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A NEW ACCESSIBILITY MEASURE ACCOUNTING MOBILITY PARAMETERS

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Abstract

Accessibility is one of the basic determinants of urban form. In all previous measures of accessibility, mobility parameters have not been included. In this paper, an accessibility index taking account of the mobility of individuals has been developed and applied to Greater Bombay, the commercial capital of India.

INTRODUCTION

Over a long time transport planning has been pursued with a bias towards provision of capital intensive infrastructures for the private mode users. This has now changed to a philosophy where the objective has been minimisation of travel demands by manipulation of land uses. Thus, the focus has shifted from vehicular mobility to personal mobility and accessibility provisions. Moreover, all the sections of the society are to be equitably provided with accessibility to participate in activities like employment, educational needs, and other basic requirements.

Accessibility indicators should constitute an important component of transport modelling and planning, as it is one of the basic determinants of urban form. Since accessibility is a function of the land use patterns and the performance of the transport system, it is the important link between transport and land use. It has a significant influence on the location of industrial, commercial and residential developments. Several broad applications of accessibility indicators may be identified including evaluation of the transport/land-use system, modelling travel choice situations, modelling urban development, etc.

A variety of accessibility measures starting from Hansen's gravity type to William's consumer surplus approach have been proposed over the past thirty years and have been applied to wide ranging problems. In addition to sensitivity to both transport supply and activity spread, it must also take account of the mobility achievable for population groups. But in all the previous studies, mobility characteristics have not been taken care of in the accessibility measure. Accessibility is meaningless without taking account of mobility (Wachs and Koenig 1979). Here the mobility refers to supply side of transport and depends on the performance of the transport system and ability of individual, but actual trip making is not a measure of mobility. In the present study, an accessibility measure that takes account of the mobility characteristics of groups of individuals is developed. The proposed measure has been applied to Greater Bombay, the commercial capital of India.

ACCESSIBILITY MEASURES

The simplest definition of accessibility of a given location is in terms of how easy it is to get there. It, therefore, indicates the spatial relationship between one location and others. There are three essential components of an accessibility measure viz . i) the location and characteristics of resident population, ii) geographical distribution and intensity of economic activities and iii) the characteristics of existing transportation system.

Accessibility can also be defined as the ease with which any land-use activity can be reached from a location, using a particular transportation system (Dalvi 1979). Accessibility thus indicates the location of a household or a group of households in relation to the distribution of activities and to the transport system connecting them. In this paper accessibility is defined as the potential of opportunities for interaction. This definition differs from the usual one in that it is a measure of the possible intensity level of the interaction rather than just a measure of the ease of interaction.

Traditional accessibility measures are based on the premise that intervening space acts like a restraint to interaction of available activities. But, as emphasised above any accessibility measure should also take the supply side of transport system into consideration. Such a measure must also show how well the transport and land-use planning system operate in allowing people to reach their destinations (Mitchell and Town 1977). In most cases it has been seen that the selection of a particular measure to quantify accessibility depends primarily on the purpose of the study and availability of data and resources. Unless a realistically quantified measure is developed, it cannot be used as a variable in the transport planning models. Better accessibility measures could help to redirect policy and planning towards the equalisation of opportunities among different groups (Wachs and Koenig 1979).

A useful classification of accessibility indicators is given by Morris et al. (1979). The two principal bases of classification are the behavioural dimension (process and outcome indicators) and a distinction between relative accessibility and integral accessibility. Process indicators are based on the supply characteristics of the system and/or individual and outcome indicators are based on actual use and level of satisfaction. The major disadvantage of using outcome indicators (eg total trip rate, total time spent travelling, accessibility satisfaction, etc.) is that it is difficult to disentangle the influence of choices and constraints.

Process indicators can be divided into two groups, i) measures which simply describe the ease of traversing space through a given transport system (eg simple network measures, Ingram (1971) measure and measures of accessibility to public transport), which may be useful only in pinpointing glaring deficiencies in the transport system and ii) those which measure accessibility to selected activities or opportunities using a given transport system. For using accessibility as a variable in land-use/transport planning, only process indicators which describe accessibility to opportunities can be used. Contour measures (eg Black and Conroy (1977) accessibility) and Hansen (1959) accessibility measures are the most widely used ones in this category. But unfortunately the mobility parameters have not been accounted in these measures.

ACCESSIBILITY ACCOUNTING MOBILITY

Accessibility is concerned with the availability of opportunities and is a function of the mobility of individuals and spatial distribution of opportunities relative to the origin of travel. Mobility is the ability of an individual, or type of person to move about (Jones 1981) and is concerned with the ability of people to use various modes irrespective of the opportunities that can be reached. So mobility and accessibility together influence an individual's capacity to travel in daily life (Morris et al. 1979). A closer integration of both accessibility and mobility considerations in transportation planning is needed.

Mobility concept

In the present study, mobility is interpreted to mean the ability of individuals to move from place to place. Mobility depends on the performance of the transport system (transport service availability and frequency/waiting time for the service etc) and characteristics of individual (income, vehicle ownership, resources he can spend on travel etc). When defined in this sense, mobility is conceptually distinct from actual travel. But unfortunately the concept of mobility has been used rather indiscriminately to refer to both the supply side and demand side of transport services (Dalvi 1979). Actual travel performed is the travel need, which is the amount of travel people ought to undertake to meet some standards of living. From literature it is observed that number of trips made still remains as the indicator of mobility used in most studies. This point encourages the planners of transport system to increase trip rates and overlooks the point that travel is a derived demand. In this paper, mobility is quantified taking into account the variables related to supply side of transport along with ability of individuals.

Proposed accessibility measure

The proposed measure is similar to the normalised version of Hansen's gravity type accessibility, except that this includes the variable representing mobility achievable for population groups in addition to a measure of the activity potential and ease of interaction. Also it satisfies all the axioms proposed by Weibull (1976) for a standard measure of accessibility. The functional form of the proposed measure is given in Equation (1).

$$A_i = \frac{\sum_j S_j f(t_{ij}).\exp(\gamma.M_i)}{\sum_j S_j} \quad (1)$$

where

A_i = the measure of accessibility of zone i to activities in the remaining zones

S_j = the size of activity in zone j, such as the number of jobs, population, etc.

$f(t_{ij})$ = calibrated travel deterrence function

M_i = mobility level of zone i

γ = coefficient of mobility to be calibrated

The detailed specification of the measure of mobility is given later in the subsequent section.

STUDY AREA AND THE DATA

Greater Bombay, the commercial capital of India has a teeming population of 10 millions (in 1991) located over an area of 429.89 sq. km having a peninsular shape. Due to its highly commercial character there is very high migration from all over the country, and the city has been having a growth faster than the rate at which civic facilities could be made available.

In the present study the spatial units adopted are the 88 census sections. Figure 1 shows the zone map of Greater Bombay, demarcating island city, western suburb and eastern suburb. While island city area has shown decline in population and stable employment, the suburban areas have experienced tremendous growth both in residential and employment activities in last two decades.

The origin-destination (OD) matrices for the year 1991 were obtained from a study conducted at I.I.T., Bombay (Yamdagni 1993) for updating the data from the matrices developed by Central Road Research Institute, New Delhi in 1979 from home interview surveys. The transport network compatible to the adopted zoning system was prepared for the year 1991. Two separate networks for public and private modes were coded for the analysis, and public transport network included the suburban railway also.

The data related to the variables used in the quantification of mobility were collected from the urban household survey conducted by Operations Research Group (ORG 1990). The survey included the data on income level of the household, expenditure on travel, as well as opinions of the households about the transport system (bus, train and taxi) availability in that zone. Other data on land use planning variables were obtained from secondary sources.

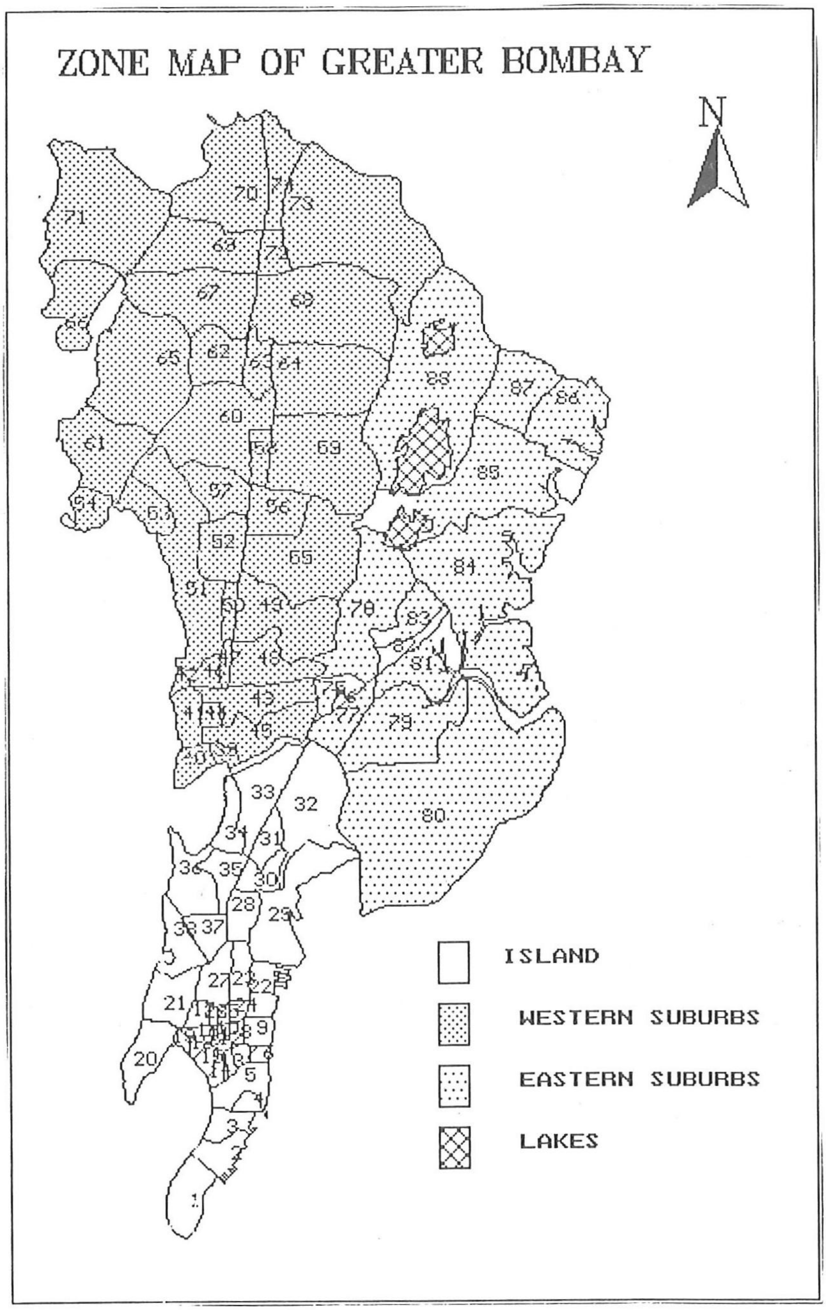

Figure 1 Zone map of Greater Bombay

QUANTIFICATION OF MOBILITY

For the quantification of mobility, five variables ie i) bus availability, ii) train availability, iii) income of the household, iv) public transport network density and v) number of train stations in a zone were taken into consideration. Time taken to access the bus or train from home effects mobility of an individual. These are taken into consideration through the network density and number of train stations. All the variables were normalised by dividing the frequency of occurrence for the variable by total frequency in the study area. This can be represented .mathematically as shown in Equation (2).

$$m_i^k = \frac{F_i^k}{\sum_i F_i^k} \tag{2}$$

where

m_i^k = normalised mobility parameter k for zone i

F_i^k = frequency of occurrence of parameter k in zone i

This normalisation is required for bringing individual parameters to a common scale. Mobility is taken as the sum of the normalised values of these variables as shown in Equation (3).

$$M_i = \sum_k m_i^k \tag{3}$$

Zonal mobility M_i represents the level of transport supply and affordability of the population located in the zone for using the transport system. This intra-zonal accessibility to transport system also represents the ease of access to activities of other zones in the study area.

Transport planning analysis often uses the distance or travel time from CBD as a surrogate measure for accessibility of a location. To make a distinction between mobility and the travel need, the variation of average travel by residents located at a distance from CBD was examined. The distance matrix for the shortest path in terms of travel time was determined. Using the distance matrix, the travel need in terms of average distance travelled per trip by all modes in Km (only vehicles assisted trips without considering return trips) was computed for each zone. Considering zone 4 (the Fort Area) in the island city as the CBD in this case, the variations of mobility and travel need with travel time from CBD were examined and shown in Figure 2 and 3. It can be observed from Figure 2 that the mobility level is decreasing as we move away from CBD. The reasons are very obvious that availability of better and well connected transport system in the CBD and vicinity provide higher mobility. Also higher income levels of the people living in the island city makes their consumption of transport services as per their higher affordability. On the contrary, travel need (Figure 3) is the reverse. This is due to the fact that more than 55 per cent of employment in Greater Bombay is concentrated in the narrow peninsular island city of 67.67 sq. km, forcing the population living in suburbs to travel more to access the job opportunities.

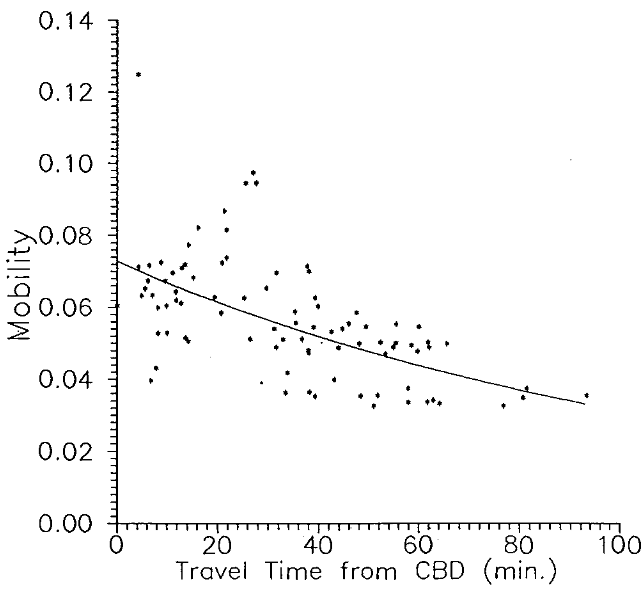

Figure 2 **Variation of mobility**

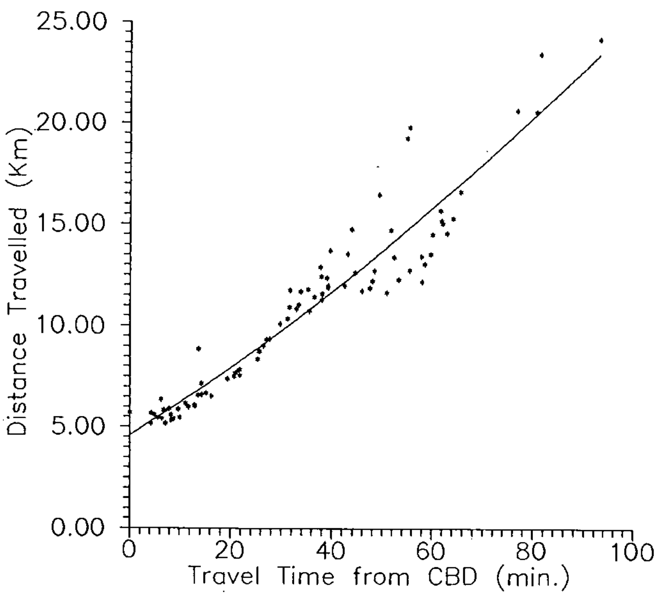

Figure 3 **Variation of travel need**

ACCESSIBILITY IN GREATER BOMBAY

The accessibility levels in the study area were computed using the proposed measure [Equation (1)]. Since the calibration was not possible as yet, γ is taken as unity in this case. Considering the travel time as the deterrence, inter-zonal deterrence matrices were obtained using a shortest path algorithm. Using the corresponding trip matrices deterrence functions were calibrated separately for private and public transport using the doubly constrained entropy maximising gravity models. The calibrated deterrence functions were in the form of Tanner function as given in the Equation .(4).

$$f\,(t_{ij})=e^{\alpha t_{ij}}.(t_{ij})^{\beta} \tag{4}$$

where

$f(t_{ij})$ = deterrence function

t_{ij} = travel time

α, β = parameters for calibration

Using the calibrated deterrence function and the computed mobility levels of the zones, the zonal accessibility in the study area according to the proposed measure as given in Equation (1) was computed. Figure 4 shows the accessibility pattern to employment by public transport. Also the average values of accessibility to employment by public transport for different areas of Greater Bombay are presented in Table 1.

Table 1 Accessibility in different areas of Greater Bombay

Area	Hansen Measure	Proposed Measure
Island	0.6973	0.7570
Suburbs	0.4739	0.4979
Western Suburb	0.4667	0.4897
Eastern Suburb	0.4923	0.5190
Greater Bombay	0.5703	0.6054

For the zones 54, 61, 66 and 71 the accessibility values are least as shown in the Figure 4. This is quite natural because of the poor level of the activities in these zones and also they are being poorly served by transportation systems. A comparison of the zonal accessibility to employment computed by the proposed measure was made with that of normalised Hansen measure, as shown in Figure 5. In the figure, the pattem of the modified accessibility is shown for different values of γ (γ =1,2 and 3). It can be observed that in both the measures accessibility is decreasing at locations away from CBD. Closer to CBD the proposed measure indicates higher accessibility due to its accounting for transport supply and other factors such as affordability. Hansen measure depicts only the influence of employment locations.

Location of economic activities has a serious bearing on accessibility. The proposed measure can very well fit in the activity allocation functions of land use transport models, as it includes the attraction of the zone expressed in terms of public transport supply characteristics. This also indicates that the coefficient of mobility, γ in the accessibility function can be calibrated using a suitable location phenomena, for example, residential location. As in the case of Hansen measure, wherein deterrence function is calibrated from the observed OD, in the present case also the value of γ can be calibrated simultaneously along with the deterrence function.

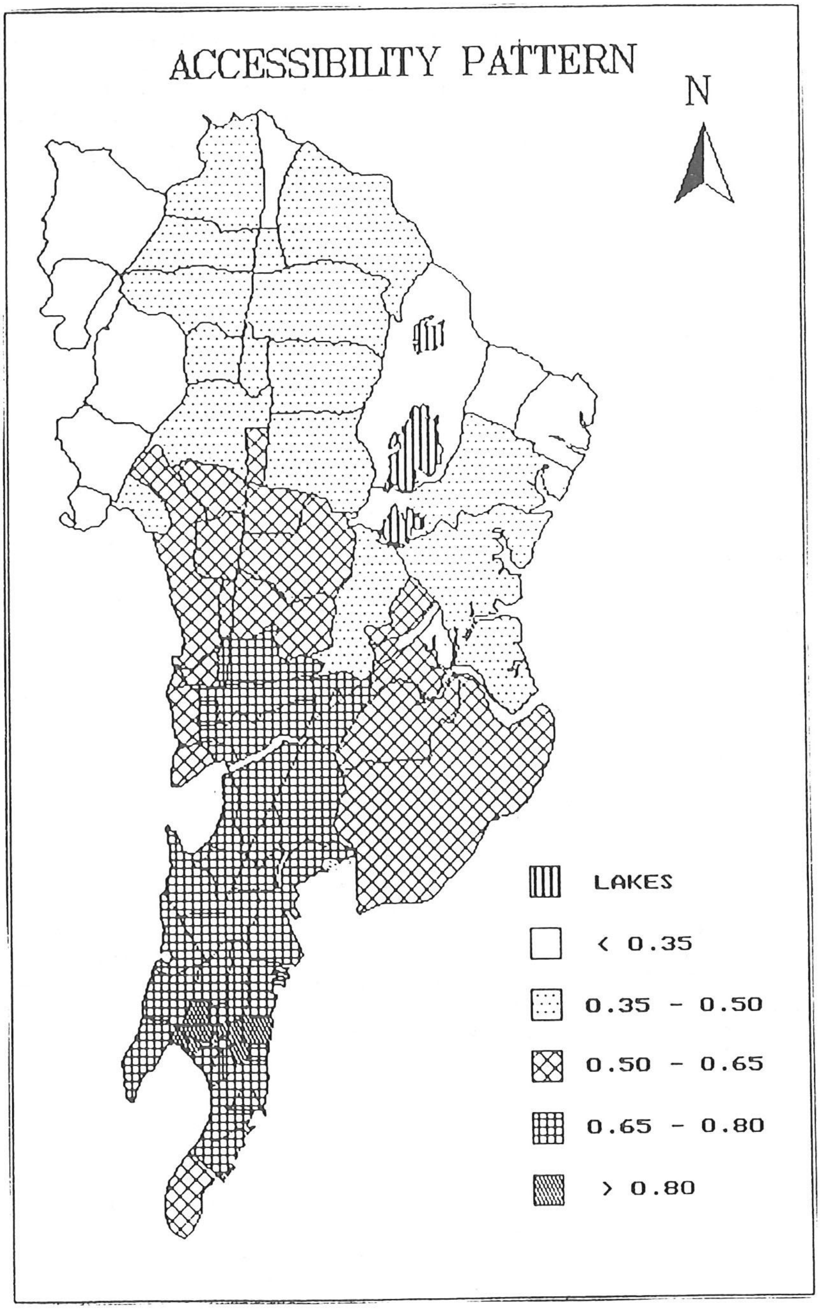

Figure 4 **Pattern of modified accessibility in Greater Bombay**

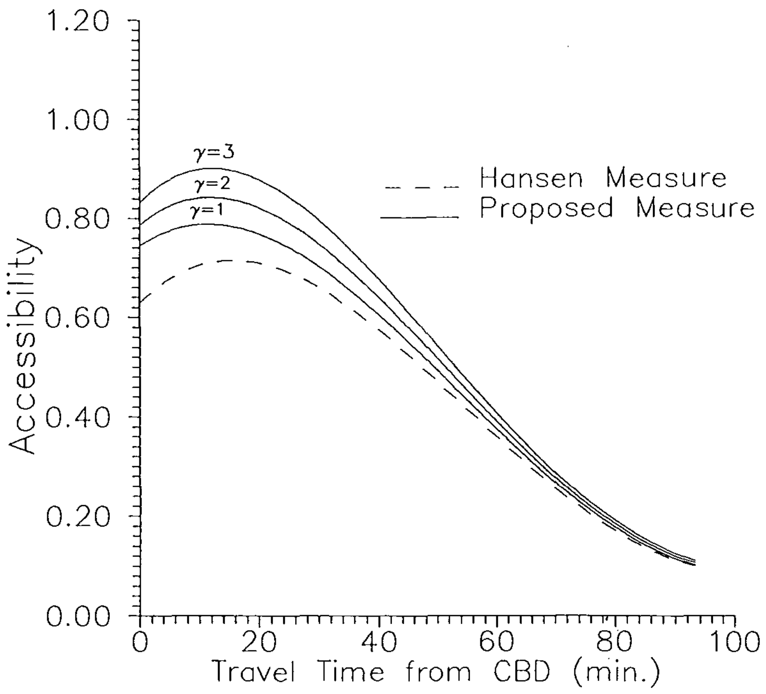

Figure 5 **Comparison of proposed measure with Hansen accessibility**

CONCLUSIONS

An accessibility measure that takes account of the mobility characteristics of groups of individuals has been developed and applied to the study area. Mobility is quantified taking into account the variables related to supply level of transport system and ability of individuals. The proposed measure could capture the accessibility more realistically including the contribution from mobility, which is missed by Hansen and other measures.

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