Towards A Sustainable Public Transport System for Khulna City, Bangladesh

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Abstract

The people of Bangladesh spend a significant part of their time and money on transport, in search of a livelihood. Inadequate public transport system in most of the cities in Bangladesh is unable to meet the travel demand of the residents. With the changing mobility needs of urban residents', policy-makers are now looking for ways which are economically, socially and environmentally sustainable. Public transport has an important role towards sustainable urban transport. Modal shift from private to public transport will contribute to a significant reduction in the road accidents, congestion, energy consumption and pollution in Bangladesh. This study finds the travel demand derived optimal bus route for Khulna City. Effective travel demand for public transport has been estimated and assigned to the road network and "P-Median Problem" model has been used with the help of GIS to determinate the optimum location for bus stop. After performing a demand derived multi-criteria analysis, 43 locations were found as optimum for bus stop. Using optimization route based network analysis four routes have been proposed in this research based on the demand, feasibility for bus stop location and road capacity. This study recommends the city authority of Khulna to use these routes to establish a public transport system which is economically, socially and environmentally sustainable.

1 Introduction

The people of Bangladesh spend a significant part of their time and money on transport, in search of a livelihood. Inadequate public transport system in most of the cities in Bangladesh is unable to meet the travel demand of the residents. With the changing mobility needs of urban residents', policy-makers are now looking for ways which are economically, socially and environmentally sustainable. Public transport has an important role towards sustainable urban transport. Modal shift from private to public transport will contribute to a significant reduction in the road accidents, congestion, energy consumption and pollution in Bangladesh.

In Bangladesh there is no installation of light rail and underground railway in the urban areas. Mostly buses, minibuses, taxi, auto rickshaws, rickshaws are found to ply in the urban areas. In Dhaka city, public transport services are provided by buses, minibuses, Compressed Natural Gas (CNG) driven buses, taxis, auto-tempos, CNG auto rickshaws, and rickshaws. Only buses, minibuses are considered as the cheapest mode available as mass transit among the public transportations. In Dhaka city, buses are representing very small proportion of movements, only 7.4% (Alimuzzaman, 2002). Public Transportation has less contribution in moving traffic in Dhaka due to the poor level of service. The second largest city of Bangladesh, Chittagong provides public transportation by buses, minibuses and shared auto rickshaws. In Khulna city the available public transportation are town service buses and auto rickshaws, vans and rickshaws.

Town service buses are the cheapest among all available public transportation modes in Khulna city. Tempo service is available to commute between Khulna and other important urban centres within metropolitan region. These important urban centres are Batiaghata, Dumuria, Bagerhat, Fakirhat, Terokhada, and Kalia. Auto rickshaw in Khulna city mostly operated on shared basis in Ferry ghat to Khalishpur, Ferry ghat to Dulatpur, and Ferry ghat to Fultala. These routes are usually long and there is no bus service in those routes. Rickshaw vans and rickshaw are two most dominant mode of non-motorized transport in Khulna city.

Town service buses started its service in 1963. At that time the route was Dakbangla to Daulatpur. Currently, there is only one bus route exists in Khulna city. It runs a distance of 22 km from Rupsha to Fultala, through Ferry ghat. Town service bus starts its journey from Rupsha and travels on Khan Jahan Ali road, Khan-E-Sabur road and Jessor road. At present there are 39 buses including two double decker, runs from Rupsha Ghat to Fultala from 6.30 A.M to 8.00 P.M. This service seems to be internally insufficient as it has been observed that most of the buses are plying in overloaded condition.

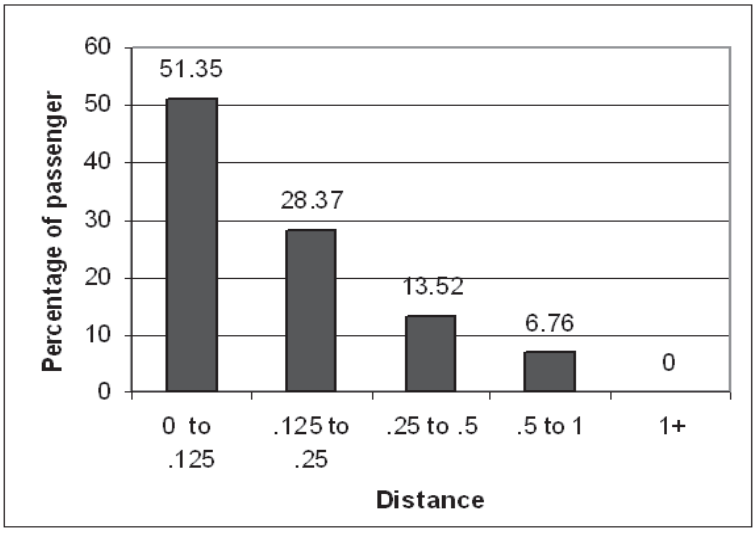

Figure 1: Preferable walking distance for bus users

The bus users also face some problem regarding the service frequency of the bus. The official frequency of town service buses is fixed at every 10 minutes interval. However, sometimes half an hour gap between bus trips is observed. People like to avail bus facilities within shortest walking distance. According to Rahman (1997), actual walking distance to avail bus facilities is about 1 km and desirable walking distance for bus facilities are calculated as about half km.

The main purpose of this study is to find out demand-oriented public transport route for Khulna city. As this route identification process tried to cover most parts of the city, the proposed routes will reduce travel distance for the people to avail bus facilities. More people will have the access to public transport which will make the public transport system socially sustainable. Modal shift from private transport to public transport and increase use of CNG in buses will make the public transport system environmentally sustainable. For the purpose of this study, travel behaviour of the city resident of Khulna city is analyzed. In this analysis the trip generation behaviour, trip distribution behaviour and modal choice behaviour for the city dwellers of different parts of the city is examined. Present performance of the town service is critically evaluated to find out the existing gap in the service. Finally, the bus routes are proposed based on location allocation analysis.

2 Methodology

Data from both primary and secondary sources is used for this study. For primary data collection, household interview survey and ridership survey by structured questionnaire is designed to collect information regarding the socio-economic characteristics of an individual trip maker, trip information and service attributes of town service buses. For the purpose of this study, the whole

Khulna city corporation area was divided into 18 Traffic Analysis zones.

The major determinant factor for the identification of TAZ boundary in this study is land use homogeneity. The second important factor is considered as the road network followed by the location of major activity centre. Gross Land use map of Khulna city is overlayed to the road network map of Khulna city. In this process, eighteen traffic analysis zones are created in the Khulna City Corporation area.

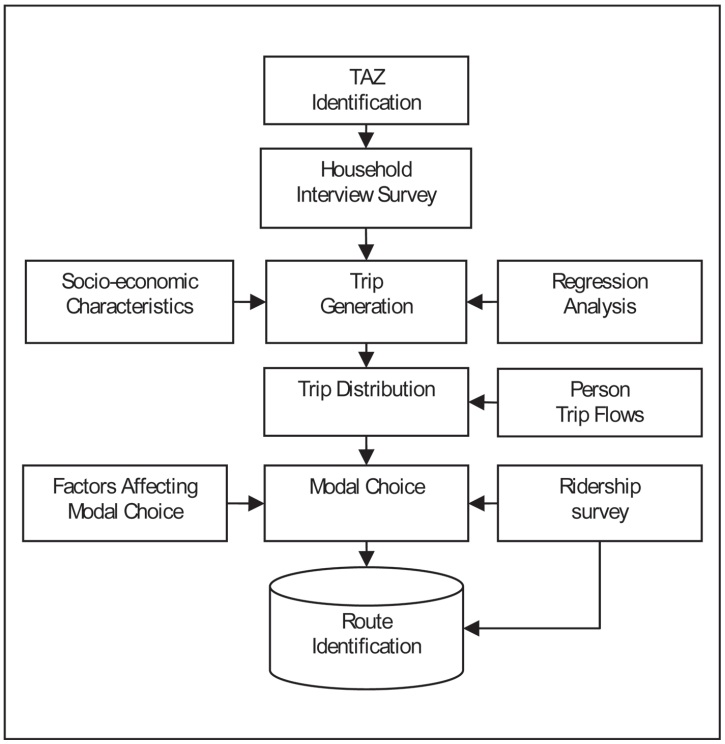

Figure 2: Methodology of the study

For the Household Interview survey, a household is chosen as a sampling unit. From the KDA Master Plan Volume-3 the number of household in the Khulna City Corporation is found as 162247. After identification of TAZ boundary a sample questionnaire survey was conducted in different TAZs.

The only limitation of selecting a large sample is time and money. In this study sample size is determined by the population proportion. This sampling technique is taken form the book "Research Methodology Methods and Technique" by Kothari (2003).The equation of sample size determination is as follows:

$$n = \frac{z^2 \times p \times q \times N}{e^2(N-1) + z^2 \times p \times q}$$

n = Size of Sample

z = the value of standard variant at a given confidence level and to be worked out from table showing area under normal curve.

p = sample proportion

q = 1- p

e = acceptable error

Sample proportion n is usually determined by past study or a pilot study. As there is no such provision is available, so the sample proportion is assumed to 0.5. The maximum allowable error is assumed as .048 or 4.8% and confidence level for the sample determination is 99%.

By putting the values in the equation and calculation, it is found that the sample size for household questionnaire survey is 640. So, for this study, in different traffic analysis zone 640 household was surveyed. The sampling technique that has been adopted for this survey was systematic random sampling.

For the determination of sample for ridership survey, a pilot study was required. In that pilot survey important bus stoppages were identified. Taking higher number of respondents from the important bus station 500 bus passengers were surveyed. Random sampling method will be used to select the respondents for interview.

For primary data collection two different structured questionnaires was prepared. One questionnaire was prepared for the household interview survey within the TAZ area and another for the riders of town service buses. The questionnaire survey for ridership survey has been done on those bus users who were departing from the bus stoppage.

Secondary data was collected from published documents and government and non-government organizations. Published books, reports, journals and other documents on mass transportation were used for basic and relevant information for the study. For the purposes of this study a great deal of relevant information and data were collected from various government and non-government organizations such as Bangladesh Road Transport Authority, Khulna City Corporation, Khulna Development Authority, Khulna Metropolitan Bus Malik Samity, Roads and Highways Department, Local Government Engineering Department etc.

In this study a large volume of data regarding transport supply and demand of Khulna city were collected from both primary and secondary sources. Statistical Package for Social Science (SPSS) was used for data entry and data analysis. SPSS is found to be the proper software for the regression analysis, so the trip generation regression analysis was done using SPSS. The desire line for trip distribution was done by using a ArcView extension “Desire Line”. Route

selection process is a completely automated process in some Transportation Planning softwares (TransCAD, EMME/2 etc). Due to unavailability of this kind of software route selection process was done by using location-allocation models available in the ARC INFO 7.2.1.

3 Travel Characteristics of Khulna City residents

Socio-economic characteristics are an important factors affecting trip generation behaviour. Remarkable differences in trip production rate are observed with the stratification of sex and age group. There are significant differences in trip production rate between male and female is found above 20 years of age. In the occupation wise stratification worker of all types have the highest trip production rate of 3.6 trips per day. Trip Production rate of the residents aged 8 years and above is estimated at 1.44 trips per day.

In this research, trip generation regression analysis is done for the purpose of modelling the trip generated from different household in Khulna city. In the regression analysis, dependent variable "trip generation per household per day" can be figured out only using the "number of family member" as independent variable. Total trips produced by any traffic analysis zone can be easily obtained from this equation. This critical regression coefficients established in this study could forecast trip generation for 10-15 years. However, changes in land use and socio-economic characteristics may lead to chose different correlation coefficients for the regression analysis.

The final prediction equation for trip generation is:

TGH = 0.765 (Constant) + 1.374 * NFM

Where, TGH= Trip Generation per Household, NFM= Number of Family Member

The research also examined trip purpose composition for different location of Khulna city. Work and education trips dominated the total travel behaviour, accounted for 48% of all trips.

3.1 Trip Production and Attraction

3.1.1 Zonal Trip production

In the Khulna city, person trips are concentrated in TAZ-11 (Dak-Banglow and its surrounding area). Although population in TAZ-11 and TAZ-12 accounts for merely 8 percent of Khulna, trips produced in the area is 21 percent of Khulna city. TAZ-17 also produces a large amount of person trips (10 percent of total trips). Other significant trip producing areas are TAZ-10, 13,14,15,16.

3.1.2 "Morning Peak Hour" Trip Production and Attraction

In this section of the study the focus will be trip production and attraction in the morning peak hour (8-10 AM). Compare to the trip production with the trip attraction of "Morning Peak Hour", the TAZ-11 indicates much higher trip attraction then trip production. This implies that many people from outside the zone come to the Dak-Banglow and surrounding area in the morning peak hour. Other areas where trip attraction in "Morning Peak Hour", exceeds trip production are seen in the TAZ-4, 7, 8, 12, 17.

3.1.3 "Evening Peak Hour" Trip Production and Attraction

In the evening peak hour people are returning home from work place. This time attraction is calculated for the people's trip to their home. Survey results shows that, in the CBD area (TAZ-11) trip production in evening peak hour (4 to 7 PM), greatly exceeds trip attraction. This implies that many people come to CBD from other zones and return to their home in these hours. Other zones with greater trip attraction in "Evening Peak Hour" disperse over the Khulna city. The zones where trip attraction exceeds trip production to a large extent can be seen in the zones with higher residential densities, such as TAZ -1,2,3,5,9,10,13,14,15,16,18.

Figure 3: a) Morning peak hour's zonal daily trips and b) Evening peak hour's zonal daily trips

3.2 Trip Distribution

3.2.1 Person Trip Flows

Person Trip flows by all modes of transportation in Khulna city are illustrated in Figure 4. All the surroundings zone of the CBD TAZ-9, TAZ-10, TAZ-13, TAZ-14, TAZ-15, TAZ-16, and TAZ- 17 show strong linkage with CBD.

However, TAZ-12 and TAZ-17 have the largest person trips flows between the two zones. The highest person trip flows originated to Dak-Banglow and surrounding areas are from TAZ-13. TAZ-12 has the highest number of trips originated from the other zones and TAZ-18 has the lowest trips. Larger Person trip demand is observed between the surrounding zones of CBD than other zones.

3.2.2 "Morning Peak Hour" and "Evening Peak Hour" Trip Flows

The zone which containing the CBD area have strong person trip flows from TAZ-10, TAZ-12, TAZ-13, TAZ-14, TAZ-15, TAZ-16 and TAZ- 17. Some other linkages from the northern part of the city also observed. Dak-Banglow and the surrounding area have largest trip demand from the TAZ-17. Morning peak hour person trip flows are dominated by the TAZ-11 with highest trip demand.

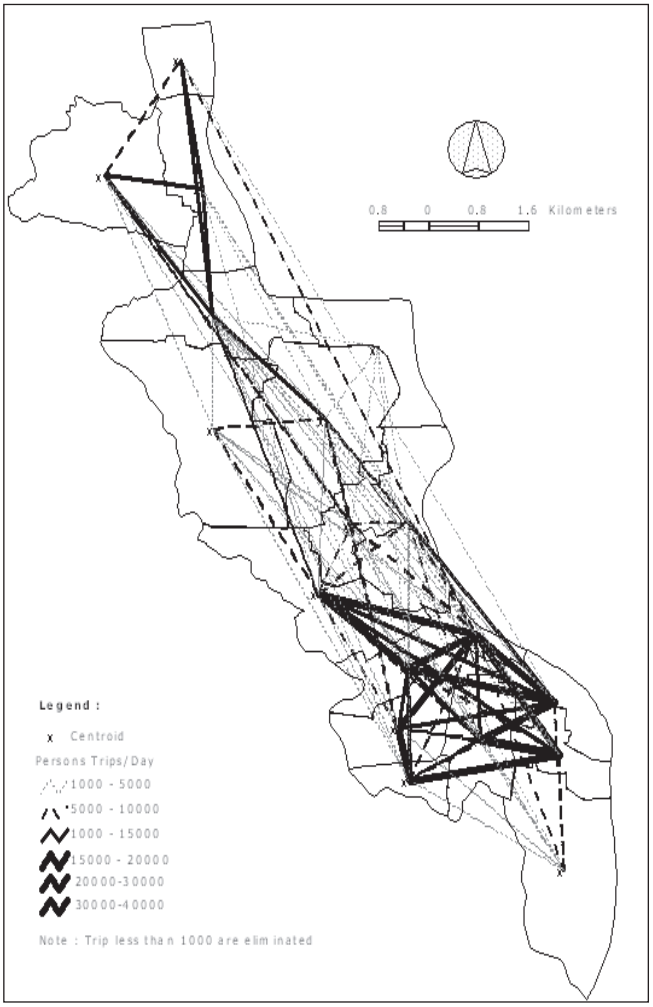

Figure 4: Trip flows throughout the day

In contrast to morning peak hour person trip flows, evening peak hour trip flows have some weak linkages to the northern zones from the TAZ-11 and 12. Person trip demand of the CBD and surrounding reduced much in the evening peak hour and person trip demand for the residential zone is also increased.

3.3 Modal Choice Behaviour

Rickshaw is found out as the most common mode of travel in this study followed by walking. The least common mode of travel is found is car/jeep. Only 6 percent of total trips are generated by bus. Modal composition varies substantially according to monthly household income. With the increment of income people are less interested to use bus and baby-taxi use is increase.

Travel time is a major factor affecting modal choice behaviour. The highest travel time is found for bus which is 32 minutes. This time is high because the speed of this vehicle is low, with less service frequency and more time in the stoppage. The lowest travel time is found for van which is 8 minutes. It is to be mentioned here that, van is operated in short distance.

Travel cost varies from the choice of mode and distance of destination. Average travel cost for rickshaw is 6 taka and for bus, average travel cost is 4 taka. On the other hand, average travel cost for baby-taxies is found 6 taka. Travel distance is considered as a significant factor for mode choice. The average travel distance for bus is found to be 7.02 km which is only 6 percent of the total trips. Auto Rickshaws have 4.28 km average trip distance and 5 percent of total trips are made by this mode.

3.4 Evaluating the Present Performance of Town service Buses

The study also evaluates the present performance of the town service bus by conducting a survey on the bus users. It is observed average acceptable time for travelling bus is found 12 minutes, 15 minutes, 24 minutes and 35 minutes for 1to 4 km, 5 to 8 km, 9 to 12 km and above 12 km distance respectively against the 22 minute, 29 minutes, 41 minutes and 53 minutes of present travel time. Most of the bus users (78.26 percent) are willing to pay less than the amount they are paying.

According to the passengers half an hour is the maximum waiting time. It has been found that there is a wide variation between the opinion of the passengers and the information from the Khulna Bus Malik Sammity about the interval of buses.

The average waiting time as stated by the passenger is 19 minutes. According to the authority it is 10 minute. No bus is found to maintain 10 minutes interval. Regarding operation it has been observed that the buses do not maintain proper rules. Sometime they take excess time at some stops without any causes. For collecting passenger buses are found to make unnecessary delay in the stoppage, mainly New market, Baikali, Daulatpur, Fulbarigate, Siromoni stoppages. From survey, desirable waiting time is found 15.59 minutes. Bus stop in the current service is not in its optimum location. Some times these are sparsely located which force the people to walk long distance or to take other modes of transportation.

4 Route Identification Process

In this section location-allocation model is used to identify demand-oriented route for town service bus, with the application of GIS. The route should enable the travellers to access to their desire destination within shortest possible time within affordable expense. The successful application of these models shows the capability of the proposed model for a typical city of Bangladesh, which has potential demand for public transportation. It also proves the capability of GIS for application to such problems.

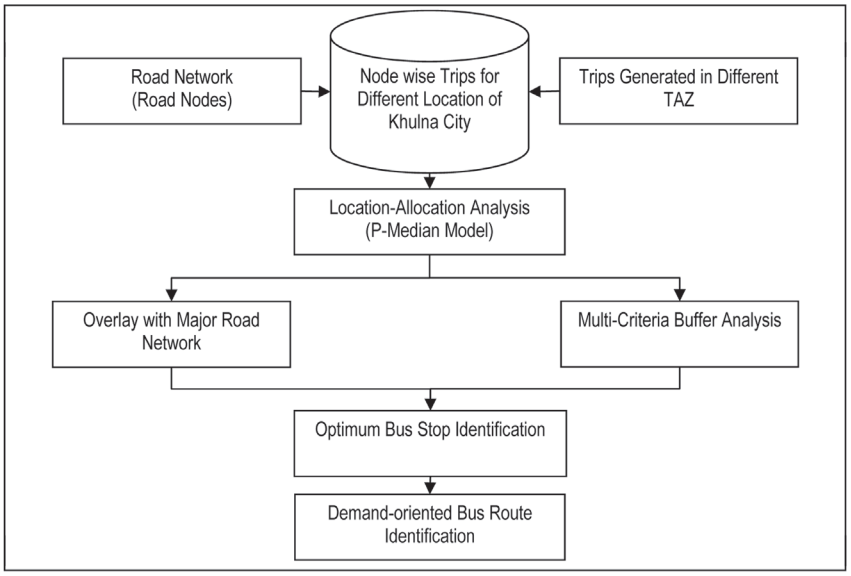

Figure 5: Route identification process

From the household Interview Survey trip Generated in different TAZ is calculated. The total numbers of trips per TAZ are calculated by interpolation technique. The road nodes for all the roads in the city area are designated using GIS operation. Then the total number of trips generated in each zone is divided equally within the node that falls in respective TAZ area.

"P-Median Problem with a Maximum Distance Constraint Model" has been selected by considering the advantages given by that model. In the following subsections the model algorithm and description is given for the better understanding of the model.

4.1 P-Median Problem with Maximum Distance Constraint Model

P-Median Problem determines the location of a given number of facilities, P, so that the total distance travelled is minimized. The facility is located at the 'weighted centre' where the majority of the demand points are, tending towards those with a high weight (Hakimi, 1965). This location would be one that is centrally located to the majority of the demand, or in other words, the median

location. Minimizing the total distance travelled may result in some demand points that are disproportionately far from their closest centre. P-Median Problem model applies primarily to private sector problems where the goal is to minimize transportation costs. Individual accessibility is not an issue in the private sector because overall cost is the primary consideration.

On the other hand, where equity of service is an issue, such as in locating a stop, it is important to consider individual access. To reduce variation between individuals, the P-Median Problem model can be modified.

The P-Median Problem objective with a specified maximum distance solves the P-Median Problem with Maximum Distance Constraints. The objective is the same as the P-Median Problem, but a constraint is added to minimize the amount of demand that will travel further than a specified distance (Khumawala, 1973). This model do not tends to pull the facility towards demand points that are further away and it is a linear function of location-allocation algorithm. For this reason, P-Median Problem with a Maximum Distance Constraint Model is applied for the identification of possible bus stop location in Khulna city.

4.2 Optimum Bus Route Identification

The P-Median with Maximum Distance Constraint Model is applied in the road node of Khulna city. The generated trips in different zones incorporated with the road node. The whole model is applied on the using ARC INFO 7.2.1. The possible bus stop locations identified after the operation. The number of stop location (p) is restricted to 150. The possible location which covers the maximum demand is distributed on all the areas of Khulna city. However, all the roads do not have the capacity for bus plying. So, the roads which have the capacity to ply bus are identified. Then the road layer is overlayed on the possible bus stop location to find out the actual number of potential bus stop location. In this process some roads are identified as the potential route for bus. These roads are Sher-E-Bangla Road, Outer by Pass Road, Majid Sarani, Sonadanga Road, BIDC Road, Old Jessore Road (within Khalishpur area), KDA Avenue and Khan-A-Sabur Road.

Four routes for bus are suggested based on the potential bus stop location. These are as follows:

Route-1: Siromoni-Natun Rasta Intersection- Sondanga- Majid Sarani-KDA Avenue-Hotel Royal-Khan Jahan Ali Road- Rupsha.

Route-2: Siromoni- Natun Rasta Intersection-BIDC Road-Old Jessore Road-Khan Jahan Ali Road-Rupsha.

Route-3: Siromoni-Natun rasta Intersection- Sondanga- Gollamari-Sher-E-Bangla Road-Moylapota-Hotel Royal-Khan Jahan Ali Road-Rupsha.

Route-4: Siromoni-Natun Rasta Intersection- Jessore Road-Shibbari More-KDA Avenue-Khan Jahan Ali-Road-Rupsha.

4.3 Optimization of Bus Stop Location

In the above process the 51 potential bus stops is identified. However, in certain area, the bus stops are closely located resulting in waste of time and space. The stops are also sparsely located which may force the people to walk long distance or to take other modes of transportation. A multi-criteria buffer analysis is performed to identify suitable location for bus stop by considering distance, importance of location, willingness to walk etc. The bus stops are also verified for their proximity to school, colleges, and commercial centres. The minimum distance between two stops is taken 0.5 kilometres. If there is an overlap in the buffers then a common point is considered for the location of the stop. The point is selected considering other criteria also. Confluence of all parameters is essential before arriving into any decision. The similar way if the distance between two buffers are more this indicate that the area in the in between region is not properly served by any of the bus stops. In these case new bus stops is created. After considering all these criteria 43 optimum bus stops are created on the proposed four routes.

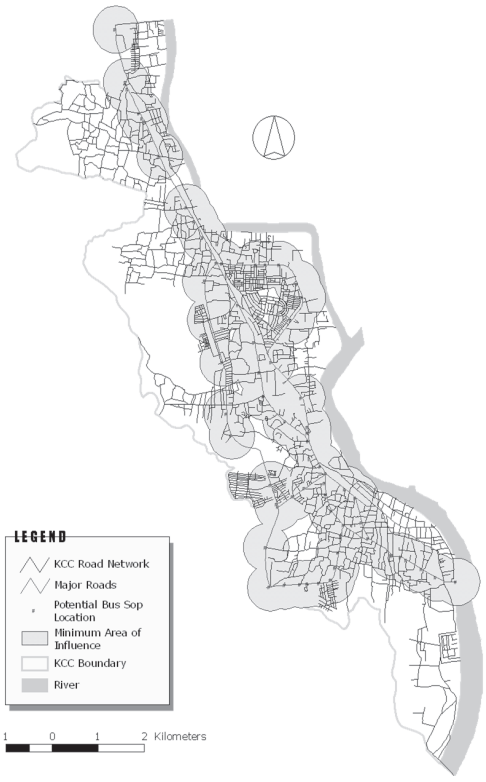

Figure 6: Optimization of Bus Stop Location by Minimum Area of Influence

5. Recommendation for Improvement of Bus service

In this section of the study some important improvement of existing bus service is recommended based on the field survey. One of the important factors, for not choosing town service bus is the bad quality of service. After finding out the demand-oriented bus route the current research are aiming to recommend some improvement in the services. These are as follows:

5.1 Increase the Number of Buses

With the additional routes the number of buses should be increased. At present there are 37 fifty two seat buses and 2 double decker buses plying on the Rupsha to Fultala route. This number of buses is inadequate for the current route. With the introduction of the additional routes the number of buses should be increased.

5.2 Abandon the Old Buses

As stated earlier buses used in the current route are not in good condition. These buses are rejected from different long routes staff buses of different offices. The emission level of these buses is high compare to other vehicles. As a result these buses should be dumped from the operation. These old buses seat condition is in the worst condition. The new buses may be CNG driven vehicle.

5.3 Construction of Passenger Shed

In the current situation town service buses have few fixed stoppages. For this reason passenger shed is not available in the bus stoppages. Passenger sheds are very essential at each stop, because it is disgusting and painful for the passengers to wait a long time for the bus under the sun or rain on the road.

6. Conclusion

For Khulna city, bus services can be most efficient and least expensive public transport option. Transport planner aims to increase the person-capacity characteristics of vehicle which is only possible by the public transport system. Public transportation system will reduce the vehicle density on the roads to avoid the traffic congestion and parking problem.

Sustainable public transport service must satisfy the requirements of travellers. It needs to serve the correct routes, offer a high frequency, be reliable and quick, use high quality vehicles and staff and be affordable (Anwar, 2003). Other important pre-requisite of sustainable public transport are timely operation, consistency and free from pollution. In this research four travel demand derived bus route is proposed. These routes are determined using location-allocation

models with the help of GIS. Forty three bus stop location is also proposed which are systematically spaced and within easy walking distance of large number of people. To provide high frequency, consistency and environmental friendliness new improved vehicle is proposed in this research.

This is an explanatory type of research. It has been attempted in this research to attain a public transport system for Khulna city which is economically, socially and environmentally sustainable. The research is not claimed to provide an account which could make complete success. However, it could be a start towards sustainability for the secondary cities of Bangladesh.

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نحو نظام مستدام للنقل العام في مدينة كولنا ببنغلادش

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الملخص:

تستنفذ المواصلات كثيرا من الوقت والمال من سكان بنغلادش خلال سعيهم لكسب العيش. فنجد انظمة النقل في معظم مدن بنغلادش غير قادرة على مواكبة متطلبات السكان. ومع ازدياد الحاجة للحركة في المدينة يبحث المسؤلين عن سياسة النقل في وسائل مستدامة اقتصاديا واجتماعيا وبيئيا. وللنقل العام دور اساسي في سياسة مستدامة للمواصلات بالمدينة. ونجد ان التكامل بين النقل العام والمواصلات الخاصة من شانه ان يقلل من حوادث الطرق والازدحام واستهلاك الطاقة والتلوث في بنغلادش. وتسعى هذه الدراسة لايجاد خط سير الباصات الامثل لمتطلبات حركة السكان في مدينة كولنا. وقد تم تقدير متطلبات الحركة بالنقل العام وتطبيقها على شبكة الطرق من خلال نموذج "P-Median Problem" مع مساندة وسائل نظم المعلومات الجغرافية (GIS)، وذلك لتحديد المواقع الامثل لمواقف الباصات. وبعد اجراء مجموعة تحاليل بناء على معايير متعددة خاصة بالمتطلبات، كانت النتيجة تحديد عدد ٤٣ موقع هي الامثل لمواقف الباصات. تلى ذلك اجراء تحليل لشبكة الطرق لاختيار المسارات الامثل لخطوط الباصات وكانت النتيجة اقتراح اربعة مسارات هي الافضل من حيث متطلبات النقل، المواقع المناسبة للمواقف وسعة الطرق للحركة. وترشح هذه الدراسة لسلطات مدينة كولنا استخدام هذه المسارات الاربعة لانشاء نظام نقل عام مستدام اقتصاديا واجتماعيا وبيئيا.