A Modeling for Forecasting Population Density Connected with Bus Networks Improvement Using Voronoi Concepts

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1. Introduction

In an expanding metropolitan, it is always required to expand or to newly design its transportation network to meet the increased demand. Many analytical as well as simulation models have been developed over the years. Most of the previous urban models considered employment subcenters to be located one or more circumferential ring roads which are symmetric about the central business district(CBD)[1,2]. But in real urban systems, employment subcenters may be located at arbitrary locations outside of the CBD. Voronoi concepts are very attractive "which can deal with an arbitrary configuration of urban development", to analyze such systems. In general, Voronoi concepts are used for solving the locational optimization problem which ask to determine the location of points so that the average distance to the nearest points is minimized. For example finding the position of public mail boxes, the main libraries and branch libraries, location of bus stops for commuters etc.[3,4,5, 8].

This paper discusses the population density of the different parts of Dhaka city for future considering a past trend, the future transport system and land price. Dhaka is the capital city of Bangladesh with a total population of 8 million and going to be a megacity with population of 25 million by 2025 [7].

Key words: Population distribution, Dhaka Metropolitan, Voronoi Model.
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The planning is performed in two phases, for the existing phase and for the forecasting phase. In the existing phase, the present Dhaka city is divided into different zones using Voronoi concepts[5]. The bus networks are planned between points of different zones using the minimum spanning tree of the points. A central point of a zone is considered as a employment subcenter of that zone. In the forecasting phase, we consider a greater metropolitan area for Dhaka city and devise a population distribution model of the city considering transportation improvement, land price and geological condition.

2. Land price and urban land use pattern in a monocentric city

A city considered in urban system, consists of a CBD and multiple employment subcentres around the CBD. It is assumed that the CBD and employment subcentres are a point set of Voronoi diagram, then it gives a tessellation of the city into a set of zones associated with the CBD and the employment subcentres. The CBD and the employment subcentres, and the zones constitute the Voronoi diagram and Voronoi polygons respectively. We consider each of the zones as a monocentric city having corresponding CBD or employment subcentre as the center of that monocentric city. Therefore, by analyzing each of the zones as a monocentric city, a complete analysis of the whole city with the CBD and multiple employment subcentres can be obtained.

Considering each zone as a monocentric city, it is necessary to study the different aspects of a monocentric city, such as, location of employment, estimation of the land-price

function, estimation of the population density etc.

2.1 ***Location of employment:*** In a monocentric city, all employments (manufactures, office, firm) and all shopping services are concentrated with the CBD. If distance from the centre of the city increases, commuting cost will increase. For decreasing commuting cost people will move closer to the city centre for employment and shopping.As a result housing demand as well as land prices will increase towards the CBD.

2.2 ***Estimation of the land-price function:*** A number of researchers have estimated the relationship between land price and distance to the city center. Mills[6] assumed the following relationship between land value and distance:

$$P(u) = Ae^{-cu}$$

where $P(u)$=Price of land u km. from the city center;
A= Price of land at the city center;
e= Base of the natural logarithm;
c is a parameter.

2.3 ***Estimation of the population density function:*** The density function describes the relationship between the population density and distance to the city center. Mills [6] assumed the following relationship between density and distance:

$$D(u) = d_0 e^{-gu}$$

where $D(u)$= population density u km. from the city center(population per square km.);
d_0 = population density at the city center;
e= Base of the natural logarithm;
g is a parameter.

3. Bus networks

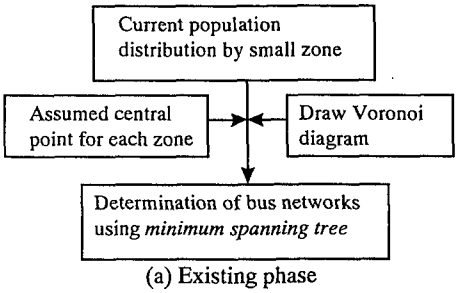
This model determines the bus networks by finding the minimum spanning tree (MST) of the center points of the zones.

A minimum spanning tree of a set of points is a minimum length tree that spans all the points: a shortest tree whose nodes are precisely those in the set. When the length of an edge is measured by the usual Euclidean length of the segment connecting its endpoints, the tree is often called the Euclidean minimum spanning tree(EMST). EMST is helpful in planning transportation networks. Although the primary consideration of minimum spanning tree is to provide some connecting route between all pairs of nodes with minimum distance, using some approximation over the MST highway routes, bus routes etc. can be efficiently designed.
In real situation, finding MST using Euclidean distance for determining bus route network is not always feasible. For example, the existence of a big river or inaccessible lands may prohibit some links of the bus networks. Again government policy may dictate to make some links although they are of long distances. One can also find a minimum spanning tree adapting those criteria.

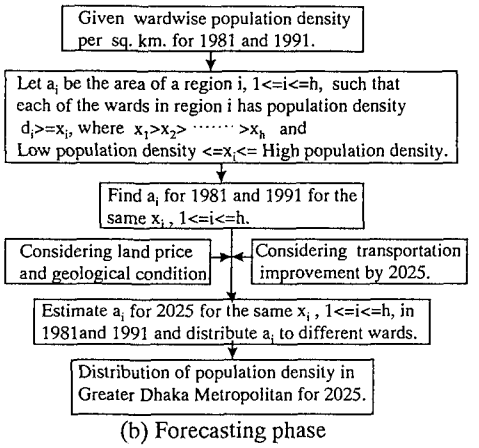
4. A simulation model for transportation planning of Dhaka city

4.1 *Flow diagram of the model*

An analytical flow diagram of our model is given in Fig. 1. Fig 1(a) is for existing phase and 1(b) for forecasting phase. The existing phase deals with the bus network planning of present Dhaka Metropolitan, considering the population density of the different zones.



(a) Existing phase



(b) Forecasting phase

Fig. 1: Analytical flow diagram

The forecasting phase deals with population distribution considering the improvement of transportation, land price and geological condition of a Greater Dhaka Metropolitan expected to appear by 2025.

4.2 *Area and population of Dhaka city*

Thanawise area, population and decadal growth rate of present Dhaka Metropolitan Area and its surrounding thanas are given in table 1. The present Dhaka Metropolitan consists of first 14 administrative unit called "thana" of the table. The city has grown up as a monocentrc city, since all employment subcentres are concentrated in CBD. The decadal growth (1981-1991) of the city as shown in the table is very high. This is because people has been attracted and come to the city for finding job and living. The present population has become a burden for the development and better management of the city. Moreover, it is expected that the city will appear as a megacity in future. Since the population of present Dhaka Metropolitan has already been saturated, it is expected that the surrounding thanas from thana no. 15 to thana no. 21 in table 1 will be included in Dhaka city and form a Greater Dhaka Metropolitan. The forecasting phase of our model will work on Greater Dhaka Metropolitan Area.

Dhaka zilla		Area in sq.km	Population in 1991	Population density per sq.km. in 1991	Decadal growth 1981-1991	Population in 1997
Thana no.	Thana name					
1.	Cantonment	29.94	190472	6362	80.27	
2.	Demra	47.35	521160	11007	78.42	
3.	Dhanmondi	9.47	201529	20691	78.33	
4.	Gulshan	53.59	281337	5250	61.56	
5.	Kotwali	2.07	210504	101693	16.67	
6.	Lalbagh	9.14	401387	43915	30.39	
7.	Mirpur	58.66	641630	10938	93.13	
8.	mohammoadpur	11.65	316203	27142	43.98	
9.	Motijheel	4.69	223676	47692	23.79	
10.	Ramna	7.85	195167	24862	86.97	
11.	Sabujbagh	18.18	354989	19526	70.27	
12.	Sutrapur	4.38	307483	70202	2.96	
13.	Tejgaon	8.75	220012	25144	17.48	
14.	Uttara	36.91	145648	20928	150.85	
Total for Dhaka Metropolitan		302.9	3.742197 million		59.64	8 million
15.	Keraniganj	166.87	530174	3177	46.61	
16.	Savar	280.13	378034	1349	44.34	
Average decadal growth rate					57.87	
Gajipur Zilla						
17.	Gajipur sadar	446	588492			
18.	Kaligang	159	175915			
Narayanganj Zilla						
19.	Narayanganj sadar	101	604561			
20.	Bandar	56	212572			
21.	Rupganj	248	375935			
Total for Greater Dhaka Metropolitan		1759.9	6.607880			

*The total population for Greater Dhaka Metropolitan is expected about 25 million by 2025.

Table 1: Thanawise area, population and decadal growth rate.

4.3 *Zoning*

In this model, the Greater Dhaka Metropolitan area is divided into 8 zones as follows. The present Dhaka Metropolitan is considered as one zone and each of the thanas from thana no. 15 to thana no. 21 in table 1 is considered as one zone shown in Fig. 2. The boundary of each zone can be decided by Voronoi concepts. The present Dhaka Metropolitan consists of 14 thanas. Fig. 3 shows the boundary of 14 thanas. The existing phase of the model divides the present Dhaka Metropolitan into zones by the following method. More than one employment subcentres with different population density are considered in each thana. Each subcenter is considered as a center of each zone. Using weighted voronoi concepts the boundary of each zone is determined where the population density of each subcenter is taken as the weight of the subcenter.

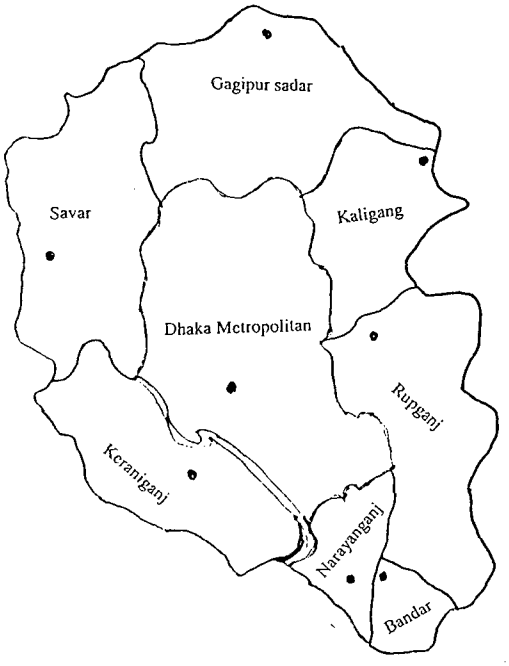


Fig. 2: Greater Dhaka Metropolitan

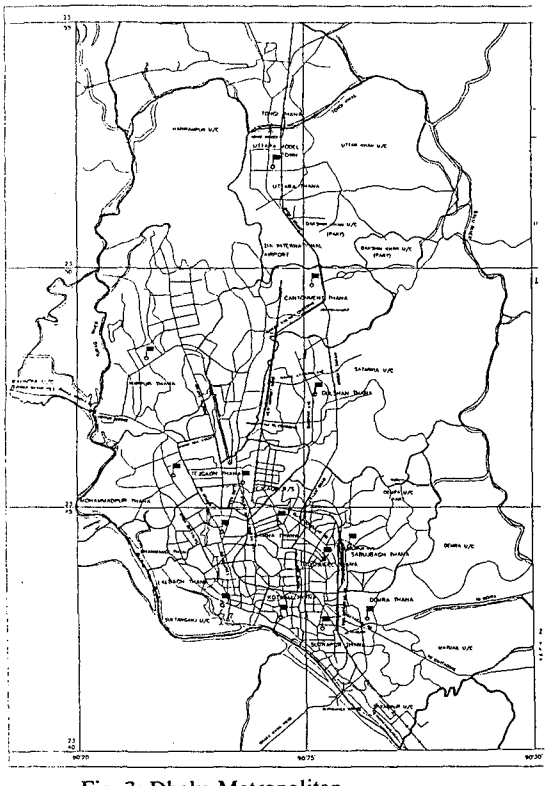


Fig. 3: Dhaka Metropolitan

5. Conclusion

This work has two phases, the existing phase and the forecasting phase. In the existing phase, the Dhaka Metropolitan has been divided into different zones with more than one employment subcenters using Voronoi concepts. The bus networks of Dhaka Metropolitan have been planned between central points of different zones using minimum spanning tree. In the forecasting phase, the population density has been distributed in Greater Dhaka Metropolitan considering the improvement of transportation, land price and geological condition by 2025.

6. References

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