# A Methodology for Selection of Bus Rapid Transit Corridors: A Case Study of Kolkata

**Tuhin Subhra Maparu and Debapratim Pandit**

**Abstract**

*The paper aims at formulation of a methodology for selection of corridors for introduction of BRTS in urban areas in India and Kolkata in particular in the context of present challenges like increasing traffic congestion and car ownership, lack of road and transport infrastructure and gradual deterioration of LOS of bus transit system. The present methodology combines both, existing travel demand estimate and feasibility analysis in terms of traffic and road infrastructure characteristics for selection and phasing of BRT corridors. Incorporation of feasibility constraints both for selection and phasing of BRT corridors would enable planners and decision makers to make more informed decisions about implementing BRTS in Indian cities.*

## 1. INTRODUCTION

Level of Service or LOS for existing bus transit operations in terms of safety, comfort and urban network performance like proper routing and scheduling has steadily deteriorated over time in Kolkata. Increase in household income has also resulted in passengers shifting to personalized modes, taxis and intermediate public transport such as three wheelers, thus, adding to traffic congestion which have further reduced the LOS for bus transit system (MUD, 2008). In addition, the problem of lack of adequate road space and transportation infrastructure has further increased the challenges for bus transit system reform and redesign towards improving its LOS.

Bus Rapid Transit System or BRTS is considered by the policy makers as a way to improve bus transit services. 'BRTS is an integrated system of facilities, services, and amenities that collectively improve the speed, reliability, and identity of bus transit (TCRP, 2003). BRT is commonly understood as a system emphasizing priority for buses and rapid movement of buses by securing segregated bus ways, although there is no precise definition of what constitutes a BRT system (Wright, 2005). The selection of elements for BRT depends on the city's characteristics such as road infrastructure and traffic characteristics of the city.

In recent years, BRTS is being increasingly adopted in many Asian cities. In 2004, the Trans Jakarta bus way was started along a 12.9 km corridor through

*__Tuhin Subhra Maparu__, is a Project Associate at the Department of Architecture and Regional Planning, IIT Kharagpur have completed B.Arch. (with Honours) from Bengal Engineering and Science University, Shibpur and M.C.P. from IIT. Email: tuhin.maparu@gmail.com*
*__Dr. Debapratim Pandit__, is an Assistant Professor at the Department of Architecture and Regional Planning, IIT Kharagpur has obtained his PhD in Urban Engineering from University of Tokyo in 2007. Email: debapratim@arp.iitkgp.ernet.in*

the city center. BRT corridors were installed in Seoul as a part of reform of its public transportation and first stage commercial operation of BRT was also started in Beijing (Matsumoto, 2006). In India, the first phase of BRT system has been implemented in Delhi (TRIPP and RITES, 2005). However, this has resulted in a few cases of accidents and traffic chaos on that particular BRT stretch and extension of the same has been halted till some of the design issues are sorted out.

The first stage for introduction of BRTS in any city involves identification of potential corridors where the improvements of bus transit facilities can be undertaken. Selection of Bus Rapid Transit corridors involves two aspects:

- Identification of possible BRT corridors; and
- Ranking or prioritizing of BRT corridors for phasing.

A survey of recent literature suggests that, BRT corridor selection is done based on the available right of way of major roads and present level of bus service operated on such corridors as in the case of Delhi (TRIPP, 2005) or using concentration of existing bus service, ridership and road characteristics inventory as in case of Miami (CUTR, 2004). In general, existing and future land use, population density and employment need to be estimated to predict ridership of BRT. At the same time it should also be checked whether it is possible to implement BRT considering the existing road infrastructure and traffic characteristics.

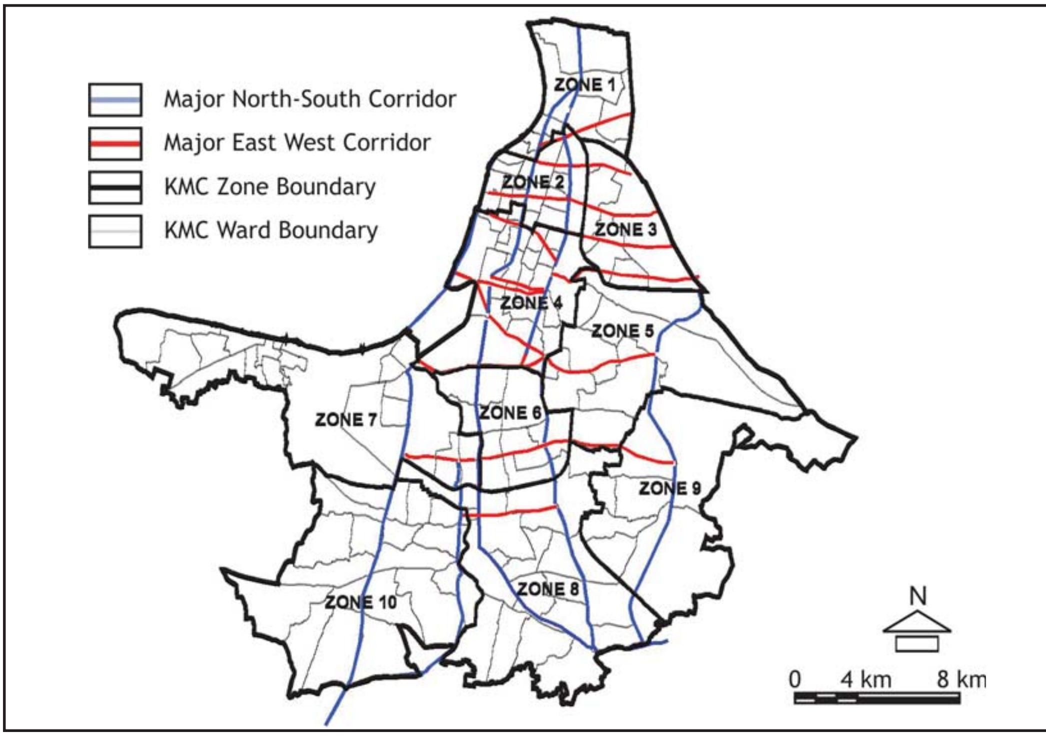
The present research considers the case of a transportation network of an existing city and aims at formulation of a methodology for selection of corridors for introduction of BRTS. The city of Kolkata, with its unique challenges like high population density, inadequate road space and transportation infrastructure, highly overlapping bus routes and very low LOS of bus transit system, is taken as the case study area. However, selection of BRTS characteristics and detailed design is not within the scope of the present paper.

## 2. STUDY AREA AND DATA COLLECTION

Kolkata Municipal Corporation or KMC is located in the eastern part of India with an area of 185 sq km and a population of 4,580,544 (Census, 2001), which is estimated to increase to 5,080,519 (World Gazetteer, 2009) in 2009. The city had population density of 24,718 persons per sq km in 2001. Administrative division in KMC includes 141 wards and 15 boroughs and the basic road network structure in Kolkata comprises of east-west and north-south corridors as shown in Fig. 1.

Average car ownership in Kolkata is 61 per 1,000 population, average trip length is 10 km, and per capita trip rate is 1.56 for all vehicles and 1.05 for

**Fig. 1 Zone Division and Major Corridors in KMC**




motorized vehicles (MUD, 2008). Mode share of public transport in Kolkata is 54 percent (MUD, 2008). The Central Business District is located at the heart of the city, on the eastern bank of river Hooghly and the major residential zones are located on the southern, northern and eastern parts of the city. Most of the bus routes in Kolkata are oriented towards the CBD.

Bus transit system in Kolkata is operated by public and private operators, which include 71 Calcutta State Transport Corporation (CSTC), 30 Calcutta Tram Company (CTC), 144 private and 98 mini bus routes in the city (Kolkata Gazette, 2003). In addition, there are a few West Bengal Surface Transport Corporation (WBSTC) and South Bengal State Transport Corporation (SBSTC) bus routes. The major issues related to bus transit system in Kolkata are uncoordinated and overlapping bus routes, unreliable bus transit system, low LOS, increased air and noise pollution, increasing number of accidents due to rash driving and overtaking, low average speed, intermixing of other vehicles with the buses, narrow right of way leading to traffic congestion and poor transportation infrastructure.

Detail data on road characteristics, bus routes, bus transit ridership, etc; were collected and organized in Geographic Information System format using MapInfo 6 software as shown in Fig. 2. Secondary data on bus routes was collected from Motor Vehicles Department, Kolkata and data on road characteristics was collected

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Fig. 2 GIS Database for Bus Routes in Kolkata

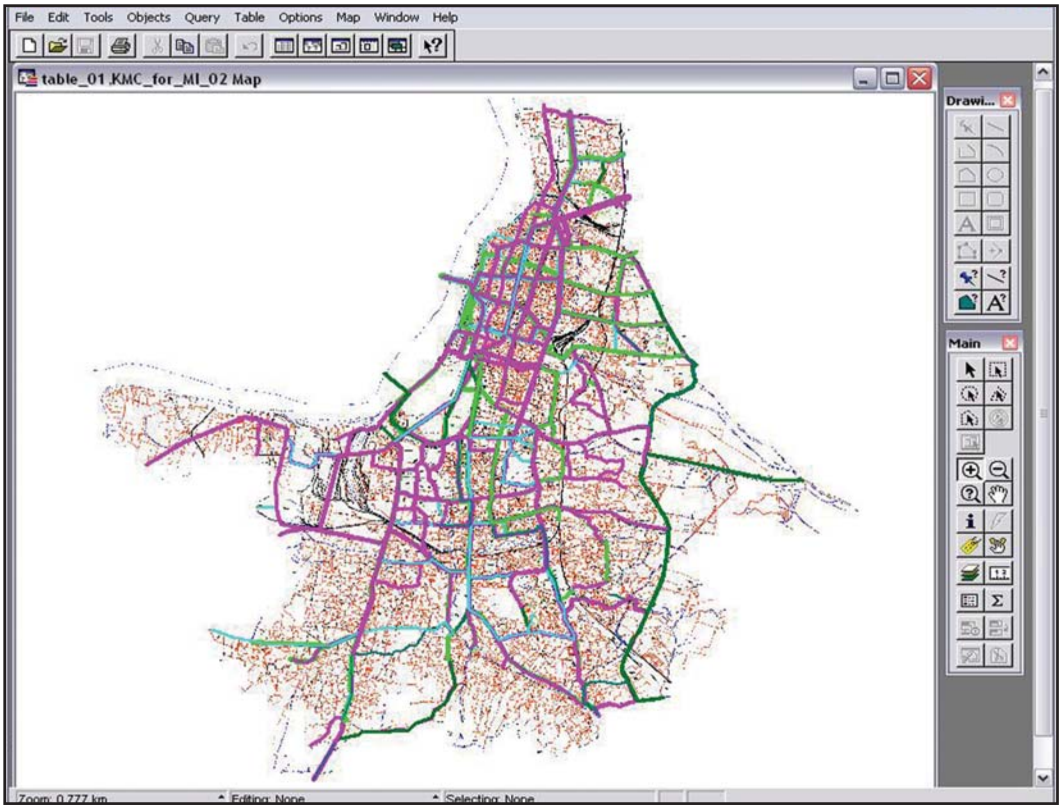
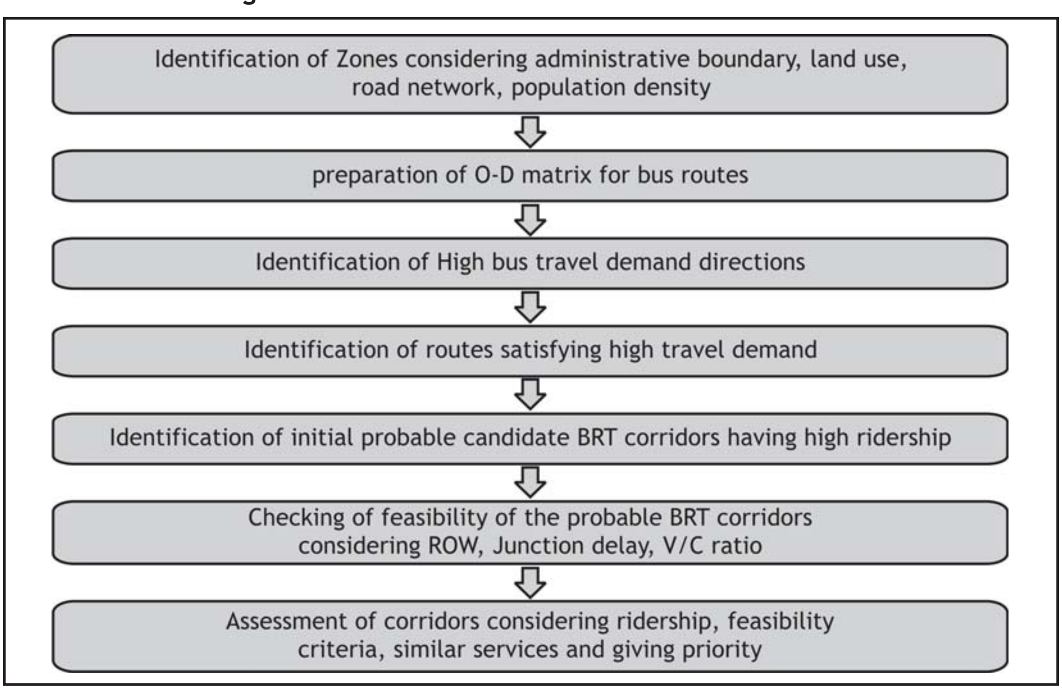



Fig. 3 Work Flow for Corridors Selection for BRTS



from Kolkata Metropolitan Development Authority or KMDA. Data for passenger loading of buses, frequency of buses, speed and delay for buses, etc; was collected through primary surveys.

## 3. METHODOLOGY

Selection and prioritization of BRTS corridors in Kolkata has been done step wise as detailed out in Fig. 3. The best way to estimate passenger travel demand by buses and their direction of travel is to ask every bus passenger his or her origin and destination at the bus stops or through household surveys after deciding the sample size, to construct the origin-destination (OD) matrix for bus passengers. However, this is very difficult for a city like Kolkata, which has a huge population and a high percentage of bus users. The method adopted here is to first prepare an OD matrix for the existing bus routes to determine the major demand directions and the routes or links through which these demands are met. Then, considering concentration of bus routes along these routes, ridership is determined for selection of initial probable BRT corridors. Finally, feasibility for BRT implementation on those corridors have been tested considering ROW (right of way), volume by capacity (V/C) ratio, etc. The detail steps for identification of BRT corridors are described below:

**Step I:** First, the city was divided into different traffic analysis zones based on administrative boundaries, land use, population distribution and existing road and bus route networks.

**Step II:** Next, Origin Destination matrix was prepared for bus routes which indicate number of bus routes connecting ith and jth zone i.e. direction of travel demand.

**Step III:** Third, directions where the number of bus routes connecting these zones were high or alternatively directions having higher travel demand were identified. New development proposals and future land use was also considered to identify future travel demand directions.

**Step IV:** Fourth, routes or links through which these travel demands met were identified. Then, concentration of bus routes along these routes or links was considered to select routes having high travel demand among those initially identified routes.

**Step V:** Further, higher the ridership, higher is its potential for BRT. Therefore, ridership along the routes identified above was estimated to identify initial probable BRT corridors.

**Step VI:** Next, feasibility for implementing BRT along these corridors was checked using road inventory data in terms of right of way (existing and future), number of major junctions and delay, existing volume by capacity (V/C) ratio, etc.

**Step VII:** Finally, priority of developing these corridors was determined considering ridership, feasibility criteria and presence of similar or alternative transit services like Metro Rail Transit (MRT), Light Rail Transit (LRT), etc; and scores were assigned for individual aspects considering equal weight for each aspect. Higher total score indicated greater suitability of the corridor for implementing BRTS.

Even though possible BRT corridors could be identified using the present methodology, the type or form of BRT system e.g. open or close type BRTS adopted will depend on implementation considerations, operational considerations and integration issues (CEPT, 2007).

## 4. ANALYSIS AND RESULTS

**Identification of zones:** First, the city was divided into 10 zones depending on the administrative boundaries (ward and borough boundary), existing road and bus networks such that there is homogeneity in distribution of land uses as well

**Table 1 Identification of Zones in KMC**

| Zone | Administrative boundary | | Significant areas/ places |
|---|---|---|---|
| | Borough | Wards | |
| **1** | I | 1,2,3,4,5,6,7,8,9 | Bagbazar, Belgachia, Paikpara, Chitpur, Sinthi |
| **2** | II & IV | 10,11,1215,16,17,18,19, 20,21,22,23, 24,25,26,27, 28,38 | Shyambazar, Shovabazar, Girish Park, Barabazar |
| **3** | III | 13,14,29,30,31,32,33,34,35 | Ultadanga, Manicktala, Narkrldanga, Beliaghata |
| **4** | V, VI & VII (partial) | 36,37,39,40,41,42,43,44,45, 48,49, 50,46,47,51,52,53,54, 55,60,61,62,63 | BBD Bag, Sealdah, Esplanade, Maidan |
| **5** | VII (majority) | 56,57,58,59, 64,65,66,67 | Tangra, Kustia, Dhapa, Tiljala, Kasba |
| **6** | VIII | 68,69,70,71,72,73,84,85,86, 87,90 | Bhawanipur, Ballygaunge, Gariahat, Golpark |
| **7** | IX & XV | 74,75,76,77,78,79,80,82,83, 88, 133,134,135,136,137,138, 139,140, 141 | Khidirpur, Garden Reach, Alipur, Chetla |
| **8** | X & XI | 81,89,91,92,93,94,95,96,97,98, 99, 100,101,102,110,111,112, 113,114 | Jadavpur, Tollygaunge, Baghajatin, Garia |
| **9** | XII | 103,104,105,106,107,108,109 | Haltu, Mukundapur, Santoshpur, Ajaynagar |
| **10** | XIII & XIV | 115,116,117,118,119,120,121, 122, 123,124,125,126,127,128, 129,130, 131,132 | Behala, Purba & Paschim Barisha, Thakurpukur |

**Table 2 Different Zone Characteristics in KMC**

| Zone | Area (sq km) | Population | Density (Person/SqKm) | Landuse (predominant) |
|---|---|---|---|---|
| 1 | 9.965 | 323903 | 32505 | Residential, Industrial |
| 2 | 6.929 | 496297 | 71624 | Residential, commercial |
| 3 | 9.336 | 340590 | 36481 | Residential, Industrial |
| 4 | 11.157 | 603512 | 54094 | Commercial, Institutional |
| 5 | 25.990 | 505491 | 19449 | Residential, Open space |
| 6 | 9.933 | 292868 | 29485 | Residential, commercial |
| 7 | 28.260 | 642398 | 22732 | Residential, Industrial |
| 8 | 23.901 | 607060 | 25399 | Residential, Institutional |
| 9 | 28.980 | 221923 | 7658 | Residential, Open space |
| 10 | 30.550 | 541115 | 17712 | Residential, Open space |

as population and density in a holistic manner. The administrative boundary of the zones and significant places within those zones are given in Table 1. Different zone characteristics such as area, total population, population density and predominant land use are shown in Table 2.

**Preparation of bus OD matrix:** In Kolkata, bus routes have developed over time in response to the travel demand of bus passengers. Thus, assuming that the existing routes cater to the present passenger travel demand in general, an OD matrix for existing bus routes was prepared for Kolkata considering state, private, CTC and mini bus routes. Each cell in Table 3 represents the number of bus routes and their origin and destination zones. If the origin or destination of a bus route lies outside KMC boundary, then the nearest zone within KMC is taken as its origin or destination. WBSTC and SBSTC bus routes are ignored from the assessment.

**Table 3 Bus Routes O-D Matrix for Kolkata**

| Zone | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | | | | | | | | | | 0 |
| 2 | 17 | 0 | | | | | | | | | 17 |
| 3 | 4 | 28 | 2 | | | | | | | | 34 |
| 4 | 36 | 21 | 28 | 5 | | | | | | | 90 |
| 5 | 4 | 8 | 1 | 6 | 0 | | | | | | 19 |
| 6 | 2 | 7 | 0 | 2 | 0 | 0 | | | | | 11 |
| 7 | 4 | 9 | 5 | 14 | 2 | 0 | 0 | | | | 34 |
| 8 | 7 | 21 | 17 | 24 | 0 | 0 | 3 | 0 | | | 72 |
| 9 | 0 | 3 | 1 | 4 | 0 | 0 | 1 | 0 | 0 | | 9 |
| 10 | 3 | 16 | 7 | 25 | 0 | 2 | 0 | 1 | 1 | 2 | 57 |
| **Total** | 77 | 113 | 61 | 80 | 2 | 2 | 4 | 1 | 1 | 2 | **343** |

**Table 4 High Travel Demand Routes in KMC**

| Connecting zones | Routes and Links | No of overlapping bus-routes |
|---|---|---|
| **1-4** | CR Avenue, BT Road | 12 |
| | APC Road, BT Road | 15 |
| **2-3** | MG Road, APC Road, Manicktala Main Road | 5 |
| | BK Pal Avenue, Aurobindo Sarani | 9 |
| | Vivekananda Road, APC Rd, Aurobindo Sarani | 6 |
| **3-4** | CR Avenue, Manicktala Main Road, CIT Road | 9 |
| | APC Road, Manicktala Main Road, CIT Road | 9 |
| **4-10** | DH Road, Khidirpur Road/ AJC Bose Rd | 15 |
| | BL Shah Road, SP Mukherjee Road | 6 |
| **4-8** | SC Mallick Rd, Gariahat Rd, AJC Bose Rd | 12 |
| | D Sasmal Rd, SP Mukherjee Rd, JLN Rd | 14 |
| **2-4** | Brabourne Road/ Strand Road | 14 |
| **2-8** | D Sasmal Rd, SP Mukherjee Rd, Strand Rd | 9 |
| | SC Mallick Rd, RB Avenue, SP Mukherjee Rd | 9 |
| **1-2** | Vivekananda Road, CR Avenue, BT Road | 5 |
| | MG Road, APC Road, BT Road | 4 |
| **3-8** | SC Mullick Rd, Surawarthy Ave., Beliaghata Rd | 10 |
| | Santoshpur/RB Avenue, EM Bypass | 4 |
| **2-10** | SP Mukherjee Rd, Mayo Road, Brabourne Rd | 4 |
| | DH Road, Khidirpur Road, Brabourne Rd | 10 |
| **4-7** | Taratala Road, DH Road, Chowranghee Rd | 7 |
| **2-7** | Taratala Rd, DH Road, Khidirpur Rd, Strand Rd | 4 |
| **2-5** | MG Road, Beliaghata road | 5 |
| **3-8** | EM Bypass | New important route |
| **3-4** | AJC Bose Road, EM Bypass | New important route |
| **3-10** | RB Avenue, EM Bypass | New important route |

**Identification of high travel demand direction:** From the matrix in Table 3, directions having high travel demand are identified and shown in Table 4 in the ‘connecting zones’ column. In addition to these, some new travel demand directions are identified considering the huge real estate boom in the eastern part of Kolkata which can be observed in Rajarhat, Baishnabghata-Patuli and Ajaynagar area and are also listed in Table 4.

**Identification of high travel demand routes:** In the next step, routes and links through which these travel demands meet were identified. Next, the bus routes along these routes and links were found out using the GIS database for bus routes in Kolkata. Routes with higher number of overlapping bus routes or higher concentration of bus routes were selected for further analysis. However, within a particular route, different links have varying number of bus-routes as most of the bus routes in Kolkata are very much circuitous in nature. Therefore, bus routes which more or less cover the entire route and connect the respective travel demand zones are considered and shown in Table 4. Higher the numbers of overlapping bus routes more is the number of buses and ridership and thus demand for BRT.

**Ridership estimation:** In the next step average ridership was estimated for the selected corridors. First, a relationship was established between fleet strength and frequency of buses using sample data from a few routes during peak hour and the same was used to determine the frequency of buses for the routes given in Table 4 as the data on fleet strength of different routes was available. Then, frequency of buses in each route was multiplied by average bus occupancy to get the number of passengers per hour per direction for a particular route. Within a route, some links or road stretches were found to have a very high number of overlapping bus routes e.g. in the Garia-BBD Bag

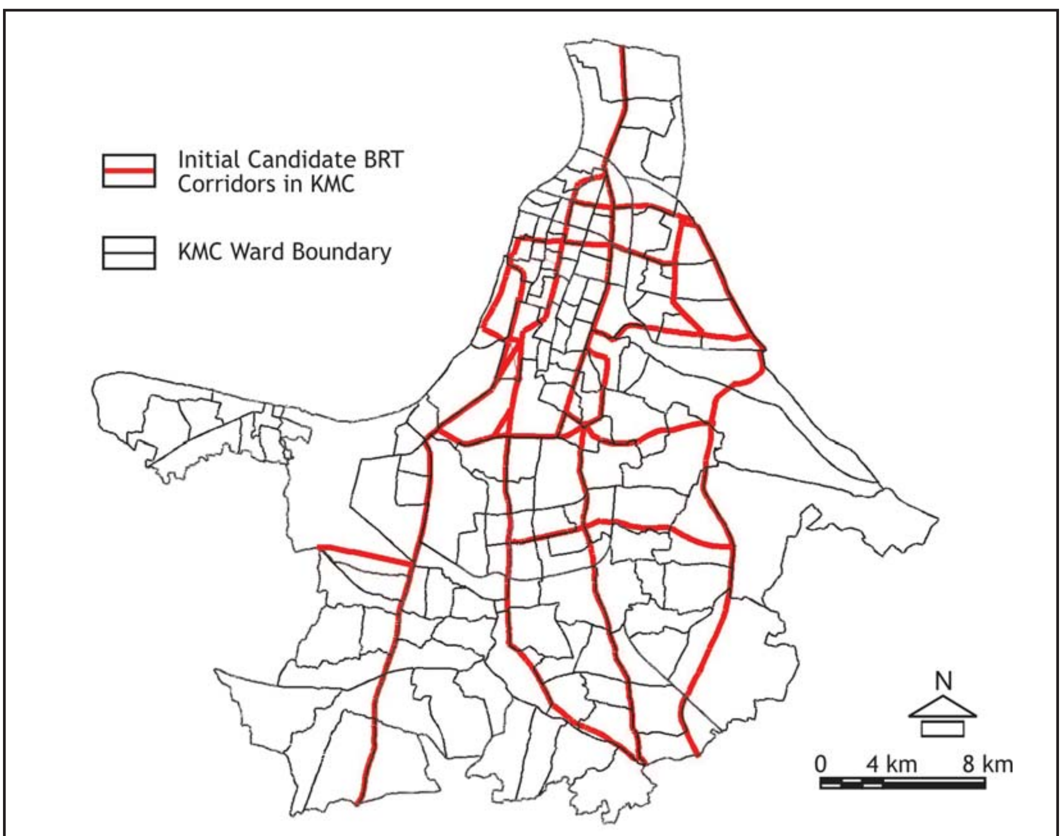
**Table 5 Ridership for Different Routes in KMC**

| Routes | Over lapping routes | Frequency (buses/ hr) | Avg. ridership (pphpd) | Max. ridership (pphpd) | Ranking |
|---|---|---|---|---|---|
| APC Road, BT Road | 15 | 55 | 2666 | 7130 | 1 |
| DH Road, Khidirpur Road/ AJC Bose Rd | 15 | 55 | 2506 | 6069 | 3 |
| NSC Bose Rd, D Sasmal Rd, SP Mukherjee Rd, JLN Rd | 14 | 58 | 2650 | 5740 | 2 |
| Brabourne Road/ Strand Road | 14 | 50 | 1961 | 5230 | 8 |
| CR Avenue, BT Road | 12 | 44 | 2113 | 3840 | 4 |
| SC Mallick Rd, Gariahat Rd, AJC Bose Rd | 12 | 48 | 2035 | 5134 | 6 |
| SC Mullick Rd, Surawarthy Ave., Beliaghata Rd | 10 | 39 | 1912 | 2948 | 9 |
| DH Road, Khidirpur Road, Brabourne Rd | 10 | 38 | 1773 | 6069 | 11 |
| BK Pal Avenue, Aurobindo Sarani | 9 | 43 | 1983 | 3993 | 7 |
| CR Avenue, Manicktala Main Road, CIT Road | 9 | 34 | 1422 | 4137 | 13 |
| APC Road, Manicktala Main Road, CIT Road | 9 | 40 | 2100 | 4137 | 5 |
| D Sasmal Rd, SP Mukherjee Rd, Strand Rd | 9 | 38 | 1694 | 5740 | 12 |
| SC Mallick Rd, RB Avenue, SP Mukherjee Rd, Strand Rd | 9 | 36 | 1896 | 5134 | 10 |
| Taratala Road, DH Road, Chowranghee Rd | 7 | 26 | 1322 | 6069 | 14 |

route, the link between Dhakuria and Golpark has a very high number of overlapping routes compared to other parts. Thus, number of bus passenger will be much higher in these stretches of the corridor, and considering this, the maximum number of total bus passengers in that link of the corridor was also found out for each route.

It is found that the carrying capacity of BRT system varies in different cities starting from 800 passengers per hour per direction as in case of Santa Monica to 45,000 passengers per hour per direction as in case of Bogota (Vaghela, 2007). In the present study, BRT corridors were identified when average ridership exceeded 1,200 passengers per hour per direction, considering 2 minutes of headway for buses having seating capacity of 40. Table 5 shows these identified BRT routes along with frequency of buses, average ridership and maximum ridership in a link within the corridor. Ranking has been assigned according to average ridership in that corridor which also indicates the demand of passenger for BRTS along that corridor. Maximum ridership was also considered as some of the extra passengers (maximum minus average ridership) particularly whose origin and destination lies within the proposed BRT corridor may use the BRT service in future. EM Bypass, AJC Bose Road-EM Bypass and RB Avenue-EM

**Fig. 4 Initial Candidate BRT Corridors in KMC**



Bypass routes were not given any rank in the list due to unavailability of sufficient data. Fig. 4 shows the feasibility of BRT corridors in KMC area based on passenger travel demand.

**Feasibility checking:** After this initial identification of probable BRT routes based on existing passenger travel demand, feasibility analysis was conducted considering the following aspects for implementation of BRT corridor.

i. **Existing right of way (ROW) of roads:** The wider the road the greater will be the scope for BRTS.

ii. **No. of Junction:** The lesser the number of major junctions the lesser will be the number of right turns and the total delay at signals resulting in higher average speed and better scope for BRTS.

iii. **Volume/Capacity (V/C) ratio:** In case of high V/C ratio, separating buses in one lane may lead to congestion in the other lanes or in the bus lane itself. Therefore, Lesser V/C ratio means lesser congestion and thus better scope for BRT.

**Table 6 Road Width for Different Corridors in KMC**

| Sl. No. | Corridors | Length within KMC(km) | 6 lanes or more (%) | 4 lanes (%) | 2 lanes (%) |
|---|---|---|---|---|---|
| 1 | APC Rd-BT Rd | 10.23 | 88 | 12 | 0 |
| 2 | NSC-DS-SP Mukherjee-JLN Rd | 13.36 | 65 | 0 | 35 |
| 3 | DH-KHIDIRPUR Rd | 15.07 | 87 | 13 | 0 |
| 4 | CR Ave.-BT Rd | 8.82 | 70 | 30 | 0 |
| 5 | APC-MANICKTALA- CIT Rd | 6.74 | 65 | 35 | 0 |
| 6 | SC Mallick Rd-GARIAHAT Rd-AJC- JLN Rd | 13.88 | 62 | 24 | 14 |
| 7 | STRAND Rd- BK Pal Ave.- AUROBINDO Sarani | 5.77 | 21 | 43 | 36 |
| 8 | BRABOURNE/STRAND Rd | 1.41 | 100 | 0 | 0 |
| 9 | SCM Rd- SURAWARTHY Ave.- BELIAGHATA- CIT Rd | 17.01 | 57 | 27 | 16 |
| 10 | SC M-RB Ave.-STRAND Rd | 16.04 | 77 | 11 | 12 |
| 11 | DH Rd-STRAND Rd | 16.48 | 88 | 12 | 0 |
| 12 | SP Mukherjee-STRAND Rd | 10.1 | 100 | 0 | 0 |
| 13 | CR Ave.-MANICKTALA- CIT Rd | 7.51 | 71 | 29 | 0 |
| 14 | TARATALA-DH Rd | 10.21 | 56 | 44 | 0 |
| 15 | EM Bypass | 15.65 | 100 | 0 | 0 |
| 16 | AJC - EM Bypass | 10.45 | 73 | 27 | 0 |
| 17 | RB Ave.- EM Bypass | 12.44 | 94 | 6 | 0 |

Table 6 shows the right-of-way (ROW) of initially identified BRT corridors in KMC in terms of number of lanes in different stretches of the route.

Table 6 also shows that a considerable portion of NSC Bose road has only two lanes, so if this part is truncated then it will be eligible for BRT. Similarly, the southern part of the SC Mallick road is quite narrow and BRT will not have a separate lane here. A large part of Manicktala main road, Vivekananda road, Aurobindo Sarani, Beliaghata road and Taratala road have four lanes and implementing BRT in those roads would leave only one lane for mixed traffic for each direction which is not supportive to improve average vehicular speed. Some parts of CR Avenue near Esplanade and Shyambazar have only four lanes and a portion of AJC Bose road between Exide and Park Circus has four lanes, but there is a flyover over that portion. Similarly, most of the parts of BK Pal Avenue and northern part of Strand road (after Burrabazar) have only two to four lanes, thus making it infeasible for implementation of BRT. Brabourne and Strand roads have a very short corridor length and can be integrated with other corridors for implementation of BRT.

Table 7 shows the length, average bus running speed and travel time without considering delay, total number of major and minor road junctions and delay at

**Table 7 Junction-delay for Different Corridors in KMC**

| Sl. No. | Corridors | Length (km) | Avg. Speed (km/hr) | Travel Time (min) | Major Juncti-ons (no) | Minor Juncti-ons (no) | Delay (min) | Delay/ Travel Time |
|---|---|---|---|---|---|---|---|---|
| 1 | APC-BT | 10.23 | 18 | 34.10 | 13 | 45 | 37.25 | 1.09 |
| 2 | NSC-SP | 13.36 | 20 | 40.08 | 14 | 58 | 42.5 | 1.06 |
| 3 | DH-Khidirpur | 15.07 | 25 | 36.17 | 12 | 40 | 34 | 0.94 |
| 4 | CR-BT | 8.82 | 15 | 35.28 | 12 | 54 | 37.5 | 1.06 |
| 5 | APC-MANICKTALA | 6.74 | 15 | 26.96 | 8 | 38 | 25.5 | 0.95 |
| 6 | SC-GARIAHAT | 13.88 | 16 | 52.05 | 17 | 56 | 48 | 0.92 |
| 7 | BK-AUROBINDO | 5.77 | 18 | 19.23 | 9 | 31 | 25.75 | 1.34 |
| 8 | BRABOURNE/ STRAND | 1.41 | 12 | 7.05 | 4 | 10 | 10.5 | 1.49 |
| 9 | SC-SURAWARTHY | 17.01 | 15 | 68.04 | 21 | 62 | 57.5 | 0.85 |
| 10 | SC M-STRAND | 16.04 | 16 | 60.15 | 21 | 66 | 58.5 | 0.97 |
| 11 | DH-BRABOURNE | 16.48 | 18 | 54.93 | 16 | 50 | 44.5 | 0.81 |
| 12 | SP-STRAND | 10.1 | 18 | 33.67 | 14 | 52 | 41 | 1.22 |
| 13 | CR-MANICKTALA | 7.51 | 14 | 32.19 | 11 | 49 | 34.25 | 1.06 |
| 14 | TARATALA-DH | 10.21 | 20 | 30.63 | 8 | 29 | 23.25 | 0.76 |
| 15 | EM Bypass | 15.65 | 30 | 31.30 | 12 | 34 | 32.5 | 1.04 |
| 16 | AJC - EM Bypass | 10.45 | 20 | 31.35 | 10 | 24 | 26 | 0.83 |
| 17 | RB Ave- EM Bypass | 12.44 | 25 | 29.86 | 7 | 41 | 24.25 | 0.81 |

these junctions for the initially selected BRT corridors. First, average delay at signals for buses was found out using sample data from a few routes during peak hour through primary survey. Using this data travel delays for other corridors were estimated.

It can be observed that BK Pal Avenue, Aurobindo Sarani and Brabourne roads have a very high Delay/Travel Time ratio making them unsuitable for BRT. However, Brabourne road has a very short corridor length and thus total delay is not very significant on that road. Therefore, Brabourne road was not discarded while feasibility checking for junction and delay.

Corridors were also analyzed for the volume/capacity ratio and their respective V/C ratio is shown in Table 8. Here, it can be observed that Manicktala Main road, SC Mallick road, and EM Bypass have V/C ratio is greater than 1. Manicktala Main road has four lanes in most of its length and there is hardly any scope for road expansion. If BRT is implemented in this road, one lane will get dedicated to buses and one lane for other motorized vehicles in each direction. However, this may cause traffic congestion because of its high V/C ratio and thus considered unsuitable for implementation of BRT. The SC Mallick road is mainly six lane road except near Dhakuria, Golpark flyover and Baghajatin where it is a four lane road and near Garia it is almost two lane road. However, road widening has been taken up on this corridor. Road widening of EM Bypass at certain places is also being done. Therefore, SC Mallick road and EM Bypass were not discarded during feasibility checking.

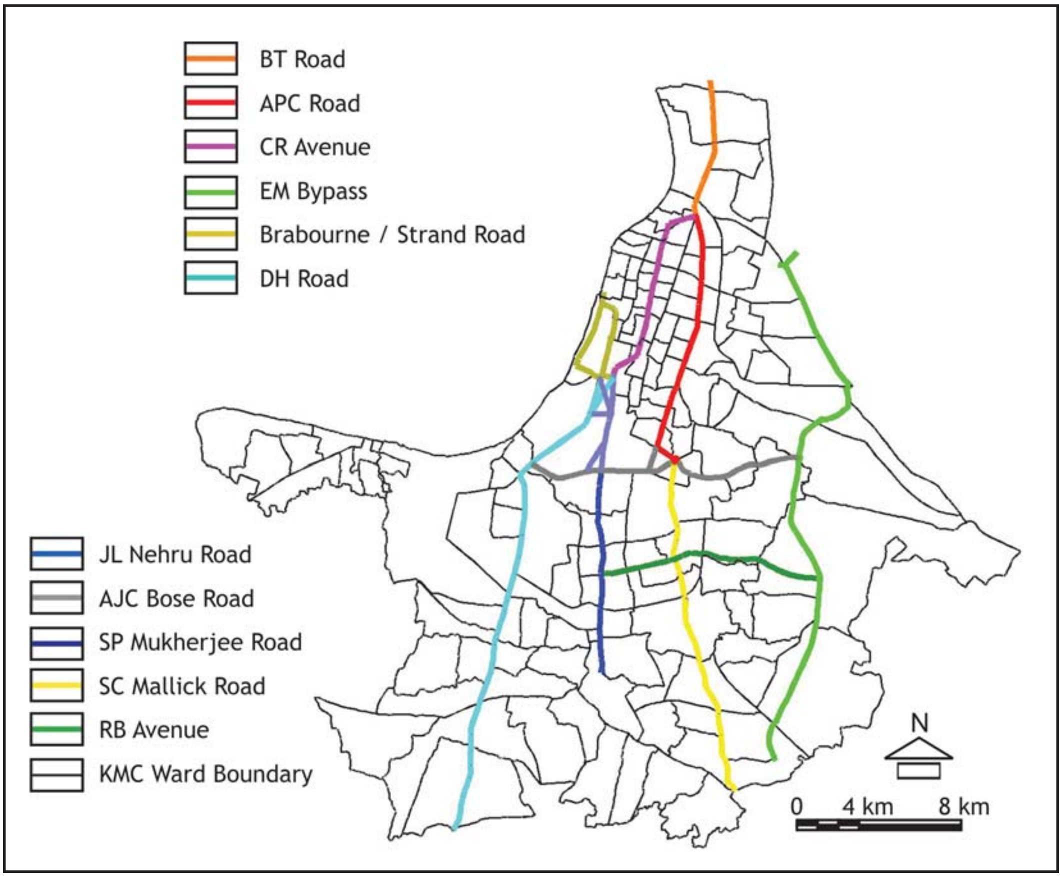
**Table 8 V/C Ratio for Different Corriodrs in KMC**

| Sl. No. | Corridors | V/C |
|---|---|---|
| 1 | APC Rd-BT Rd | 0.88 |
| 2 | NSC-DS-SP Mukherjee-JLN Rd | 0.84 |
| 3 | DH-KHIDIRPUR Rd | 0.45 |
| 4 | CR Ave.-BT Rd | 0.91 |
| 5 | APC-MANICKTALA- CIT Rd | 1.16 |
| 6 | SC Mallick Rd-GARIAHAT Rd-AJC- JLN Rd | 1.09] |
| 7 | STRAND Rd- BK Pal Ave.-AUROBINDO Sarani | 0.99 |
| 8 | BRABOURNE/STRAND Rd | 0.46 |
| 9 | SCM Rd- SURAWARTHY Ave.-BELIAGHATA- CIT Rd | 0.63 |
| 10 | SC Mallick Rd-RB Ave.-STRAND Rd | 0.92 |
| 11 | DH Rd-STRAND Rd | 0.46 |
| 12 | SP Mukherjee-STRAND Rd | 0.84 |
| 13 | CR Ave.-MANICKTALA- CIT Rd | 1.16 |
| 14 | TARATALA-DH Rd | 0.45 |
| 15 | EM Bypass | 1.01 |
| 16 | AJC - EM Bypass | 0.86 |
| 17 | RB Ave.- EM Bypass | 0.92 |

**Table 9 Feasible BRT Corridors in KMC**

| Feasible Corridors |
|---|
| • APC Road, BT Road |
| • D Sasmal Rd, SP Mukherjee Rd, JLN Rd |
| • DH Road, Khidirpur Road/ AJC Bose Rd |
| • CR Avenue, BT Road |
| • SC Mallick Rd, Gariahat Rd, AJC Bose Rd |
| • Brabourne Road/ Strand Road |
| • EM Bypass |
| • AJC Bose Road, EM Bypass |
| • RB Avenue, EM Bypass |

**Fig. 5 Feasible BRT Corridors in KMC**




After examining feasibility conditions, some candidate BRT corridors were found to be unsuitable for implementation of BRTS and thus discarded. The feasible BRT corridors are shown in Table 9 and Fig. 5.

**Table 10 Priority Ranking for Feasible BRT Corridor in KMC**

| Corridor | Ridership score | ROW score | Junction-delay score | V/C score | Similar transit services score | Total Score | Priority |
|---|---|---|---|---|---|---|---|
| APC-BT Road | 100.00 | 87.88 | 74.35 | 51.14 | 100 | 413.37 | 2 |
| D Sasmal-SPM-JLN | 99.40 | 65.04 | 76.60 | 53.57 | 0 | 294.61 | 8 |
| DH Rd-Khidirpur Rd | 94.00 | 87.19 | 86.40 | 100.00 | 100 | 467.59 | 1 |
| CR Avenue-BT Road | 79.26 | 70.07 | 76.41 | 49.45 | 0 | 275.19 | 9 |
| SC M-Gariahat-AJC | 76.33 | 61.82 | 88.07 | 41.28 | 100 | 367.51 | 7 |
| Brabourne/ Strand Rd | 73.56 | 100.00 | 54.53 | 97.83 | 50 | 375.92 | 5 |
| EM Bypass | 90.02 | 100.00 | 78.22 | 44.55 | 100 | 412.80 | 3 |
| AJC - EM Bypass | 45.01 | 73.21 | 97.93 | 52.33 | 100 | 368.48 | 6 |
| RB Ave- EM Bypass | 56.26 | 93.97 | 100.00 | 48.91 | 100 | 399.15 | 4 |

Table 10 shows the priority assessment of the proposed BRT corridors considering several criteria such as ridership, ROW, junction delay, V/C ratio and presence of similar or alternative transit services like MRT, LRT, etc. Priority assessment of the proposed BRT corridors was done such that the best score either satisfying higher demand for BRTS as in the case of ridership criteria or most suitable for BRTS implementation without additional infrastructure and land use modification as in the case of ROW, V/C, etc; for each criteria was converted to 100 and others accordingly and ranking was given according to the total score after giving same weight for each criterion. For example, in case of ridership criteria, APC-BT Road has maximum ridership of 2,666 passengers per hour per direction among the feasible BRT corridors and was assigned a score of 100. Next, D Sasmal-SPM-JLN route with a ridership of 2,650 passengers per hour per direction was assigned a lower score of 99.40 comparing ridership of these two routes in a scale of 100. Similarly, scores were assigned for different criteria to different routes.

## 5. CONCLUSIONS

This paper aims to deliver a methodology and planning framework for selection of BRT corridors for bus transit reform and redesign in urban areas in India and Kolkata in particular in the context of the present challenges of increasing traffic congestion, car ownership, and lack of road and transport infrastructure and gradual deterioration of LOS of bus transit system. Detailed design for BRTS on these corridors or integration of bus transit services in between these corridors is not undertaken in the present paper. For estimation of bus ridership on different corridors, average occupancy and frequency of buses were estimated based on sample survey data. However, for detail design, extensive surveys should be conducted to get more accurate ridership estimates for these routes. The present methodology combines both existing travel demand estimate and feasibility analysis in terms of traffic and road infrastructure characteristics for selection and phasing of BRT corridors. Incorporation of feasibility constraints both for selection and phasing of BRT corridors would enable planners and decision makers to make more informed decisions about implementing BRTS in Indian cities.

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