.T.C.) operating in Delhi. These corporations play a significant role in their respective cities of operation catering to a considerable proportion of urban transport trips, especially for movement to and from work.

Unearthing the behaviour of 'costs' is crucial for examining economic characteristics of transportation industries. 'Cost functions' which depict the relationship between costs and factors affecting costs can be empirically estimated to throw light on various economic facets of these industries such as the extent of scale economies, substitution possibilities between factors of production, the elasticity of demand for these factors, possibilities of reaping economies of density and scope as well as productivity growth over time.

Generally speaking, the structure of costs has a significant bearing on policy issues. For instance, the nature of costs could provide guidelines for a sound pricing policy, for determining optimal levels of subsidy or for prescribing the economically efficient size of an undertaking. Intra-modal cost comparisons could be facilitated, forming a basis for policies designed in accordance with the notion of 'balanced transportation' (Miller, 1970, pp.32) meant to determine 'that traffic allocation which will satisfy transport needs of the economy at minimum cost' (Meyer et al.. 1959, pp.16). Broader policy matters in relation to the extent of regulation, the question of privatisation, the impact of past policies on efficiency could be assessed more rationally by a cost function analysis, thereby 'introducing a degree of quantification into what has often been essentially, a qualitative series of arguments.' (Button, 1985, pp. 9)

Thus, more specifically, the purpose of this research work is to estimate appropriately specified 'cost functions' separately for each of the urban bus transit firms mentioned above, on the basis of monthly time series data. A sound theoretical and quantitative base, that characterises this cost function, has been embedded to ensure authenticity of results. A host of 'economic effects' have been subsequently derived and interpreted for the purpose of providing overall directions for efficient operation of bus services. The rationale for covering three major transit corporations was to upgrade the interpretation of results by providing scope for comparison of the same across these firms.

Sections 2 to 5 form the core of this presentation. The origin and growth of any urban transit system is intricately connected with the urban growth process specific to the city where it operates. Section 2 focuses on the consequences of varying operating conditions across the cities for the cost function analysis. To aid in appropriately specifying cost functions for the urban bus transit firms under study, a critical review of literature, related to the application of cost functions in transportation industries, was attempted. The main findings of this exercise are summarised in Section 3. The purpose of Section 4 is to provide a detailed outline of the basic methodology used and the data base resorted to for depicting the cost structure of the three urban bus transit firms being scrutinised. The constraints involved and the assumptions made surrounding the procedural intricacies in relation to the theoretical base, the quantitative base and the variables incorporated into the cost function are highlighted at every stage. Section 5 presents the final results of our empirical analysis and the interpretations thereon. The last section provides a brief summary of this research work highlighting the implications that emerge from the cost function analysis directed towards deciphering and providing a quantitative evaluation of 'economic characteristics' related to the three urban bus transit firms under study. The need for technology upgradation, the significance of a rigorous maintenance policy, the necessity of designing, implementing and enforcing innovative 'bus priority measures' are some important implications that emerge from our analysis. Presence of different kinds of 'economies' within the existing set-up was detected in each case. Considerable cost savings could accrue by exploiting these economies judiciously.

2. Significance of Time Series Analysis

As a prelude to the quantitative analysis of bus transit costs, an attempt was made to unravel interdependencies and interlinkages between the urban growth process and the transportation system in each of our case study cities. An important methodological proposition emerged out of this qualitative assessment. Varying patterns of urban growth as well as differing characteristics and peculiarities of the transportation systems[2] across the case study cities seemed quite apparent. This could have crucial implications as regards overall operating environment and therefore 'costs'. Any attempt to capture these diversities accurately in terms of measurable variables for incorporation into the cost function could be a complex exercise. The preferred procedure was to estimate cost functions separately for each of the three case study bus transit corporations. It was contended that the appropriateness of this 'city-specific' time-series analysis could be confirmed by assessing how far cost function coefficients differed across the transit firms, manifesting diverse operating conditions.

In a study conducted to scrutinise costs of U.S. railroad operations, Braetigam et al. (1982, pp. 274) point out that failure to capture firm-specific effects could lead to biases in estimated coefficients important to policy prescriptions. There is therefore an important role for econometric analysis of costs at the level of a single firm using time series data '...avoiding the effects of mixing technology.' Under similar contextual considerations Berechman (1983) and Berechman et al (1984) rationalise the importance of firm-specific time series analysis in their study of bus transit costs pertaining to cities in Israel and the U.S. respectively. They stress that lack of homogeneity in production structure as well as output units across firms in a cross-section sample may be an important cause behind erroneous results. They contend that in order to circumvent this problem it may be preferable to utilise time series data at the firm level.

[2] A review of the transit firms revealed varying institutional set-up. This could result in varying working environment within the bus corporation especially, accountability and motivational factors. The B.E.S.T. (Bombay) has been under the municipal corporation of Greater Bombay since August, 1947. The P.T.C. (Madras) is a company with an equity base (53% of the net worth being paid up equity and the remaining 47% being loan capital) under the Indian Companies Act' since 1972. During the study period, the D.T.C. (Delhi) was a statutory corporation, established under the 'Road Transport Corporation Act' of 1950 directly under the control of the Government of India. The regulatory framework, fare-structures, types of services and even technology varied across the corporations, reinforcing the importance of 'city-specific' time-series analysis.

Based on this methodological premise, cost functions have been estimated separately for each of the three urban bus transit corporations under study. Disaggregated monthly time-series data has been resorted for this purpose. Data relating to all variables was obtained from each bus transit firm's records and internal departmental publications. Due to data constraints, the study periods vary somewhat across the firms. However, an important consideration was to have as large a data set as possible in order to ensure feasibility and accuracy of the econometric analysis. Accordingly, for B.E.S.T. (Bombay) the study period covers the months between April'86 and March'94 but for P.T.C. (Madras) the study period covers the months between April'81 and March'94. The respective study period for D.T.C. (Delhi) encompasses the months between April'80 and February'94.

3. Review of Literature

A detailed and critical review of literature which traces the evolution of cost studies applicable to transport industries was conducted to aid in specifying cost functions appropriately for the three case study urban bus transit firms. While the focus has been on the urban bus transit sector, studies undertaken to analyse the behaviour of costs of other land-based transport modes has been quite comprehensively covered as part of the survey.

Overall, cost functions as applicable to transport industries have evolved from simple analytical constructs to fairly complex structures. Considerable research efforts have been invested for strengthening the theoretical base of the cost function specification. Emphasis has shifted towards the use of flexible functional forms which permits the study of a wide range of 'economic effects' related to the industry. Advances made with respect to the definition of 'output' have also contributed to a better depiction of the cost structure of transport industries.

Most of the earlier bus cost studies attempt to depict the cost structure in terms of simple statistical relationships between costs and factors affecting costs. These studies exemplify the straightforward methodological framework involved. Cost functions are estimated by intuitively 'itemising potential influences on costs' (Williams, 1979, pp. 210). Generally, linear and log-linear functional forms are used to depict the cost relationship, which are therefore easy to estimate by standard least square regression techniques. Despite these advantages of procedural simplicity, a serious limitation of these studies is that the cost models developed are theoretically deficient, making it difficult to impart economic meaning to the results emanating from the analysis. The structure of these cost models impose apriori restrictions on the underlying production technology. For instance, the linear cost function implies a Leontief technology while a log-linear cost function implies a Cobb-Doulas technology[3]. Any investigation into substitution possibilities between factors is therefore ruled out and the hypothesis of a 'U-shaped' average cost curve with regions of increasing, constant and decreasing returns to scale cannot be tested. Thus, inherent properties of linear and log-linear functional forms makes any bus transit cost study narrow in scope and limited in focus.

A second limitation of the earlier bus cost studies relates to the definition of 'output' of a transit firm. In all cases the 'output' variable has been incorporated into the cost function by using aggregate measures such as 'vehicle-miles' or 'seat-kilometers'. This is a serious misspecification because the output of a transit firm is multidimensional by its very nature. '...Since the mix of output and the way in which it is produced affect the firm's costs, it is clearly inappropriate to estimate cost functions by using a single measure of output' (Friedlaender et al, 1981, pp. 16).

Due to these lacunae, considerable research efforts appeared to have been aimed at reinforcing the theoretical base of cost function specifications relating to transport industries. As an outcome of these pursuits, since the early eighties, cost functions have been developed in consonance with 'duality' theory of production and costs and expressed in terms of flexible functional forms such as the 'translog'. This has permitted the study of a whole host of 'economic effects' related to these industries. Further, the possibility of depicting 'heterogenous' nature of output of a transport firm has contributed significantly to a better potrayal of costs in these industries. The basic approach has been to disaggregate 'output'

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[3]The 'linear' cost function implies a fixed-proportion technology ruling out substitution possibilities between factors, while, the 'log-linear' cost function implies that the elasticity of substitution between factors is always unity. Similarly, these functional forms imply a restrictive framework as regards 'economies of scale'. The 'linear' cost function depicts either increasing or decreasing or constant returns to scale. Thus scale economies can vary with 'output' but only in one direction. The 'log-linear' form is even more restrictive as, in this case, economies of scale would turn out to be a 'constant' value throughout the entire 'output' range.

into different kinds or to expand the 'output' vector to include 'output attribute' variables. Railroad cost studies are examples of the first kind wherein output is disaggregated into 'freight' and 'passenger' services. While, in the case of trucking cost studies, in order to represent trucking technology more accurately, the thrust of research work has been to expand the output vector to include operating characteristics such as 'length of haul', 'load size', 'shipment composition' in addition to the physical measure of output 'ton-miles'. Most of these studies infer that costs can be quite sensitive to service characteristics. These cost functions termed as 'hedonic cost functions', have become common in literature following pioneering work by Spady and Friedlaender (1978). 'If point-to-point transportation movements are viewed as the true cost-causative outputs of the firm, a firm operating even a relatively small network must be viewed as producing an astronomical number of products.[4] The hedonic approach has, in large part, arisen as an attempt to deal with the problem of networks... Use of hedonic cost functions enables the investigator to, in effect, perform often unavoidable aggregation based upon informed judgements about characteristics that are likely to have important impacts upon the costs associated with producing a given aggregate output vector' (Panzar, 1989, pp. 43). The evidence emerging from these trucking studies clearly indicates that the multiproduct approach not only yields more robust empirical results than the single product approach, but also provides insights into industry behaviour that cannot be provided by single product specifications (Bailey et al., 1982, pp. 1033).

Few cost studies related to the urban bus transit sector have explicitly incorporated the multi-output nature of transport industries. This is partly because most urban transit firms were considered to be typically 'single-service' firms, providing the conventional type 'fixed-route' and 'fixed-schedule' services on city roads. However, with changing contextual conditions and better conceptual developments the somewhat more recent literature attempts to unearth the cost structure of urban bus transit firms under a multiproduct framework of analysis. Both types of multi-output approaches have been attempted in urban bus transit cost studies. For instance, while determining the cost structure of the U.S. urban bus transit industry, Windle (1988) utilised a hedonic translog cost specification by expanding the output vector to include output characteristics such as 'speed', 'average trip length', and 'load factor' in addition to

[4]Ideally, for instance, the extent of disaggregation could depend on the ability to view transport cost-causative output as a vector 'Y' such that $Y=\{Y_{ij}^{kt}\}$ where, 'Y_{ij}^{kt}' is the flow of commodity 'k' between origin 'i' and destination 'j' at period 't' (Jara Diaz, 1982, pp. 268).

the generic measure of output namely, 'passenger-miles'. Talley et al. (1986) and Colburn et al. (1992) in their analysis of a multiservice transit firm in the U.S., decompose total service-miles into different types of services such as conventional 'motor-bus' service-miles, 'elderly and handicapped paratransit' service-miles, 'van-pool paratransit' service-miles and 'dial-a-ride' paratransit' service-miles. Such multi-output cost specifications, on which these studies are based, permitted the computation of economies of 'scale', 'scope' and 'density'[5] providing useful and new evidence on the operational and cost characteristics of the urban bus transit industry and therefore directions for innovative policy implications for cutting costs and minimising inefficiencies. In our present analysis of bus transit costs in the cities of Bombay, Madras and Delhi both types of multi-output analyses have been experimented with. For B.E.S.T. (Bombay), the output vector has been decomposed into 'ordinary services' and 'limited services'. A similar procedure was adopted in the case of D.T.C. (Delhi) wherein the generic measure of output has been disaggregated into 'city services' and 'inter-state' services. The 'hedonic framework' has been attempted in all the three cases by expanding the output vector to include output attribute variables such as 'speed of service', 'frequency of service' and 'load factor'.

4. Methodological Framework

4.1 Theoretical base:

In this study, the analytical framework underlying the empirical cost structure estimation is based on developments in duality theory which unravels the relationship between the neo-classical production and cost functions.[6] Given a 'well-behaved'[7] production function, duality principles establish the existence of a unique cost function which is the minimum cost of producing a given output level during a given time period, expressed as a function of input prices and output. The neo-classical cost function is specifically applicable to regulated

[5]When the proportionate increase in costs is less than the proportionate increase in output, 'economies of scale' are said to exist. A multiservice transit firm exhibits 'economies of scope' if the cost of providing different types of services jointly in one firm is less than the cost that would have to be incurred if these were produced separately. The manner in which output is provided across the network in terms of the routing pattern, scheduling of services could affect costs. The measure of 'economies of density' attempts to capture some of these relationships. More specifically, 'returns to density' reflects the relationship between unit costs and the extent to which existing capacity is being utilised.

[6]Chambers, (1988).

[7]Satisfies regularity conditions such as 'monotonicity', 'concavity' and 'essentiality'.

transport industries as it depicts the optimising behaviour of decision units fairly well. Under the regulatory framework, these industries are required to supply services demanded at predetermined rate structures, implying that 'output' can be treated as an exogenous variable.[8] Exogeniety of 'factor prices' is justified on grounds that the transport firm is a price taker in the factor market. Given output level and factor prices, entrepreneurial decisions are aimed at minimising costs by selecting the optimum combination and levels of factor inputs.[9] '...in light of the increasing pressure on public firms to hold down costs this would appear to be an unobjectionable assumption.' (Williams et al., 1981, pp.265)

However, the theoretical assumption of 'cost minimisation' may be somewhat stringent, discounting problems of 'x-inefficiency' (Leibenstein, 1966).[10] In situations where competitive pressures are light, as in the case of the B.E.S.T. which has a virtual monopoly in the provision of bus services, firms may be simply lethargic or otherwise not motivated to control costs. Hence input costs are not minimised. This may no doubt be of significance when we consider the three bus transit firms under study which by and large have been protected from competitive pressures. Inability to quantify and account for these qualitative factors that constitute 'x-efficiency' parameters directly into the cost function analysis is no doubt a limitation of the present exercise. We therefore proceed with the conventional 'cost minimisation' assumption attempting to ascertain whether the phenomenon of 'x-inefficiency' gets reflected indirectly in terms of violations of the theoretical consistency conditions.

[8]'The assumption of exogenous output in regulated industries is an established feature of statistical cost analysis' (Koenkar, 1977, pp. 58, FN 4).

[9]As compared to the production function, the cost function may be preferable as use of input prices in the cost function limits multicollinearity problems. Further, derivation of elasticities of substitution and demand from the production function can be a complicated exercise involving matrix inversions of coefficients, thereby exaggerating estimation errors. Derivation of these economic effects from the cost function is comparatively straightforward avoiding these problems (Binswanger, 1974, pp. 377).

[10]'There is more to the determination of output than the obviously observable inputs. The nature of management, the environment in which it operates and the incentives employed are significant' (Leibenstein, 1966, pp. 401). The concept of 'x-efficiency' encompasses all these qualitative factors which termed as "non-input output growth factors" may well contribute to the enhancement of output. Unit costs would then depend on 'x-efficiency' which would vary in consonance with the degree of competitive pressures as well as other motivational factors. Response to such pressures in the nature of effort, search or the utilisation of new information can be quite significant.

4.2 Cost function variables:

Broadly speaking, 'output' and 'factor prices' constitute the principal independent variables in the cost function analysis. In addition a 'time trend' variable has been included to infer the nature of technical change over time. Basic data relating to all variables was obtained from the respective bus transit firm's internal departmental records. Both 'producer-related' and 'user-related' variables have been experimented with while specifying the 'output' variable in the cost function. 'Producer-related' measures of output such as 'effective-kilometers' or 'seat-kilometers'[11] reflect the output capacity of the bus transit firm. The advantage of using these output measures is that data is easily available and less susceptible to measurement errors. What is more, major cost items like 'labor' and 'fuel' may tend to be more correlated with these measures of output, enhancing the possibility of good statistical results while estimating the cost function. However, these technical measures of output may not adequately reflect the basic economic motive of providing bus services namely, carrying passengers. 'User-related' measures of output such as 'passenger-kilometers', 'passengers carried' or 'passenger-revenue' have been used in more recent studies on urban bus transit costs to mitigate this problem. The limitation surrounding 'user-related' output variables is that inputs may not vary systematically with these output variables. Further, data pertaining to these output magnitudes may not be as accurate as 'producer-related' output measures.[12] In this study, two cost models have been estimated, one based on the 'producer-related' measure of output 'effective-kilometers' and the other based on the 'user-related' measure 'deflated passenger-revenue'.[13]

[11]'Effective-kilometers' reflects kilometers reflects kilometers operated for the purpose of earning revenue. It therefore, excludes 'dead-kilometers' which arise due to movement of buses from depot to terminus. movement of buses for testing or movement of buses sent as relief in case of accidents and breakdown. This measure of output has been widely used in a number of studies conducted for analysing the cost structure of the urban bus transit industry. 'Seat-kilometers', which is the product of effective-kilometers and the seating capacity of the bus, has been used in some studies to capture the variation in costs associated with the size of the vehicle. This may be of significance in cross-section analysis where the sample may consist of bus companies operating vehicles of different sizes.

[12]For instance, data on 'passengers carried' or 'passenger-revenue' is primarily obtained from data on sale of tickets. However fare-evasion or misappropriation of fare-box revenue, which may not be an uncommon phenomena in public bus corporations in developing countries (Armstrong et al., 1987), might lead to an underestimate of 'passengers-carried' or 'passenger-revenue' hampering accuracy of results.

[13]Conceptually, the 'passenger-kilometers' measure comes closest to representing the output of a transit firm. Passenger-kilometers for a certain distance category is given by the product of passengers traveling this distance and the distance traveled. Aggregating over all such distance categories we get the total 'passenger-kilometers' for a transport firm. But very often, it may be difficult to obtain data on distance traveled by each passenger. This may require a detailed sample survey. If the requisite data is not available, proxies for passenger-kilometers may have to be used. For instance, in some studies 'deflated passenger-revenue' has been used, the logic being that, since fares are related to distance, 'passenger-revenue' can be perceived of as being a crude multiple of 'passenger-kilometers'. 'Passenger carried' or number of fare paying passengers, has been

The rationale for estimating two models is that each would have different implications from the point of view of interpretation of results.

Four factors, 'labour', 'energy', 'capital', and 'maintenance' have been identified as the main inputs in the bus transit industry. Accordingly, four factor prices enter the cost function specification. Due to lack of requisite data, construction of factor prices implicitly assumes the need for homogenisation of heterogeneous inputs especially, different types of labor and capital or the whole array of maintenance inputs that exist. Further, as will be evident 'stock variables' have been used in place of 'flow variables' for the same reason. Fixity of certain inputs was ruled out and it was assumed that all inputs adjust instantaneously to their long run equilibrium values.[14]

Construction of the unit price of 'energy' does not present any particular problem and was arrived at in the following way:

P_e=Total expenditure on fuel / Total quantity of fuel consumed.

Similarly, the unit price of 'labor' was constructed as:

P_l=Total expenditure on labor / Total number of employees.

Two comments on the unit price of labor, constructed above, are warranted. Firstly, the denominator in the above expression, 'total number of employees', is a stock measure. Ideally, a flow variable such as 'man-hours of operation' would have been preferable. Secondly, time-series data on average pay scales for different categories of labor was not available. Hence there was no way of determining a weighted average unit price of labor which takes into account the heterogeneous nature of the labor input. Data on total expenses incurred on

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incorporated to reflect 'output' in other studies since it is more directly related to the actual market transaction of a bus corporation.

[14]Instead of assuming that all inputs adjust instantaneously to their full equilibrium levels researchers in the last decade have increasingly adopted a framework that distinguishes variable from quasi-fixed inputs, where the latter adjust only partially to their full equilibrium levels within one time period. Though, 'capital' has generally been specified to be the only fixed input in most studies, the existence of life time contracts may imply that both 'capital' and 'labor' may be better considered as fixed in the short run. A distinction has to be made between the long run cost function and the short run cost function and the methodology for deriving the same assumes new complexities. All inputs are considered to be variable in this study. There was sufficient variability as regards the 'labor' input in all the three cases under study during respective study periods. Further, the bus industry has relatively small capital requirements and it is our contention that the bus fleet which represents 'capital' input can be adjusted easily at least in comparison to the fixity of the capital input say in the case of railroads, shipping or even the airlines industry.

'energy' and 'labor' as also total energy consumed and staff strength was obtained from the internal records maintained by the bus corporation.

The price of capital, 'P_k' was constructed to approximate the one period 'user cost of capital' as closely as possible. This is given as:[15]

$$P_k=P_n(r+d)$$

The aggregate price of a new bus 'P_n' was obtained from the 'engineering department' in the case of B.E.S.T. (Bombay) separately for 'single-deckers' and 'double-deckers'. In the case of P.T.C. (Madras), 'P_n' refers to the price of a new 'chassis' as body-building work is undertaken indigenously at the 'Chrompet' body building unit which is owned by the P.T.C. 'Tata' as well as 'Leyland' company chassis are purchased by the D.T.C. The body-building is then undertaken by sub-contractors who finish the buses. The aggregate price of a new bus was computed by taking both these components of the price into account. For each bus corporation the mean rate of interest 'r' was arrived at by averaging across all the lending rates prescribed by various funding agencies.[16] During the study period, the computed mean rate of interest varied between 8.21% and 16.01% per annum for B.E.S.T., was constant at 12.5% for P.T.C. and varied between 15% and 18.43% per annum for D.T.C. The depreciation rate 'd' was obtained from the respective 'accounts section' of the bus corporations. It was 11.25% per annum for B.E.S.T. (Bombay), 40% per annum for P.T.C. (Madras) and 12% per annum for D.T.C. (Delhi). The above formulation with respect to the price of 'capital' would give the annual 'user cost of capital' since the price of a new bus, the interest rate and the depreciation rate relate to a particular year. This was transformed to a monthly series to be compatible with the monthly time series analysis in the following manner:

$$P_k=P_n(r+d)/12$$

An attempt was also made to refine this version of the 'user cost of capital' so as to reflect the heterogeneous nature of the capital input in the case of B.E.S.T. (Bombay). Almost 26% of B.E.S.T.'s total fleet of buses are 'double-decker' buses. The rest are 'single-deckers'. The

[15] This is the 'Jorgensonian rental price'

[16] During the study period, the B.E.S.T. obtained loans from the World Bank, the 'HDFC', the 'BMRDA' the 'HDFC' the 'IDBI', the 'SIDBI' and floated a public loan. Overall the interest rates varied between 7.25% and 18.07% across the agencies and over the study period. The P.T.C. has only one source of funding namely, the 'State Government'. Information gathered revealed that the interest rates on long term loans as well as 'ways and means advances' was 12.5% for the entire study period. The D.T.C. was authorised to obtain loans only from the 'Central Government'. The interest varied with the nature of the loans namely, 'ways and means advances' and 'capital loans'.

price of a new bus (P_n) would vary depending on the type of bus under consideration. Thus, the above formulation was computed separately for single-deckers and double-deckers and the the final version of the 'price of capital' variable incorporated into the cost function was a weighted average of these prices, given as:

$$P_k=[(P_k^s \cdot K^s)+(P_k^d \cdot K^d)] / [K^s+K^d]$$

where, P_k^s=monthly user cost of capital for a 'single-decker'; K^s=number of 'single-deckers' in the fleet; P_k^d=monthly user cost of capital for a 'double-decker'; K^d=number of 'double-deckers' in the fleet.

The price of 'maintenance' variable poses an aggregation problem. There are innumerable material inputs used for maintaining buses. It is not possible to aggregate across all these materials to arrive at one measure of maintenance input. An attempt was made to develop a composite price index of maintenance to overcome this problem. Conceptually, if 'M_1', 'M_2' and 'M_3' are three principal maintenance inputs, for which data on time-series price index is available then a composite price index could have been computed as:

$$P'_m=\alpha P_{M1} + \beta P_{M2} + [1-(\alpha+\beta)]\, P_{M3}$$

where, P_{M1}, P_{M2} and P_{M3} , denote prices of maintenance inputs 'M_1', 'M_2' and 'M_3', respectively, and α, β, denote shares of specific maintenance input in the total maintenance expenditure. We identified 'tyres', 'tubes' and 'lubricants' for which time series data on price index was available for developing the above composite price index. However, as proportion of total maintenance expenses, these items account for only about 40% of the expenditure. If we based our maintenance price on these items alone, it would be erroneous as important maintenance inputs accounting for about 60% of the total maintenance expenses would be left out.[17] To circumvent this problem, the total number of 'maintenance' department employees was used as a proxy for the total quantity of maintenance inputs used and the unit price of maintenance entering the cost function was given as:

P_m=Total expenses on tyres, tubes, spares and materials / Total maintenance employees.[18]

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[17]The records showed that this 60% was presented under the heading 'spares and materials' in the expenditure' statements. Our discussions with the maintenance department officials indicated that a large number of maintenance materials are clubbed together in this category.

[18]Berechman et al. (1984) and Williams et al. (1981) use a similar formulation in their cost function analysis of urban bus transit services, the only difference being that they use a flow variable: 'labor hours of maintenance' in the denominator in place of the stock variable we have used.

In addition to the 'output' and 'input price' variables, a time trend variable 't' was also incorporated into the cost function to assess the nature of technical change over time. Econometric necessity and the fact that technical advances usually requires the passage of time led to the widespread identification of technical change with a time term in the production function[19] (Chambers, 1988, pp. 203). Conventionally, technical change is deciphered from the cost function as the downward proportionate shift in the cost function over time which could be obtained by differentiating costs with respect to the time trend variable in the cost function.

The dependent variable 'total costs' was computed using the accounting relationship:

$$C=P_k.K+P_l.L+P_e.E+P_m.M$$

where, C=total costs; $P_i(i=k,l,e,m)$= price of inputs and K,L,E,M are total quantities of inputs 'capital', 'labor', 'energy' and 'maintenance'. The dependent variable in the share equations was derived as:

$$S_i=(P_iX_i)$$

where, S_i= share of input 'i' in total costs and P_iX_i= the total expenditure on input 'i'

Detailed investigation of the data revealed a common trend in all cases. The study periods are marked by a substantial increase in the prices of inputs leading to a staggering increase in total costs. Specifically, what stands out prominently is the rising trend as regards the share of 'labor' costs as a fraction of total costs during the entire study period. Increasing share of 'labor' costs may no doubt indicate the 'labor-intensive' nature of the bus transit industry, but it may also call for substantial restructuring in order to enhance 'labour' productivity if costs are to be curtailed. This point needs to be stressed particularly in the case of public undertakings, like the ones under study, wherein work contracts may not permit the possibility of outright expulsions.

4.3 Capturing output heterogeneity:

Attempts were made to depict output heterogeneity by disaggregating generic measures of output into different types of services provided as well as by expanding the output vector to include qualitative variables that depict 'service characteristics'. For B.E.S.T. (Bombay), the

[19]The criticism of this approach is that it is a passive way of measuring technical change without clearly mentioning what motivates technical change.

multi-output framework was conceptualised in terms of two different types of services namely, 'limited' services and 'ordinary' services. To account for higher travel speeds and consequent better quality of service the fare structure of 'limited' services is higher than that of 'ordinary' services. Trip lengths also vary widely across these two types of services. However, the estimates obtained on the basis of this output specification was not found to be satisfactory. Firstly, only a restrictive 'homogenous' version of the translog cost function could be estimated. Further, even after correction, the problem of 'autocorrelation' could not be removed. For D.T.C. (Delhi) the multi-output framework was visualised in terms of two types of services namely, 'city' services and 'inter-state' services. Route-lengths differ markedly across the two types of services. Until recently, market conditions also differed significantly. Inter-state operations have always faced stiff competition from other state transport undertakings as well as authorised and unauthorised private operators who operate bus services between Delhi and neighbouring townships. Whereas, as regards city services, D.T.C. has had a virtual monopoly in the provision of these services at least for most part of the study period. In this case, although the estimates of the non-homothetic translog cost function could be obtained, the multi-product scale economies implied a negative 'marginal cost' in the case of 'inter-state' services which is theoretically inconsistent.

Due to these limitations, a 'hedonic' framework[20] was preferred to represent output heterogeneity for all the three bus corporations under study. The general form of the 'hedonic' cost function including the service attribute variables may be given as:

$$C=c(\mathbf{P},y,t,\mathbf{z})$$

where, C = total costs; **P** = vector of input prices; y = generic measure of output; **z** = vector of service attributes and t=time trend variable. In this study attempts were made to include three service attribute variables namely 'speed of service',[21] 'frequency of service'[22] and 'load factor'.[23] Out of these three variables only the 'frequency of service' variable could be effectively incorporated. Due to lack of data on 'hours of operation' the 'vehicle utilisation' ratio had to be used as a proxy for 'speed'. Probably, this was not an accurate way of representing the 'speed of service' because, when incorporated into the cost function problems

[20]To recapitulate, hedonic functions are often used because of aggregation problems (Gillen et al., 1990, pp. 13). Given varying conditions across the network, each origin-destination pair should be treated as separate outputs. Since it is impossible to estimate a cost function with innumerable, some kind of 'aggregation' is inevitable. Output attribute variables are introduced to control for some of the aggregation bias.

[21]Speed of service=Effective-kilometers operated daily/Average number of buses on road daily. This is the vehicle utilisation ratio. Ideally, 'speed' should have been measured as: Effective-kilometers operated daily / Hours of operation daily.

[22]Frequency of service=Effective-kilometers operated daily/ Total route-kilometers.

[23]Load factor=Passengers carried daily/ Total carrying capacity offered daily.

of multicollinearity were detected and the variable had to be dropped. Inability to include the 'speed of service' variable is no doubt a limitation of the study. As a result the interrelationship between 'speed', which captures an important aspect of the external operating environment and operating 'costs' could not be analysed.

4.4 Functional form and estimation procedure:

A flexible 'translog' cost function was selected for econometric estimation of the neo-classical cost function. The translog cost function can be envisaged as a second-order Taylor's series approximation in logarithms to an arbitrary cost function. The translog functional form is advantageous as it places no apriori restrictions on substitution possibilities, allows scale economies to vary with the level of output and permits a multiproduct framework of analysis. Further, parametric restrictions can always be imposed to confirm the superiority of the unrestricted translog cost function (non-homothetic) over other more restricted forms such as 'homothetic', 'homogenous', 'constant returns to scale' or the 'Cobb-Douglas' form.[24]

The cost function is estimated along with the share equations,[25] which only increases the degrees of freedom without adding to the number of parameters to be estimated. The share equation system possesses a special property in that for each observation, the sum of the dependent variables (cost shares) over all the equations always equals unity. Or,

$$\Sigma_i S_i (= P_i X_i / C) = 1$$

Therefore, the sum of disturbances across equations must always equal 'zero'. This means that the errors associated with the cost share equations cannot be mutually independent and the disturbance covariance matrix of the share equations is 'singular', $[E(u_i u_j)]=0$. The procedure adopted to overcome this problem is that, prior to estimation, one of the share equations is dropped and the remaining set of equations estimated in order to reduce the system to a 'non-singular' one.[26] If we impose the constraint that the cost function must be homogenous of degree one in prices, which is a theoretical necessity,[27] the system is reduced to a non-singular

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[24] 'The literature has produced something of a competition in the development of exotic functional forms. However, the translog function has remained the most popular and by one account, (Guilky et al., 1983) is the most reliable of several available alternatives' (Green, 1990, FN.25)

[25] Share equation for input 'i' may be given as 'S_i' where $S_i = \delta \ln C / \delta \ln P_i$ wherein $\delta C / \delta P_i = x_i$ by 'Shephard's lemma' (x_i=quantity of input 'i')

[26] It has been shown (Barten, 1969) that maximum-likelihood estimates of a system of share equations with one equation deleted is invariant to which equation is dropped.

[27] This means that only relative prices matter, or, $C(t\mathbf{P},y) = t.C(\mathbf{P},y)$

one. Imposing the linear homogeneity in input prices[28] and dropping the 'energy' share equation the final system of equations to be estimated may be given as:

$$\ln(C/P_e) = \alpha_o+\alpha_y \ln y+\Sigma_i\alpha_i \ln(P_i/P_e)+ \alpha_t t+ \alpha_{er}\ln er+1/2\, \alpha_{yy}[\ln y]^2+1/2\, \Sigma_i\Sigma_j\alpha_{ij}[\ln(P_i/P_e)\ln(P_j/P_e)]+1/2\alpha_{tt}t^2+ 1/2\alpha_{erer}[\ln er]^2+\Sigma_i\alpha_{iy} \ln(P_i/P_e)\ln y+\Sigma_i\alpha_{it} \ln(P_i/P_e).t+\Sigma_i\alpha_{ier} \ln(P_i/P_e)\ln er+\alpha_{yt} \ln y.t+\alpha_{yer}\ln y \ln er+ \alpha_{ert} \ln er.t$$

$$S_i=\alpha_i+\alpha_{ii} \ln(P_i/P_e)+\Sigma_j\alpha_{ij} \ln(P_j/P_e)+\alpha_{it}t+\alpha_{ier}\ln er$$

where, $\alpha_{ij}=\alpha_{ji}$ and C=total cost; y=output (Model 1: y=effective-kilometers; Model2: y=passenger-revenue); P=vector of input prices where; t=time trend variable where t=1,2,...n; r=frequency of service and $S_i(=P_iX_i/C)$=share of 'i' th input in total costs where X_i=input usage with respect to the 'i'th input.

Given the special property that sum of cost shares always equals unity, the system of share equations provides a 'seemingly unrelated regression model' that can be used to estimate the parameters of the system of equations. For efficient estimation one must take into account the correlation between error terms across equations. This is achieved through a systems method of estimation. Zellner(1962), devised a method which takes these factors into account when there is a system of equations ('Zellner's Seeminly Unrelated Estimator). The parameter estimates which emerge are numerically equivalent to those of the 'maximum likelihood estimator'. This method was therefore used to estimate the system of equations consisting of the cost function and the share equations.[29] After parameter estimates have been obtained the cost function has to be tested for theoretical consistency or 'well-behavedness'. Two main aspects to be checked are 'monotonicity' and 'concavity'.[30]

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[28] To impose linear homogeneity in input prices the following constraints have to be imposed: $\Sigma_i\alpha_i=1$; $\Sigma_i\alpha_{ki}=0$; $\Sigma_i\alpha_{li}=0$; $\Sigma_i\alpha_{ei}=0$; $\Sigma_i\alpha_{mi}=0$; $\Sigma_i\alpha_{ti}=0$; $\Sigma_i\alpha_{eri}=0$; where, i=k,l,e,m; y=output, t=time trend and er=frequency of service.

[29] This method uses equation by equation 'OLS' to obtain an estimate of the disturbance covariance matrix and then does 'generalised least squares' given this initial estimate on an appropriately 'stacked' set of equations. Further, one can update the estimates of the disturbance covariance matrix and iterate the Zellner procedure until changes from one iteration to the next in the estimated parameters and the estimated disturbance variance-covariance matrix becomes arbitrarily small.

[30] 'Monotonicity' implies that the cost function should be monotonically increasing in input prices. This can be detected by observing whether the fitted 'shares' are positive or not at all observations. 'Concavity' indicates that the cost function should be strictly 'quasi-concave' in input prices. This calls for 'negative semi-definiteness' of the bordered 'Hessian' of the cost function or, alternatively the 'nxn' matrix of substitution elasticities must be negative semi-definite at each observation.

5. Empirical Results: Interpretations and Overall Implications.

5.1 Some preliminaries:

Prior to the actual estimation exercise it was essential to look into the question of 'stationarity' and 'cointegratedness' of the variables since we have specified a regression model in time-series. Testing for cointegratedness can be quite complex in the case of multi-variate regression analysis encompassing a system of equations as in this study.[31] Hence, this was not attempted. Rather, the approach was to check whether the variables in the cost function were 'stationary'[32] or not to begin with, by resorting to the 'Augmented Dickey-Fuller' unit root test. If the variables were found to be stationary (integrated of the order zero) then it would imply that they are cointegrated. The results of this exercise indicated that none of the variables were stationary, but these variables were all found to be integrated of the order '1'. We proceeded with the assumption that since all the variables were integrated of the same order, there may exist a possibility that these could be cointegrated as well. It was not verified whether there exists a unique vector of 'β's ' as well, due to the fairly complex procedure involved. This is no doubt a limitation of our exercise. In this context it may also be worthwhile to note that the length of the study period in our analysis may not be sufficient enough for robustness of the cointegration analysis. Hakkio et al. (1991) have pointed out that the tendency of researchers to resort to more frequently sampled observations for enhancing the number of observations, thereby ensuring feasibility of cointegration tests, may be an erroneous procedure. They demonstrate that cointegration is a long-run concept and requires long spans of data to give tests for cointegration more power rather than merely large number of observations.

Another consideration that had to be assessed before presentation of the final results was to ascertain the 'structure of the cost function' which best depicts the underlying technology. The procedure involved was to check the validity of the parameter restrictions imposed on the 'non-homothetic' translog cost function by resorting to the 'likelihood ratio test'[33] (Christensen et al., 1976). For B.E.S.T. (Bombay), the non-homothetic version of the cost function could not be estimated at all due to problems of multicollinearity between the 'output' term and the

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[31] See Harris, R. (1995).

[32] Stationarity requires that a time series be in a particular state of statistical equillibrium. Non-stationarity implies the existence of some sort of a trend (stochastic or deterministic) in the series, implying that the moments of the distribution are likely to change over time.

[33] The likelihood ratio is given as: $\lambda=\{\Omega_R/\Omega_U\}^{-(T/2)}$ where, T=number of observations; Ω_R=determinant of the restricted disturbance covariance matrix (absolute value); Ω_U=determinant of the unrestricted disturbance covariance matrix (absolute value). Manipulating we get the test statistic which is distributed asymptotically as 'chi-squared' with degrees of freedom equal to the number of independent restrictions being imposed and is given by: $-2\ln\lambda=T\{\ln\Omega_R-\ln\Omega_U\}$

second-order 'output' terms in the cost function. Consequently, these second order 'output' terms had to be dropped from the more general non-homothetic cost function. In the case of the alternative with 'effective-kilometers' as the measure of output (Model 1), the resultant cost structure turned out to be 'homothetic'.[34] For the alternative with 'passenger revenue' as the measure of output (Model 2) only a 'homogenous' version of the more general translog cost function could be estimated. Due to these constraints the likelihood ratio test was conducted only in the case of P.T.C. (Madras) and D.T.C. (Delhi) to the test the validity of parameter restrictions. The test results confirmed the superiority of the 'non-homothetic' translog cost function over other more restrictive forms.

The main problem encountered while trying to estimate the system of equations was that of 'autocorrelation'. The system was therefore corrected for autocorrelation of the first order. More specifically, the procedure involved was to estimate each alternative before correcting for autocorrelation and noting the value of the 'Durbin-Watson' statistics. In the next step, correction for autocorrelation was undertaken, the 'Durbin-Watson' statistics noted and the presence or absence of the problem of 'autocorrelation' reconfirmed by the 'Box-Pierce' test based on the 'Q-statistics'.

5.2 *Estimates of the translog cost function:*

The final results of the estimation exercise for the three urban bus transit firms is given in Table 1.

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[34]Berechman (1983, pp. 19) found evidence of a homothetic production structure while developing a translog cost function for two bus co-operatives in Israel. Similarly, De Borger (1984, pp. 46) confirmed that the hypothesis of homotheticity could not be rejected while trying to estimating a translog cost function for a regional bus transport company in Belgium. A homothetic production structure was also reported by Williams et al.(1981) while estimating a translog cost function for twenty publicly owned municipal bus operators in the State of Illinois, the U.S.

Table 1: Estimates of the 'Hedonic' Translog Cost Function.

	B.E.S.T. (Bombay)		P.T.C. (Madras)		D.T.C. (Delhi)	
	Y=Effective-kms. (Model: 1)	Y=Pass-revenue (Model: 2)	Y=Effective-kms. (Model: 1)	Y=Pass-revenue (Model: 2)	Y=Effective-kms. (Model: 1)	Y=Pass-revenue (Model: 2)
Coefficient	*Homothetic*	*Homogenous*	*Non-Homothetic*	*Non-Homothetic*	*Non-Homothetic*	*Non-Homothetic*
α_o	1.160*	9.266	-20.434*	-166.833	-25.443*	6.445*
α_y (OUTPUT)	1.070*	0.016	2.282*	20.082	4.579*	1.534*
α_k (CAPITAL)	-0.056*	-0.041*	-0.453	-0.194*	-0.254*	-0.472
α_l (LABOR)	0.648	0.668	0.843	0.381	0.823	0.480
α_m (MAINT.)	-0.242	-0.250	-0.319*	-0.074*	0.542	0.170*
α_e (ENERGY)	0.650	0.623	0.929	0.887	-0.111	0.822
α_t (TIME)	0.009*	0.014	-0.026*	-0.091*	0.023*	-0.021
α_{er} (FREQ.)	0.584*	1.057*	2.361*	0.863*	-2.915*	-3.298*
α_{yy}	-0.055*	-	-0.059*	-1.111*	-0.250*	-0.153*
α_{kk}	0.200	0.197	0.218	0.218	0.222	0.219
α_{ll}	0.226	0.226	0.140	0.176	0.240	0.239
α_{mm}	0.037	0.040	0.091	0.066	0.110	0.110
α_{ee}	0.127	0.125	0.127	0.120	0.130	0.126
α_{tt}	1.968E-06*	1.027E-05*	-9.539E-05*	-1.067E-05*	-6.719E-05	-0.0001
α_{erer}	0.041	-0.023	0.410*	-0.043*	0.237*	-0.227*
α_{kl}	-0.135	-0.134	-0.102	-0.123	-0.124	-0.123
α_{km}	-0.008	-0.009	-0.046	-0.031	-0.044	-0.044
α_{lm}	-0.025	-0.026	-0.014	-0.016	-0.053	-0.054
α_{ke}	-0.057	-0.054	-0.071	-0.064	-0054	-0.051
α_{le}	-0.068	-0.066	-0.025	-0.037	-0.063	-0.062
α_{me}	-0.004	-0.005	-0.023	-0.019	-0.013	-0.012
α_{ky}	-	-	0.014*	-0.017	0.004	0.020
α_{ly}	-	-	-0.018*	0.0002	-0.037	-0.012
α_{my}	-	-	0.025*	0.010	-0.029*	-0.0001*
α_{ey}	-	-	-0.021	0.007	0.062	-0.0079
α_{tk}	-0.001	-0.001	0.0002*	0.0002	-0.0007	-0.00009
α_{tl}	0.0007	0.0005	-0.0005	0.0002	0.0004	0.0004
α_{tm}	0.0007	0.0008	0.0001*	-0.0004	6.228E-05*	-0.0001*
α_{te}	-0.0004	-0.0003	0.0002	0.0001	0.0002	0.0006
α_{ty}	-	-	0.004	0.005*	-0.001*	0.003*
α_{erk}	-0.062	-0.062	-0.067	5.987E-05*	-0.048*	-0.065
α_{erl}	-0.078	-0.079	-0.048	-0.0002	0.018*	-0.008*
α_{erm}	0.049	0.050	-0.039	-0.012	0.011*	-0.017
α_{ere}	0.091	0.091	0.154	0.012	0.019	0.090
α_{ery}	-	-	-0.210*	-0.042*	0.120*	0.284*
α_{ert}	-0.0006*	-0.001*	-0.003	0.002*	0.003*	-0.004

Notes: * Indicates not significant at the 5% level of service. Maint=Maintenance; Freq=Frequency of service

Table 1 (Continued): Important Statistics.

	B.E.S.T.	**(Bombay)**	**P.T.C.**	**(Madras)**	**D.T.C.**	**(Delhi)**
	Y=Effec-kms. (Model: 1)	Y=Pass-rev. (Model: 2)	Y=Effec-kms. (Model: 1)	Y=Pass-rev. (Model: 2)	Y=Effec-kms (Model: 1)	Y=Pass-rev (Model: 2)
	Homothetic	*Homogenous*	*Non-Homothetic*	*Non-Homothetic*	*Non-Homothetic*	*Non-Homothetic*
COST FUNCTION						
R^2	0.986	0.986	0.989	0.923	0.998	0.998
R^2	0.982	0.981	0.986	0.907	0.998	0.998
SER	0.020	0.020	0.023	0.060	0.012	0.012
DURBIN-WATSON	2.650	2.653	2.168	1.384	1.825	1.699
Q-STATISTIC	17.447	17.349	12.439	17.523	11.20	13.229
SUM OF SQUARED RESIDUAL	0.028	0.030	0.068	0.469	0.018	0.020
F-STATISTICS	230.74	227.37	393.51	56.781	3650.28	3425.78
SHARE EQUATION						
1. CAPITAL						
R^2	0.953	0.955	0.968	0.958	0.949	0.951
DURBIN-WATSON	2.572	2.581	2.620	1.293	1.801	1.771
2. LABOR						
R^2	0.968	0.969	0.980	0.969	0.997	0.997
DURBIN-WATSON	2.690	2.688	2.510	0.984	2.247	2.268
3. MAINTENANCE						
R^2	0.696	0.713	0.960	0.936	0.968	0.968
DURBIN-WATSON	2.663	2.663	2.397	0.642	2.310	2.323

@Critical values of the 'Q-Statistics': 5% level of significance ($\chi_{0.05}^2$)=21; 1% level of significance ($\chi_{0.01}^2$)=26.2

Table 1 indicates that coefficient estimates vary across the urban transit firms reflecting diverse operating conditions both internal and external to the bus firms. This reinforces the importance of conducting 'city-specific' time-series analysis rather than combining the three 'panel' data sets for estimation purposes. Coefficient estimates seem to alter depending on 'output' measure used as well. Accounting for these differences is crucial for meaningful interpretation of results. Coefficients associated with the 'price of maintenance' proxy variable are mostly significant and so are the coefficients linked to the only output attribute variable 'frequency of service'. The time trend variable coefficients are small partly because of the monthly time series data base which precludes major shifts in the cost function. Further economic interpretation of the parameter estimates was attempted by analysing derived 'economic effects' such as patterns of factor substitution, economies of scale and density as well as nature of technical change over time. These are summarised in the following sections.

5.3 *Elasticities of factor substitution and demand:*

A major advantage of the translog functional form is that it places no apriori restrictions on the elasticities of factor substitution and demand. The 'Allen partial elasticity of factor substitution' which has been widely used in many studies, was resorted to for the purpose of computing these elasticities (Chambers, 1988, pp. 93). The results are summarised in Table 2 for each of the three urban bus transit firms under study and for both versions of the translog cost function.

Table 2: Elasticities of Factor Substitution and Own Price Elasticity of Factor Demand

Estimate	B.E.S.T. Effective-kms. (Model: 1)	(Bombay) Passenger-rev. (Model: 2)	P.T.C. Effective-kms. (Model: 1)	(Madras) Passenger-rev. (Model: 2)	D.T.C. Effective-kms. (Model: 1)	(Delhi) Passenger. rev. (Model: 2)
σ_{kl}	0.0148	0.0224	0.1148	-0.0728	-0.0348	-0.0184
σ_{ke}	-0.3536	-0.2861	-0.0084	0.0777	-0.1925	-0.1528
σ_{km}	0.6334	0.5870	0.0477	0.8249	0.2196	-0.2226
σ_{le}	0.1023	0.0997	0.5816	0.3790	0.1021	0.0921
σ_{lm}	0.3563	0.3329	0.6586	0.5965	0.0445	0.0409
σ_{em}	0.6882	0.6440	0.0688	0.2279	0.3984	0.4212
σ_{kk}	-0.0175	-0.0536	-0.1087	-0.1249	0.2654 @	0.2189 @
σ_{ll}	-0.0980	-0.0976	-0.7697	-0.3944	-0.0289	-0.0346
σ_{ee}	-0.0379	-0.1351	-0.7511	-0.9390	-0.2548	-0.3222
σ_{mm}	-5.6784	-5.3008	-1.3187	-2.7870	-0.1647	-0.1743
ε_{kk}	-0.0049	-0.0150	-0.0402	-0.0462	0.0742 @	0.0613 @
ε_{ll}	-0.0480	-0.04787	-0.2386	-0.1223	-0.0125	-0.0149
ε_{ee}	-0.0057	-0.0203	-0.1427	-0.1784	-0.0418	-0.0515
ε_{mm}	-0.4542	-0.4241	-0.1714	-0.3623	-0.0214	-0.0226

Notes: Cross Allen partial elasticities of factor substitution in terms of the parameters of the translog cost function is given as $\sigma_{ij}=(\alpha_{ij}+S_iS_j)/(S_iS_j)$ If 'σ_{ij}' is greater than zero then it indicates that factors 'i' and 'j' are substitutes while if 'σ_{ij}' is less than zero then it implies that factors 'i' and 'j' are complements and own elasticities of substitution $\sigma_{ii}=[\alpha_{ii}+S_i(S_i-1)]/S_i^2$. The '$\sigma_{ii}$' are meaningless conceptually but need to be for regularity conditions to be satisfied. Or else, the own price elasticities of factor demand will not be negative, which is a theoretical necessity for a downward sloping factor demand curve. The own price elasticities of factor demand were computed as: $\varepsilon_{ii}= \sigma_{ii}. S_i$ which have to be negative.

There seems to be a fair amount of consistency in the magnitudes and signs of the elasticities irrespective of the output measure used. It may be worthwhile to note that Berechman et al. (1984) noted significant differences in magnitudes of the elasticities depending on which measure of 'output' was being used in the analysis. This is not substantiated by our analysis. If we compare the elasticities across the three urban bus transit corporations, we find that by and large, there is variation in the magnitudes of these estimates. This result once again probably reflects the varying conditions across the firms, justifying the importance of conducting 'city-specific' time series analysis. The own elasticities of factor demand have the theoretically correct negative sign, except in the case of D.T.C. (Delhi) where 'ε_{kk}' is positive for both the models experimented with. This reflects theoretical inconsistency.

Looking more closely at the elasticity estimates we find that the values of 'σ_{kl}' indicate either weak substitutability or complementarity between 'labor' and 'capital' implying that there is not much scope of adjusting the way in which these inputs are combined.[35] Complementarity between 'capital' and 'energy' as revealed by the estimates of 'σ_{ke}', reflects that buses are not fuel efficient. This only reinforces the fact that fuel efficiency levels measured in terms of 'kilometers per litre' (KMPL) have remained almost static or gone down.[36] In this connection, it must be noted that in the Indian context, bus chassis are actually truck chassis unsuitable for intra-city operations representing obsolete and out-moded state of technology' (Nagaraja, 1988). The fuel inefficiency depicted via this complementary relationship may also be a result of the adverse external operating environment in the context of our three case study cities wherein rising levels of congestion hampers efficiency of operations in terms of slower speeds and consequent deteriorating fuel consumption levels. There seems to be an ardent need for research and development efforts directed towards the design and development of fuel efficient buses more compatible with city driving conditions.

The most significant result that emerged out of the elasticity estimates was that substitution possibilities seemed to exist between 'maintenance' and all other inputs in the production process. The coefficients 'σ_{km}', 'σ_{lm}' and 'σ_{em}' are consistently greater than zero in all cases except in the case of D.T.C. (Delhi), where 'σ_{km}' is less than zero. Better maintenance of buses would ensure better day to day performance and go a long way in prolonging the

[35] Berechman et al. (1984), in their study of a single major California bus transit system in the U.S. qualify that this result may seem reasonable given the 'one bus one driver' technology which characterises most bus services. Button (1985) refers to this fixed factor proportions technology as the 'technologically unprogressive' nature of the bus transit industry.

[36] For B.E.S.T. (Bombay) the fuel consumption rate has remained static at 2.84 kilometers per litre, has gone down from 3.50 to 3.18 kilometers per litre in the case of D.T.C. (Delhi) and from 4.84 to 3.56 kilolometers per litre in the case of P.T.C. (Madras)

service life of a bus reducing the need for costly fleet replacement.[37] A strong maintenance drive would enhance energy efficiency in terms of kilometers run per litre of fuel consumed, resulting in higher vehicle-utilisation, greater fleet-utilisation and through better scheduling raise productivity of labor as well. Thus, the entire system could be effectively revamped, in a bid towards achieving better performance levels of all inputs in the production process. The contrary complementarity relationship between 'capital and 'maintenance' obtained in the case of D.T.C. (Delhi), is not an unexpected result given that there is a large number of over-aged buses in the fleet[38] which obviously require more maintenance. This clearly justifies the ardent need for fleet replacement by new buses. Needless to say, a determined maintenance culture would have wider ramifications in terms of reducing 'negative externalities' of bus operations such as pollution problems. This is of specific relevance for our case study cities of Bombay, Madras and Delhi wherein rising levels of pollution, mainly through vehicular emissions,[39] has become an issue of critical concern. Since emission levels of diesel fueled vehicles such as buses are very sensitive to proper tuning and maintenance, a persistent effort invested in enhancing maintenance standards seems inevitable.

Focusing on the own price elasticities of factor demand ('ε_{ii} ') what is worth noting are the low values of the estimates irrespective of the bus transit firm under scrutiny. This indicates that input demand is fairly inelastic in response to price changes, possibly due to fixity of certain factors or due to rigidity in factor proportions in the production process.[40]

Examining the elasticities of factor substitution and the own price elasticities of factor demand across the the three urban bus transit corporations the comparatively low values of the estimates in the case of D.T.C. (Delhi) is quite apparent. There seems to be some kind of a

[37] Williams et al. (1981, pp. 273) obtained a similar result stressing that 'repair and maintenance' act as best substitutes for 'capital' while analysing the cost structure of bus transit firms in the state of 'Illinois', the U.S.

[38] The extent of overaged buses (life exceeding 8 years) for the D.T.C. at the beginning of the study period, was 18% of the total fleet owned. This increased to 27% at the end of the study period.

[39]The inventory of air pollution statistics collected and monitored by various agencies in India, indicates a common trend that in the case of the major metropolitan cities such as Bombay, Delhi and Madras, nearly 60-70% of the air pollution comes from vehicular emissions alone.

[40] As De Borger, (1984, pp. 49) in his study of regional bus operations in Belgium, construes that this creates adjustment lags which may be reflected in low price elasticities. Some rigidity as regards the capital input may also arise. Since the urban bus transit firms under study have socio-economic obligations to cater to growing demands for commuting at all costs, fleet strength curtailment in response to price rise is inconceivable. The inelastic demand for energy implies that efforts to encourage energy conservation through increases in fuel prices would probably meet with little success. Spady et al. (1978, pp. 174) arrive at a similar conclusion in their study of hedonic cost functions estimated for the regulated trucking industry in the U.S.

status-quo in the way in which inputs are combined and adjusted, possibly attributable to poor management practices and weak motivational factors. This may have prevented re-organisation, hindered substitution possibilities between input factors, dampened innovations and other such pursuits which may not seem unlikely in an over-regulated environment amidst weak competitive pressures. We are then in the domain of the 'x-inefficiency' parameters which seem to be influencing the working of the D.T.C. (Delhi).

An important by-product of the cost model that we have developed is to get an insight into the degree of 'scale economies' in the provision of bus services. These aspect is scrutinised in the following section.

5.4 Economies of scale:

What should be the optimum scale of operations in order to be cost-effective is a matter of serious debate. Even in the Indian context several committees have initiated this debate, right from the 1930s, stressing the need to configure "viable size" units which would have lower costs of operation and higher earnings for a given unit of service provision (Padam, 1990, pp. 23-25). The wave of privatisation, liberalisation and deregulation have swept quite a few sectors of the economy since the early 1990s and queries in this regard are being raised with reference to the urban bus transit sector as well. The main concern is whether bus services should continue to be provided by the existing large regulated corporations or whether all 'barriers to entry' should be done away with permitting private operators active participation in the urban bus transit market. Our analysis of scale economies attempts to provide some kind of quantitative basis to resolve these issues.

Conventionally, the extent of scale economies has been expressed as the proportionate increase in costs resulting from a small proportionate increase in the level of output. or the elasticity of costs with respect to output. Scale economies has been generally defined as unity minus this elasticity. As already noted, it is advantageous to portray costs by the translog functional form since economies of scale can vary with output as well as with other variables. Thus the hypothesis of a 'U-shaped' cost curve with regions of increasing and decreasing returns can be verified.

The interpretation of results pertaining to scale economies would depend on which of the two models in our analysis is being considered for calculating the values. If the model based on 'effective-kilometers' (Model:1) is being used then scale economies would denote variations in costs due to changes in capacity. We denote this type of scale economies as 'economies of scale with respect to service provision'. Whereas, if the model incorporating 'passenger revenue' as the measure of output (Model:2) is being resorted to for computing the values then scale economies would depict the behaviour of costs with respect to capacity utilisation.[41] We designate this type of scale economies as 'economies of scale with respect to service use'.[42] To begin with, Table 4 presents estimates pertaining to 'economies of scale with respect to service provision'.

Table 3: Economies of Scale with Respect to Service Provision*

YEAR	B.E.S.T.(Bombay)@	P.T.C.(Madras)	D.T.C.(Delhi)
'80-81	-	-	0.5706
'81-82	-	0.3169	0.6016
'82-83	-	0.2576	0.6541
'83-84	-	0.212	0.7161
'84-85	-	0.2344	0.7574
'85-86	-	0.1969	0.7931
'86-87	0.8399	0.1574	0.8181
'87-88	0.8405	0.1019	0.8303
'88-89	0.8392	0.0619	0.8528
'89-90	0.8352	-0.0134	0.8956
'90-91	0.8393	-0.0685	0.8901
'91-92	0.8466	-0.1233	0.9090
'92-93	0.8548	-0.1717	0.9181
'93-94	0.8587	-0.2426	0.9023

Notes: * Economies of scale were computed at all points in the sample given monthly time-series data. In terms of the translog cost function this was obtained by deriving the expression: $\eta_c = 1-(\delta \ln C/\delta \ln y)$. The results presented in the above table are means of these estimates for a particular year @ Given a 'homothetic cost structure in this case, $\eta_c = 1-(\alpha_y+\alpha_{yy}\ln y)$

The estimates in Table 3 vary considerably across the three urban transit firms under study. The values are markedly different especially in the case of P.T.C. (Madras). This reinforces the relevance of conducting 'city-specific' time-series analysis. If we observe the trends corporation-wise, we find that in the case of B.E.S.T. (Bombay), the entire study period exhibits 'economies of scale with respect to service provision'. Thus, there is considerable scope for reaping the cost advantages arising from increasing returns to scale by expanding

[41] Berechman et al. (1985)

[42] It may be noted that Windle (1988), in his analysis of urban bus transit firms in the U.S., formulates a similar measure termed as 'returns to passenger density' which shows the effect on costs of increasing passenger-miles and load factor.

operations in terms of 'effective-kilometers' within the existing set-up of a single large corporation. A very similar conclusion can be drawn in the case of D.T.C. (Delhi). In addition, the opportunities for exploiting scale economies seem to be improving over time. The apparent geographical vastness as regards area of operation, may be put forth as an explanation for this phenomena. Therefore, in relation to the size of these bus transit corporations, the respective markets being served are very large in terms of geographical coverage, conferring sufficient cost advantages which accrue from increasing scale of operations. What these results also seems to hint at is the futility of introducing other new entrants into the market for providing bus services. The trends observable in the case of P.T.C. (Madras) are somewhat different. There appears to be mild increasing returns up to 1988-89 but, diminishing returns have set in thereafter. In this context, it may be noted that a policy to bifurcate the P.T.C. (Madras) into two was implemented in January'94. The decision was justified on grounds that the P.T.C. had grown vastly and proper attention could not be given to the maintenance of the growing fleet leading to inefficiency in operations. Our results corroborate the bifurcation decision. Though, the bifurcation policy could have been implemented earlier since 'diminishing returns' seem to have set in much before January'94 as per our results.

'Economies of scale with respect to service use' derived from Model: 2, provides an insight into the behaviour of costs with respect to capacity utilisation. These estimates are summarised in Table 5.

Table 5: Economies of Scale with respect to Service Use*

YEAR	**B.E.S.T.(Bombay)@**	**P.T.C.(Madras)**	**D.T.C.(Delhi)**
'80-81	-	-	1.022^
'81-82	-	0.451	1.013^
'82-83	-	0.555	0.983
'83-84	-	0.546	0.977
'84-85	-	0.563	0.958
'85-86	-	0.534	0.937
'86-87	0.984	0.534	0.969
'87-88	0.984	0.561	0.968
'88-89	0.984	0.598	0.989
'89-90	0.984	0.510	0.974
'90-91	0.984	0.439	0.980
'91-92	0.984	0.387	0.976
'92-93	0.984	0.327	0.989
'93-94	0.984	0.217	0.989

Notes: *Mean values for a particular year; @Homogenous cost structure implies $\eta_c=\alpha_y$; ^ theoretically inconsistent values.

Estimates differ marginally as regards B.E.S.T. (Bombay) and D.T.C. (Delhi). But the results relating to P.T.C. (Madras), follows a completely different time-trend. Not only are cost advantages accruing from 'economies of scale with respect to service use' minor, in this case, but these benefits seem to be declining over time. On the contrary, considerable economies exist with respect to service use, for B.E.S.T. (Bombay) and D.T.C. (Delhi). This means that cost savings would accrue by tapping areas of high patronage and times of the day when demand for service peaks. Thus, the routing and scheduling patterns could be redesigned taking this factor into account.[43] Since high patronage will be assured along prime catchment areas such as busy traffic corridors, and during peak-hours, this may call for innovative traffic management schemes such as 'exclusive bus lanes' so that users can have easy access to transit services and buses can move smoothly which may be virtually impossible given the existing high congestion levels in these areas of the city and at these times of the day. This result also emphasises high social costs of the policy of operating a large number of uneconomic routes, reflecting low passenger density, served by these transit firms.

Another measure which needs to be distinguished from 'economies of scale with respect to service provision' and 'economies of scale with respect to service use' is referred to as the 'economies of density'. The distinction is specially significant in industries where output is provided over a network. The following section highlights the significance of this measure specially relevant in the case of transportation industries.

5.5 *Economies of density:*

Output produced by the bus corporation has to be distributed over a network. The manner in which output is provided across the network in terms of the routing pattern, scheduling of services could affect costs. The measure, 'economies of density', attempts to capture some of these relationships. If route-kilometers broadly reflects the network configuration then, a measure of network density can be computed as:

Frequency of service(er)= Effective-kilometers / Route-kilometers.

[43] Evans (1991, pp. 137), while analysing Britain's local bus service provides evidence to support the greater profitability of high density routes. It is rationalised that cost per passenger are lower on high density routes because the same bus operating costs are spread over more passengers. Windle (1988, pp. 130) detected substantial 'returns to passenger density' in his analysis of urban bus transit firms in the U.S.

Since we have already incorporated this variable into our cost function, the degree of 'economies of density' can be derived by computing the following elasticity:

$$\eta_{er} = \delta \ln C / \delta \ln er$$

The estimates of 'economies of density' relating to the three urban bus corporations are presented in Table 5.

Table 5: Economies of Density*@

YEAR	B.E.S.T.(Bombay)	P.T.C.(Madras)	D.T.C.(Delhi)
'80-81	-	-	-0.284
'81-82	-	-0.432	-0.246
'82-83	-	-0.504	-0.171
'83-84	-	-0.553	-0.111
'84-85	-	-0.472	-0.076
'85-86	-	-0.501	-0.032
'86-87	0.106	-0.547	-0.003
'87-88	0.092	-0.659	-0.014
'88-89	0.063	-0.717	-0.053
'89-90	0.041	-0.823	-0.009
'90-91	0.037	-0.852	-0.029
'91-92	0.021	-0.894	-0.001
'92-93	0.036	-0.959	-0.002
'93-94	0.035	-1.001	-0.040

Notes: *For computing 'economies of density' we resorted to the cost model:1 which incorporates producer-related output measure, 'effective-kilometers'. This approach was adopted since it was felt that the 'frequency of service' on which this scale economies measure is based is an attribute which the producer can partly influence while designing service provision.[@] The estimates are mean values based on monthly data for a particular year.

Estimates vary in sign and magnitude across the three urban bus transit firms under study. However, the overall implication in all cases is that there are considerable cost advantages to be gained by enhancing the frequency of service. Costs actually decline when frequency of service is increased, in the case of P.T.C. (Madras) and D.T.C. (Delhi). This implies that there is an ardent need to optimise scheduling patterns so to enhance frequency of service. At the same time 'exclusive bus lanes' seem to be a prerogative so that buses can move swiftly and adhere to better frequency of service.

The notion of 'performance' has been closely linked to the functioning of urban transit corporations almost everywhere. We conclude our discussion relating to economic effects by scrutinising the nature of technical change over time in an attempt to throw light on the overall performance of the urban bus transit firms during respective study periods.

5.6 The nature of technical change:

The time trend variable was incorporated into the cost function to diagnose the nature of technical change over time. Differentiating 'costs' with respect to the time trend variable 't' would depict shifts in the cost function or technical change over time. Most economists tend to identify the 'shift' concept with the notion of productivity growth. (Oum et al., 1992, pp. 502). The 'shift' phenomenon aids in throwing light on the extent of innovations in the industry such as new knowledge of technology, new managerial organisations or new policy towards an industry. Thus this measure would aid in ascertaining whether productivity levels had improved or deteriorated during the study period for each of the three urban bus transit firms under study. Although technical change is usually measured in terms of the production function, Winston (1985, pp. 69) stresses that it is more appropriate to estimate cost changes over time rather than output changes (as depicted by shifts in the production) since in the case of regulated industries, service obligations are often specified and productivity measures focusing solely on output changes may yield potentially misleading results. Since all the three urban bus transit firms that form our case studies are regulated concerns with specified service obligations to cater to, we also adhered to this contention.[44] Our results depicting the nature of technical change is given in Table 6.

[44] Before analysing our results regarding the nature of technical change it may be noted that: (a) We are assuming that 'time' is continuous and therefore measures of technical progress (or regress) can be expressed in terms of the differentials of the cost function. (b) We assumed 'disembodied' technical change, which implies that the underlying production function does not change in shape or form but merely shifts up or down over time. (c) Since our data is based on monthly observations, we had to convert the 'per month' shifts in the cost function to 'per annum' shifts since, conventionally, productivity changes are expressed in terms of annual changes.

Table 6: Technical Change over Time@*

YEAR	B.E.S.T.(Bombay) -[δlnC/δt] (%)	P.T.C. (Madras) -[δlnC/δt] (%)	D.T.C. (Delhi) -[δlnC/δt] (%)
1980-81	-	-	-8.52
1981-82	-	-26.93	-7.34
1982-83	-	-26.10	-6.36
1983-84	-	-24.87	-5.34
1984-85	-	-22.34	-4.29
1985-86	-	-20.82	-3.26
1986-87	-6.56	-19.58	-2.08
1987-88	-7.11	-18.72	-0.79
1988-89	-7.42	-17.71	0.82
1989-90	-7.77	-16.66	1.92
1990-91	-7.98	-15.43	3.34
1991-92	-8.15	-14.12	4.28
1992-93	-8.73	-13.00	5.32
1993-94	-9.43	-11.46	6.80
Mean (Study period)	**-7.90 per annum**	**-19.06 per annum**	**1.11 per annum**

Notes: @Technical change can be deciphered from the cost function as the downward proportionate shift in the cost function over time. Symbolically, this is given as: $\rho_t = -[\delta \ln C/\delta t]$. If '$\rho_t$' is greater than zero it implies technical progress, if 'ρ_t' is less than zero it means that there is technical decline and if 'ρ_t' is equal to zero, it implies that there is no technical change.* For deriving measures of technical change the alternative based on producer-related measure of output effective-kilometers' (model: 1) was used. It was reasoned that since productivity is supposed to reflect performance form the producers side, this was the correct approach.

The nature of technical change differs markedly across the three urban bus transit firms under consideration. In the case of B.E.S.T. (Bombay), the entire study period seems to be characterised by increasing rate of technical decline. For instance, the rate of technical decline increased steadily from 6.56% per annum at the beginning of the study period to 9.43% per annum at the end of the study period. For P.T.C. (Madras) also, we find that the entire study period reflects technical decline. However unlike the case of B.E.S.T. (Bombay), the rate of technical decline seems to be falling over time. The rate of technical decline is comparatively quite high, resulting in a mean rate of technical decline equivalent to 19.06% per annum during the study period. The nature of technical change with respect to D.T.C. (Delhi) indicates a mixed picture. The period between 1980-81 and 1987-88 is characterised by technical decline. Thereafter the study period is characterised by increasing rates of technical progress. Overall, the mean rate of technical progress was 1.1% per annum .

At this juncture, it must be stated that these results pertaining to the nature of technical change were not entirely as anticipated and somewhat ambiguous. What motivated our analysis of costs related to bus transit operations in the three major Indian cities of Bombay, Madras and Delhi was that crude indicators and mounting deficit levels seemed to suggest poor performance levels and deteriorating levels of service. Falling rate of technical decline reflected by our analysis in the case of B.E.S.T. (Bombay) clearly supports this preliminary notion of declining productivity and performance. However, the nature of technical change as decipherable from our cost function analysis, in the case of P.T.C. (Madras), and D.T.C. (Delhi) was contrary to our expectations. For instance, the high rate of technical decline detected in the case of P.T.C. (Madras) was inconsistent with our initial prognosis. With relatively lower deficits and better partial productivity indices [45] as compared to the other two corporations, the adverse technical change trends for P.T.C, emerging out of our analysis, seems inexplicable. Likewise, the picture obtained for D.T.C. (Delhi) is undubiosly optimistic.

In this context, it must be reiterated that the coefficients associated with the time trend variable 't', were not found to be very significant statistically especially in the case of P.T.C. (Madras) and D.T.C. (Delhi) questioning the validity of the results and implications thereon in these two cases. This probably reconciles the discrepancy between our elementary expectations regarding the nature of technical change and what actually emerged out of the cost function analysis. Amidst these ambiguities and statistically unacceptable coefficient estimates linked to the time trend variable 't', further analysis of technical change in terms of the 'input-share' biases[46] was not attempted as it would not be a meaningful exercise.

6. Conclusions

The principal purpose of this research work was to make an analytical assessment of deficiencies in bus transit operations related to three major regulated bus transport undertakings operating the cities of Bombay, Madras and Delhi. This was attempted by scrutinising the behaviour of 'costs'. Catering to a sizable proportion of urban transport trips these corporations between 25 lakh and a little over 55 lakh passengers daily. And with fleet ranging between 3000-4000 buses coupled with staff strengths of 20,000 to 40,000, these transit systems are easily amongst the largest city level bus transit corporations in the world.

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[45] The three main conventional partial productivity indices computed were 'effective-kilometers per bus held' (output/capital= O/K), 'effective-kilometers per employee' (output / labor=O/L) and 'effective-kilometers per litre of fuel consumed, '(output/energy=O/E). The P.T.C. had a consistently better standing in these respects. P.T.C. also had better 'operating ratios'.

[46] The ceterus paribus change in the share of factor 'i' over time indicates the input share bias of technical change. This can be obtained from the share equation by computing the expression: $\delta S_i/\delta t$. If $\delta S_i/\delta t < 0$, it implies that technical change is relatively factor 'i'-saving, while, If $\delta S_i/\delta t > 0$, it implies that technical change is relatively factor 'i'-using.

Despite the significant role played by these corporations, services have deteriorated while rising levels of deficits appears to be a persistent problem.

Care was taken to assign a sound theoretical and quantitative base to the cost function towards ensuring greater accuracy of results. An important methodological issue that was resolved was the importance of conducting 'city-specific' time-series analysis. Coefficient estimates as well as the estimates pertaining to the 'economic effects' varied sufficiently confirming the significance of this approach. On the whole, the empirical analysis revealed vital measures that could be taken for efficient operation of bus services. Summing up, important implications of our analysis relevant for the case study bus transit firms may be briefly enumerated:

(i) There seems to be an ardent need to upgrade technology in terms of fuel-efficient buses, specially designed for urban operations.

(ii) A rigorous maintenance policy would go a long way in enhancing overall service efficiency and service effectiveness. In this respect, wider ramifications in terms of reduced emission levels and fuel conservation is also apparent.

(iii) Innovative 'bus priority measures' such as 'exclusive bus lanes' are necessary so that these transit systems can provide high levels of accessibility and achieve their maximum potential. In this connection it is noteworthy that contemporary advocators of buses and 'bus priority systems' claim that these are quite flexible systems capable of providing high volume movements at low costs and superior at collecting and distributing passengers at the hubs along high volume corridors (Hensher, 1993, pp. 65)

(iv) Detection of 'economies of scale with respect to service provision', especially in the case of B.E.S.T. (Bombay) and D.T.C. (Delhi) indicates that it would be cost-effective to expand operations in terms of 'effective-kilometers' within the existing set-up. While, the presence of 'scale economies with respect to service use' points at the cost advantages to be gained by tapping areas and times of the day with high patronage. Considerable cost savings would also accrue by enhancing the frequency of service on specific routes. All in all, various types of scale economies appear to generate significant advantages for these large urban bus transit firms operating services amidst conditions reflecting high density of urban development. In a similar tone Berechman (1993, in Pucher, 1994, pp. 364) finds that the possibility of exploiting various kinds of economies probably generate significant advantages for large firms in large central cities (those with over 1,00,000 population) rationalising the tendency towards large transit monopolies in such markets.

(v) Lastly, there are reasons to believe that the D.T.C. (Delhi) is functioning under conditions of 'x-inefficiency'. This condition is supported by the theoretically inconsistent positive sign of the own price elasticity of factor demand for 'capital', the comparatively small magnitudes of the elasticities of factor substitution and the own price elasticities of factor demand, and the statistical insignificance of some important coefficients in the cost function.

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