INTEGRATED APPROACH FOR MEASUREMENT OF SPATIAL ACCESSIBILITY OF HEALTHCARE SERVICES IN URBAN AREAS.

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Abstract:

Provision of equitable access to healthcare services is a key priority for any nation. In literature wide variety of flow catchment area (FCA) methods have been extensively used to estimate the spatial accessibility to healthcare services. However, these methods capture the only interplay between the availability (supply) and accessibility factors. In India, the landscape of healthcare services availability in urban areas is heterogeneous in nature, it ranges from high speciality hospitals to individual physician to unskilled practitioner, the quality of care and affordability varies accordingly. In this context, present flow catchment area methods can overestimate the healthcare demand. Thus, the present research proposes an integrated approach to analyze the spatial accessibility covering multiple dimensions of healthcare access. This approach can help in efficient resource planning, while estimating the proper healthcare demand. The innovativeness in the research is consideration of spatial affordability based competition into two-step flow catchment area method.The proposed approach is illustrated on Mumbai, which has the high spatial variability of maternity healthcare services.This study compares an integrated spatial accessibility method and two step flow catchment area (2SFCA) method. The results indicated that proposed model is efficient for measurement of spatial accessibility of healthcare services in urban areas.

1. Introduction:

Equity has become an important policy indicator in healthcare planning. In health care, equity can be broadly categorized into equal access to healthcare, equal utilization (healthcare services) and equal health outcomes(Braveman, 2003; Wang & Tang, 2013; Welch et al., 2013). However, equal access to healthcare is considered as an important policy objective in healthcare(Serra, Marianov, & ReVelle, 1992). To achieve equity in access requires that all cohorts of the society should have adequate and equal access to basic healthcare services regardless of geographic barriers, socio economic status, personal and regional factors(Neng Wan, Zou, & Sternberg, 2012). This is essential for improving the healthcare access, health disparities and plummeting disease risk(Richard et al., 2016; Tirado, 2008). In this context, it is impractical to achieve equal accessibility or complete fairness in the society, but it can be achieved through minimization of the healthcare inequalities by identifying medically underserved areas(Wang & Tang, 2013).

The term accessibility is very important in healthcare access. Accessibility is defined as the relative ease or difficulty with which population of a given area can reach the healthcare facilities and medical services(Church, 2008; Goddard & Smith, 2001; Wang & Tang, 2013). In other words, accessibility refers to the potential interaction between the healthcare services, the population in need and geographical barriers such as travel distance and travel cost (Guagliardo, 2004). It is most evident from the literature that the probability of visiting healthcare facilities decreases with increased travel distance or travel cost(Hawthorne & Kwan, 2013; Panagopoulou et al., 2012). A study on mammography access in Los Angeles urban county found that, increased travel distance decrease utilization of screening(Meersman, Breen, Pickle, Meissner, & Simon, 2009). Hence, the geographical proximity of healthcare facilities is very crucial in ensuring the spatial accessibility to healthcare facilities and overall health outcomes.

In India, healthcare delivery system in urban areas is diverse in nature and it is complex in nature. It varies from Public healthcare to private health services to faith healers, the quality of care and affordability varies accordingly. Majority of primary health care in urban areas is provided through private hospitals in India. This is surprising because, if we look at key recommendations given by many committees including "Bhore committee" before independence, the policy of the government has always been to provide health access to all people through a state financed health care system at low cost. On the other hand, the investment of government in public healthcare has been decreased significantly from 1991, from the time when the release of new economic policy in 1991(Gangolli, Duggal, & Shukla, 2005). The role of government in health service changing from providing services to financing(Bajpai & Saraya, 2010; Kumar & Rao, 2016; Kurian, 2014).

In this context, urban poor experiences healthcare access barriers; despite being poor health status and high healthcare need. These barriers not only limited to the public funding and health services, the high cost of care at private hospitals forced these people to take self-medication. Hence, it is very important to identify the locations and social groups that have poor access to health services to locate healthcare services proximity to the population in need(Halasa & Nandakumar, 2009). Spatial characteristics such as the location of facilities, type of facilities (public or private), operational timings, services type, cost of care and population demand factors, provide key criteria for identifying the healthcare inaccessibility regions and social groups. There is a strong correlation between the healthcare affordability and utilization rate. If the costs of services are too high, people tend to avoid the care. In this study, we propose an integrated approach to analyze the spatial accessibility covering the multiple dimensions of healthcare access including affordability. Most of the present accessibility models ignore affordability dimension in healthcare measurement. In India, it is very important determinant in healthcare choice. To define affordability, in our study consultancy charges has taken as the proxy variable.

The main aim of this article is to propose an integrated approach which can measure spatial access near to the real-life scenario and identify healthcare shortage areas. Especially, it introduces an affordability parameter into two- step flow catchment area (2SFCA), to overcome the overestimation of the healthcare demand and access. Then, the proposed approach is assessed by measuring spatial access to maternity healthcare services in an urban area and identifies the shortage areas in the Mumbai city, India. This framework would help policy makers, planners and health practitioners to measure accurate spatial access to healthcare facilities in urban areas.

2. Literature Review:

Access to care is a multidimensional concept(Aday & Andersen, 1974; Penchansky & Thomas, 1981). Accessibility methods are broadly classified into two categories: Potential accessibility and revealed accessibility. Potential accessibility refers to the ability to get care or the probability of people in need get care from a given location of facilities within the defined threshold distance. This method is widely used in the absence of actual consumption data. Latter one refers to “the actual utilization of services from a location of facilities based on their socio-demographic conditions. It needs lot of survey data and time-consuming process; however, it is a very accurate process. There are number of aspects that can impact progression from potential to revealed accessibility(Bissonnette, Wilson, Bell, & Shah, 2012; Lin, Crawford, & Salmon, 2005). (Penchansky & Thomas, 1981) have grouped these aspects into five dimensions of healthcare access: accessibility, availability, affordability, accommodation and accountability. The first two dimensions are spatial in nature because health centre locations and access to these facilities have a strong relationship in overall health access and health status of individuals.

Accessibility is the key issue for many stake holders in policy making in the fields of transport, urban planning and regional planning, healthcare planning and marketing. Because The research on spatial accessibility to medical care has been prolific in recent years. Numerous methods have been proposed to measure the spatial accessibility to healthcare. These methods include some of the simple metrics such as distance to nearest provider, travel time reaches nearest facility and provider to population ratio. These methods have gained the attention of medical practitioner and researchers due to their advantages such as easy to analyze with the basic knowledge of GIS and easy to interpretable in quantitative terms (Neutens, 2015). However, these methods failed to capture the relation between supply (hospital location) and demand (Population) with geographic impedance.

With an increase of advanced GIS tools, the spatial access models are developed with more complex and accurate. Some of these models include gravity based models, regional availability model and kernel density models. Among these models, gravity based models are very popular and conceptual in nature but not intuitive (Luo and Qi 2009). The advantage of the gravity-based model is that it takes into consideration of travel impedance. Most of the spatial accessibility models are based on distance or travel time to a particular facility. The travel distance is the distance between supply (location of medical facilities) and demand (Population centroid or census tract).Various measures of travel distance has been applied in healthcare accessibility literature, Various distance measures include Euclidian distance, Manhattan distance, shortest network distance(Apparicio & Seguin, 2006; Cervigni, Suzuki, Ishii, & Hata, 2008; Tanimura & Shima, 2011; Tanser, Gijsbertsen, & Herbst, 2006) and shortest network time. Most of the studies have used shortest network distance or travel time for accurate measurement of spatial access. In our study, we have used network travel time as a distance measure between the healthcare facilities and population centroid.

To overcome the limitations of on gravity model, the family of floating catchment area (FCA) method started with two-step floating catchment area (2SFCA) method was developed. It was first proposed by (Radke & Mu, 2000), later it was modified by (Luo & Wang, 2003). Since then, it has been extensively used in the measurement of spatial accessibility to healthcare facilities (McGrail, 2012; McGrail & Humphreys, 2009). Recently, there are some enhancements have been done to the 2SFCA methods; these include enhanced two-step floating catchment area method (E2SFCA)(Luo & Qi, 2009; Zhan, Wang, & Sliuzas, 2011), three-step floating catchment area method (3SFCA)(Delamater, 2013; N Wan, Zou, & Sternberg, 2012), optimized 2SFCA(Ngui & Apparicio, 2011), Kernal density 2SFCA(Polzin, Borges, & Coelho, 2014), variable catchment size 2SFCA(Luo & Whippo, 2012), commuter-based 2SFCA(Fransen, Neutens, De Maeyer, & Deruyter, 2015) and Community-based 2SFCA.

The advent of wide variety methods in FCA family that have proliferated in recent years have not paved the way for a better assessment. Rather, it has hampered the robustness of the newly developed methods. FCA is an interdisciplinary research, it needs inputs from various other field such as public health, geography, econometrics and policy makers. There is need of scientific way of computing spatial accessibility. Thus, in our study we develop an integrated approach in a realistic way of measuring spatial accessibility in urban area. This proposed methodology takes into consideration of affordability along with availability and accessibility. This is more appropriate in the case like India, where healthcare landscape is heterogeneous in urban areas.

3. **Study Area**:

The proposed integrated approach was evaluated on Mumbai, which is the financial capital of India. It is one of the largest metropolitan cities in India. It is located at western part of India, Arabian Sea in North, East South, and West direction respectively. It lies between the latitude of 19.0760° N, and longitude of 72.8777° east. The total population of the study area was 1.25 crore in 2011 as per census 2011.It also had more than 42 % of the households as slum population in 2011. It has the total area of 603.4 square kilometers. It had a population density of 21000 persons/per square kilometer. Mumbai has divided into total 24 wards as administrative boundaries and 227 electoral wards. There is an absence of data at electoral level, in our study, we have taken 88 transportation network zones (sections) of Mumbai as case study area. The section map of the Mumbai has shown in figure 3.1

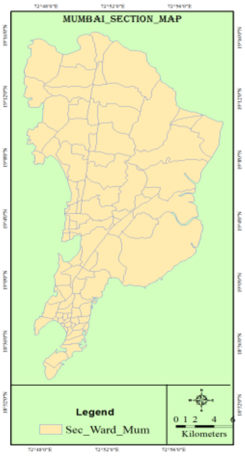

Figure 3.1 Study area: Mumbai

4. **Proposed Methodology and Data collection**:

4.1: Data

The data used in this study has been collected from the public health department of greater Mumbai, regional census Mumbai and web resources. The locations of public and private maternity healthcare facilities were collected from the public health department of Mumbai. Data include the name, address and type of facility (public or private). The collected data was geocoded into 406 Maternity sites. There are total 406 maternity healthcare facilities in Mumbai including 32 public hospitals. Hospital capacity and attribute parameters such as bed capacity, specialty type, number doctors, operational timings and consultancy charges were collected through web sources. In this study, a total number of maternity doctors is considered as supply capacity at each facility. This is more suitable parameter compared to total number beds available in each health centre. To define the affordability, consultancy charge is considered as the proxy parameter. Due to the lack of data on consultancy cost total 11 maternity hospitals data were excluded from the analysis. Population demographics and other infrastructure availability data were collected from the regional census, Mumbai. The total population divided into three income groups such as high, middle and low based on the asset variables of each household using principal component analysis.

4.1.1: Spatial distribution of healthcare facilities:

To understand the spatial distribution of healthcare facilities over the census tracts of Mumbai, the location layer has been projected on the zones layer in ArcGIS software. All the maternity facilities are mapped on GIS layer. From as shown in figures 4.1 and 4.2, it is known that distributions of the public and private facilities are unevenly distributed in the study area.

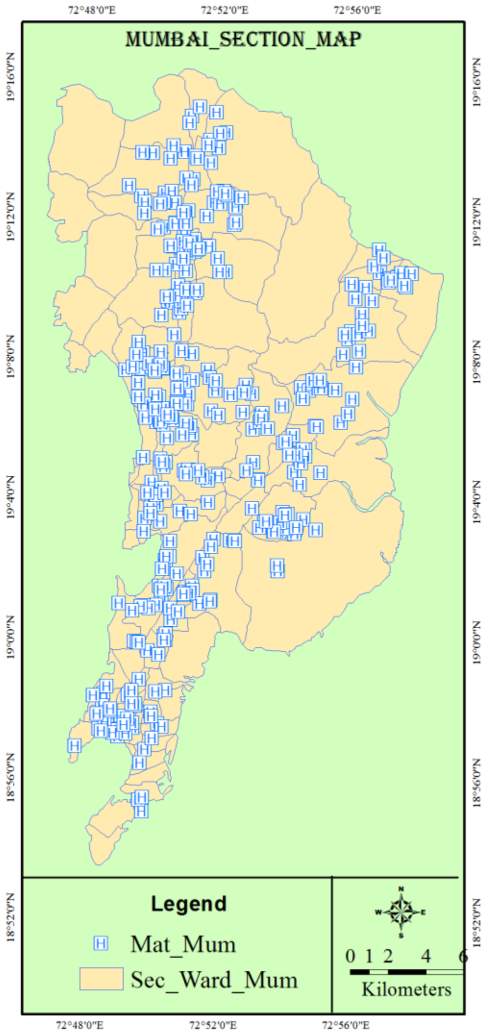

Figure 4.1 Distribution of private maternity hospitals

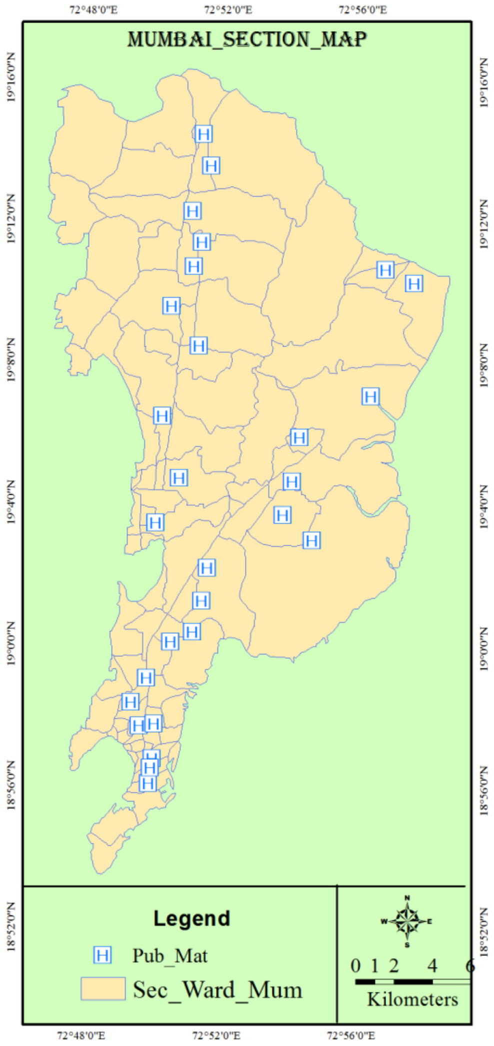

Figure 4.2 Distribution of public maternity hospitals

4.2 Methodology:

The proposed integrated approach is based on the 2SFCA method with inclusion of affordability parameter in supply and demand side. To measure the distance between population and services site, a population weighted centroid was calculated based on the population distributed of its census zone. In this study, population demand represent as population weighted centroid. Travel time was used to measure the distance between facility and population demand. In this study, 30 minute travel time was taken as threshold time. The basic procedure of 2SFCA consists of two steps: In step one is concerned with the supply side, step two concerned with the demand side. The relation between supply and demand is explained by the gravity models; how both the groups interact with each other. The basic 2SFCA method can be explained as follows:

$$R_j = \frac{S_j}{\sum_{K\varepsilon(dij\le do)} P_k} \quad .... \quad (1)$$

$$A_i = \sum_{j\varepsilon d_{ij}\le d_o} R_j \; .... \quad (2)$$

The term S_j refers to healthcare capacity of j. The term P_k refers to the total population at location K. The term d_{ij} represents the travel distance between the population location i and facility location j. The term R_j represents the provider to population ratio.

Step1: In first step, from every service site j, generate a catchment with a threshold travel time d_o and search for all population locations within the catchment d_o and measure the provider to population ratios.

Step2: In second step, for each population i, generate a catchment with a threshold travel time d_o search for all previously computed providers to population ratio R_j values within the buffer zone and compute the accessibility index A_i by summing all provider to population ratios R_j.The 2SFCA method is more intuitive compared to basic gravity model, but it has some limitations as mentioned earlier. This basic 2SFCA model doesn't consider the affordability while estimating the spatial access. It assumes that all population within the catchment area are homogeneous in nature, but this assumption is not true in the case of real life. Within same census tract or geography boundary, different socio-economic people can live and all people mightn't have the same capability to access these services. To overcome this limitation, we have divided all population into three different economic groups of any area unit K in equation (1) using principal component analysis: Low income, middle income and higher income based on our field survey, the affordability values of each economic classes are mentioned below:

i. Consultancy cost (S_{j1}) 0 – 500 low-income people (P_{k1})
ii. Consultancy cost (S_{j2}) 501-1000 Middle-income people (P_{k2})
iii. Consultancy cost (S_{j3}) 1001-2000 Higher-income people (P_{k3})

Here P_{k1}, P_{k2} and P_{k3} represent the total population of low, middle and higher income groups at population location k. S_{j1}, S_{j2} and S_{j3} represent the consultancy cost at service site j range between 0 to 500, 501 to 1000 and 10001 to 2000 respectively. The remaining procedure is similar to the 2SFCA method. In our study, the threshold travel time was taken as 15 minutes.

4.2.1 Proposed Methodology:

In step1: for every service site S_{j1}, generate a catchment with a threshold travel time 30 minutes and search for all population locations within the threshold time and measure the provider to population ratios. It is assumed that if the consultancy cost is low, even higher income people can access these facilities within the catchment area.

$$R_{j1} = \frac{S_{j1}}{\sum_{K\varepsilon(dij\le do)} P_k} \quad .... \quad (3)$$

Here, $P_k = P_{k1} + P_{k2} + P_{k3}$

For every service site S_{j2} generate a catchment with a threshold travel time 30 minutes search for population locations within the threshold time and measure the provider to population ratios. In this case, population of middle and higher income groups were considered.

$$R_{j2} = \frac{S_{j2}}{\sum_{K\varepsilon(dij\le do)}(\mathrm{Pk2} + \mathrm{Pk3})} \; .... \; (4)$$

Similarly, for the every service site S_{j3} the provider to population ratio is

$$R_{j3} = \frac{S_{j3}}{\sum_{K\varepsilon(dij \le d0)} P_{k3}} \text{ .... } (5)$$

In step 2: In second step, for each population i, generate a catchment with a threshold travel time 30 minutes search for all previously computed providers to population ratio R_j values within the buffer zone and compute the accessibility index A_i as shown in equation (6)

$$A_i = \sum_{j\varepsilon d_{ij} \le d_o} R_{j1} + R_{j2} + R_{j3} \text{ .... } (6)$$

5. Results and discussion:

An integrated approach was used to measure spatial accessibility to maternity healthcare facilities in urban area. This approach integrates the affordability with 2SFCA method. It is very efficient in resource planning. The spatial access index (SPAI) of each census zone was calculated using 2SFCA and Integrated approach. The comparative results of SPAI indicated that proposed method is efficient in identifying the medically underserved areas. The spatial pattern of SPAI of both the methods was mapped on GIS as shown below figures 5.1 and 5.2.

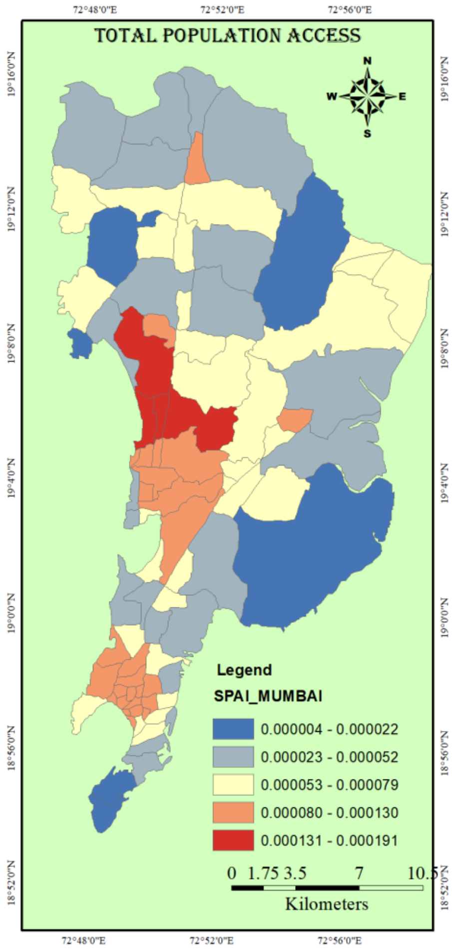

Figure 5.1 spatial pattern of SPAI (2SFCA)

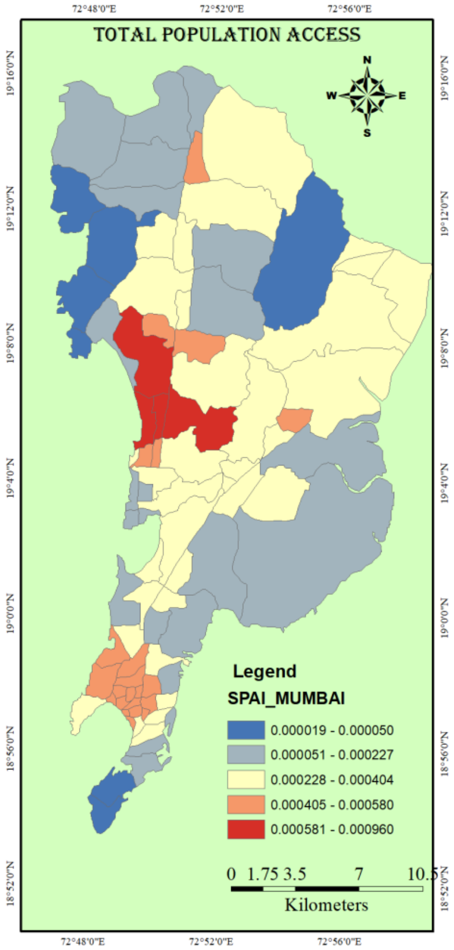

Figure 5.2 spatial pattern of SPAI (Proposed method)

Discussion: This paper proposes an integrated approach for measuring the spatial accessibility of healthcare facilities in urban areas. As the case study results indicated that proposed model minimize the overestimation of demand. It is known that healthcare choice is influenced by many factors. Distance alone is not major factor; specially, in the case of urban areas where more healthcare facilities are concentrated. The majority of the present spatial accessibility models ignore this fact and they measure only interplay between supply and distance impedance. This turns into over estimation of the demand. The study results document the potential of the integrated approach method to identify medically underserved areas in a region. The study results will be helpful to the planners, health practitioners and policy makers.

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