A framework for bus transit reform & redesign: Case study Kolkata

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Abstract

The existing level of service (LOS) of bus transit system in Kolkata is low due to poor quality of buses, unreliability of bus service, demand and supply mismatch, rash driving and overtaking between buses resulting in an increasing number of accidents and low average speed resulting from the intermixing of both motorized and non motorized vehicles and poor transportation infrastructure. In the context of these present challenges, there is an urgent need to reform and redesign the existing bus transit services in Kolkata. The present research involves developing an appropriate framework for bus transit reform and redesign for Kolkata through identification of possible Bus Rapid Transit (BRT) corridors, a formalization scheme for transit buses which include proposals for BRT routes and detail planning for individual BRTS routes which include existing bus route merging, proposals for feeder routes and planning of new BRT services based on user perception and satisfaction on existing services and a management plan for revenue & route sharing involving the bus operators and other stakeholders of the system. The present research framework builds upon existing relevant frameworks of bus transit reform and redesign through incorporating user perception of existing service quality and user satisfaction at different service levels for determining optimum service levels of the proposed BRT system.

1. Introduction

Bus transit system in Kolkata serves about 54% of the total passenger travel demand [35]. However, there has been an increasing shift towards private vehicles and para-transit modes due to rising levels of household income and economic growth. During the period from 1991 to 2001, cars and two-wheelers increased by 2.7 times in India [29] while the share of buses declined from 11.1 percent in 1951 to 1.1 percent in 2006 [28]. The existing level of service (LOS) of bus transit operations is very low due to poor quality of buses, overlapping of bus routes operated by different agencies and private bus syndicates, unreliability of bus service and adherence to schedule, demand and supply mismatch [25], rash driving and overtaking between buses to get passengers resulting in an increasing number of accidents [19] unscheduled stops to pick up passenger and sometimes ignoring of designated stops mainly by public buses [1] and low average speed resulting from the intermixing of both motorized and non motorized vehicles and poor transportation infrastructure and inadequate road space [18]. At present, the high mode share of buses despite the poor LOS reflects the lack of a viable alternative for the majority of the users either due to accessibility or affordability or both [1]. The poor LOS of urban bus transit would further accelerate the growth of private vehicles mainly motorized two-wheelers due to their low cost, low door to door journey time and ability to be parked easily [1] and para-transit modes such as three-wheelers thus resulting in increased levels of congestion, air pollution and greenhouse gas emission [25]. Thus, urban public transit services and particularly bus transit should be maintained and enhanced to reduce the growth of personal motor vehicles and due to the fact that low income commuters depend on this low cost mode for their mobility and economic survival [1].

In the context of these present challenges, there is an urgent need to reform and redesign the existing bus transit services in Kolkata. The objective of the present research is to develop a framework for bus transit reform and redesign for improving the LOS and average speed of bus transit in Kolkata which could also be used as a template for similar cities. Scope of work for this research includes exploring the appropriate bus priority scheme for Kolkata, identification of corridors for implementation of BRT routes, detail design of these BRT routes through existing bus route merging, proposals for feeder routes, planning of new BRT services based on user perception and satisfaction on existing services and a management framework for revenue and route sharing between the bus operators and other stakeholders of the system.

2. Background of research

In recent years, bus rapid transit system (BRTS) is considered by the policy makers as a way to improve bus transit services [18]. The national urban transport policy of India [24] has also identified the need to allocate urban road space on a more equitable basis, i.e., through implementation of BRT systems. Like many cities in Asia [20], Europe [27], China [40] where BRTS have been implemented successfully, several BRTS projects have also been initiated in India [29]. BRTS refers to bus transportation systems with improved transportation infrastructure and schedules which provide a service that is of a higher quality than an ordinary bus line [12, 4]. Commonly, BRT is understood as “a mass transit system using exclusive right of way lanes which mimic the rapidity and performance of metro systems but utilizes bus technology rather than rail vehicle technology” [36] with emphasis on priority for buses [37]. There is no precise definition of what constitutes a BRT system [37] and the selection of elements such as bus types, BRT type, corridor type (either segregated or shared) etc. depends on the characteristics of the urban area such as land use, road infrastructure and traffic conditions [18]. Two cities namely Bogota in Colombia and Curitiba, in Brazil are well known for their efficient bus transit system and complementary supporting measures [38]. BRTS adopted in different cities are of different types such as “Basic Bus ways”, “BRT Lite” which indicates some form of bus priority but not fully segregated bus lanes, improved travel time etc., “BRT” and “Full BRT” where integration of all transport modes can be observed along with segregated corridors and extensive ITS application [34]. Both open and closed systems of BRT have been adopted worldwide. While in open system, access to the BRT lane is not restricted to other bus operators, in closed system only prescribed operators are allowed [5, 6]. Design of BRT routes is also done either as a “Cross-route” service where main routes crosses each other or as a “Trunk and branch” service where different trunk routes overlap in some link and then branches out to different direction or as a “Trunk and feeder” service where trunk services are along the high demand corridors and feeder services connect the trunk corridor with other comparatively low demand routes [5, 6]. The carrying capacity of BRT corridors also varies significantly in different cities ranging from 800 pphpd (people per hour per day) in case Santa Monica to 45000 pphpd in Bogota [34]. Different levels of BRT services are also operated namely “urban corridor” type (stops at every 500m), “express” type (stops about every 1.5 km) and “direct service” (travels nonstops between major points) [5].

Bus transit services operated by both private and governmental operators are undergoing some fundamental changes all over the world [31, 27]. While most researchers support privatization and deregulation of public transit due to the inefficiency of government services, uncontrollable growth of the public sector and reduced personal initiative of individuals and organizations [21] there are also questions related to the composite effects of privatization on efficiency, ridership, fare increase, LOS and the overall welfare improvement achieved by the same [21]. In general, it is believed that the private sector produces a given level of service more efficiently than the public sector [21]. However, concerns related to the provision of service by the private sector in lower density areas, reduction in peak capacity [21] etc. also highlights the need of the public sector as a facilitator and the controlling agency for public transit services. Public transit service privatization is usually carried out either by contracting out, franchising or through privatization competition [26]. Privatization of bus transit and bus rapid transit (BRT) services are being increasingly adopted in many cities resulting in improved services, reduced cost and reduced government subsidy. In addition to privatization where the role of the public agency is shifting from the provider of services to a "manager of mobility" [31], public transit services are also undergoing changes through incorporating measures of the quality of customer experience instead of service outputs to evaluate service investments, improving collaboration among different agencies, organizations, modes etc., increasing integration of services, functions and resources across agencies, incorporating information technologies and through changes in the organizational structure of the public agency to support this transformation [31].

The importance of customer experience or user perception for bus transit service quality assessment has been established in various researches worldwide and its particular relevance in the Indian context has been comprehensively reviewed by Das and Pandit (2013) [9]. Three measures based on user perception, namely, 'Level of Service' (LOS), 'Zone of Tolerance' (ZOT) and determination of critical service area gaps has been identified by researchers to be important in assessing service quality of bus transit services [9]. While, LOS is defined as "a designated range of values for a particular service measure, such as "A" (highest) to "F" (lowest), based on a transit passenger's perception of a particular aspect of transit service" [16], ZOT is defined as a range of service level for a particular service attribute with two bounds i.e., 'desired service' and 'minimum acceptable service' or 'adequate service' [39]. It is also important for service providers to identify the critical service areas that needs to be addressed to improve user perception of the service quality, i.e., service quality attributes that users perceive to be of significance and are not at a satisfactory level.

3. Bus transit reform: Case studies

Worldwide, many cities has undergone reform and redesign of their bus transit service where public transit authorities have transformed to a "purchaser of services that is also responsible for planning, fare policy, service standards, and marketing" [27], preparation of tenders, auctions, selection of the most competitive bidder and evaluation of the contractors' performance [27]. For example, the United Kingdom Transport Act of 1985 [26] allowed "London Transport Bus" an independent agency to determine the service standards, fare policy, performance standards, etc. whereas, the actual operation/service was provided by multiple private operators which resulted in increased ridership, reduced operating cost and reduction of subsidy [31]. Bus transit reforms were also carried in the three Scandinavian countries namely Finland, Sweden and Denmark following the contracting out model where strict controls of service standards and fare policy determination, financing, marketing tenders and contract supervision were maintained by the public agency [27]. Both private and public operators were awarded the tenders and the contracts were of fixed price based on revenue hours and miles of service. This has resulted in increased ridership, fare box recovery, lower operating costs and improved user satisfaction [27]. Similar reforms have been undertaken in the other European countries like France, Switzerland, Spain etc. and have been comprehensively reviewed by Karlaftis(2010) [21]. In Curitiba, bus sector reform started during the year 1962 and BRT was introduced in the year 1974 through 'corporatization' of bus services [13]. 321 smaller bus companies were consolidated into 10 companies who were given licenses to operate buses in different sections of the city. Bus transit services in Seoul, South Korea underwent an extensive reform and redesign in the year 2004. The first reserved curb side bus lanes were installed in 1984 and expanded to 89km by 1993, 174km by 1994, and 219km by 2003. Even though, this network of bus lanes increased the speed of bus travel, it did not succeed in increasing the mode share of buses [15]. The bus system was further reformed after 2004 through the introduction of PPP (public-private partnership) model where the Seoul Metropolitan Government increased its control over bus routes, schedules, fares, and overall system design and private stakeholders took the role of operators. The private operators were reimbursed on the basis of vehicle-km of service instead of passenger trips. This significantly improved the service quality and reduced reckless driving and overtaking behaviour. The bus route network was also entirely re-designed integrating over 400 different bus routes while meeting the travel demand. Bus and metro service were also integrated. Commercial operation of BRT was also started in Beijing, China [20] which resulted in an increase in the efficiency of the bus transit service [40]. The daily passenger volume of BRT buses in the south-centre corridor increased by 3.9 times and vehicle journey time doubled compared to the regular public buses [40].

In India, the first phase of BRT system has also been implemented in Delhi [33] by the Delhi Integrated Multimodal Transit System (DIMTS) which is a “Special purpose Vehicle”/organization entrusted with the operation, maintenance and management of the BRTS corridors and the overall public transport systems in Delhi. Out of a total of 26 planned corridors covering 310 kilometres, the first corridor from Ambedkar Nagar to Delhi Gate is already operational covering 14.5 kilometres. However, this has resulted in a few cases of accidents and traffic chaos on that particular BRT stretch initially which are gradually being sorted out. The bus lane has been kept in the middle of the road and 180 road marshals are deployed on the corridor. The passenger information system is installed on all the bus platforms which are guarded by security personnel [11]. The buses are run both by private and public (Delhi Transport Corporation (DTC)) operators [29].

As per the Motor Vehicles Act in India [32], the regional transport authority grants permits for operation of stage carriage buses (buses which stop at different stages/stops along the route they run on). At present, DIMTS has initiated a new scheme called ‘Corporatization of private stage carriage’ or the ‘cluster approach’ where all of Delhi’s 657 bus routes are organized into 17 clusters including both profitable and unprofitable routes and companies can bid for the same. These clusters also include the BRTS routes. While DIMTS has the overall responsibility of bid management, monitoring and management of bus transit operation and infrastructure, preparation of time table and monitoring of LOS etc., DTC acts as a provider of service (without participating in the bidding process) along with the private operators [29].

4. Study area and data

The present study area is limited to the boundary of Kolkata Municipal Corporation (KMC) having an area of 185 square kilometer and population of 4,580,544 as per “Census 2001”. It is one of the major metro cities located in the eastern part of India and is situated on the eastern bank of the river Hooghly. The road network of Kolkata comprises of east-west and north-south corridors as shown in Fig. 1 with the Central Business District (CBD) located at the centre and the residential zones in the southern, northern and eastern part of the city. Public transportation in Kolkata is provided by both surface and underground railway transit, trams and bus transit systems. The bus transit system in the form of buses and minibuses is operated by both government and private agencies which include 71 CSTC (Calcutta State Transport Corporation), 30 CTC (Calcutta Tram Company), 144 private and 98 mini bus (private) routes in the city [25]. In addition, there are also a few WBSTC (West Bengal Surface Transport Corporation) and SBSTC (South Bengal State Transport Corporation) bus routes [18]. Most of the bus routes in Kolkata are oriented towards the CBD and shown in Fig. 2. In addition to bus transit, Kolkata is also served by rapid transit systems in the form of suburban railways and metro railways. The metro railway operates only on a single line at present and is being expanded to include new areas and shown in Fig. 3. However, bus transit will still remain the only viable choice in these corridors for low income commuters who are very sensitive to fare increase due to the relatively higher cost of a metro ticket. In spite of this highly captive user base [22], bus transit ridership along these corridors will be affected with diminished ridership and with few routes even becoming redundant.

Fig. 1. Road Network in Kolkata [25]

Like Delhi, the regional transport authority under the state transport department grants permits for operation of stage carriage buses in Kolkata and the bus fares are fixed by the state government. While the public agencies are operating at a huge loss and heavily subsidized by the government, the private owners could still maintain their profitability only due to low staff salaries, extended operating periods, poor maintenance and intense competition resulting in rash driving and overall poor LOS. Recently, the Kolkata High Court ordered a ban on 15 year old commercial vehicles which has resulted in a drastic reduction of buses in Kolkata. On the other hand, Ministry of Urban Development, under the Jawaharlal Nehru National Urban Renewal Mission (JNNURM) has approved 1200 new buses in the first phase out of a total of 3600 proposed buses for Kolkata [23]. These significant higher quality buses include 900 semi low floor and 300 low floor air conditioned buses [30]. Some of these buses have been been offered on franchise basis to the bus operators against the existing buses in the same routes (Notification by Transport Department, Govt. of WB on 07/10/09) by the State Government of West Bengal. However, the private operators are finding it unprofitable to use these high horsepower, wide bodied buses considering their fuel economy in the repeated stop and go and slow moving traffic in Kolkata [25]. On the other hand, these buses could be very efficient if considered as a part of a BRT system with separate lane provisions. Recently, most of the private operators have stopped making the payment claiming loss and some have even stopped bus operations which highlights the need for an alternative arrangement for bus transit operations in the city. The private operators in Kolkata are individuals or companies running a single to a few buses which make it even more difficult to either recover the instalment fee for the franchise buses or to enforce service quality standards etc. With the government bus service heavily subsidized, the overall subsidy could probably be reduced through incorporating privatization either in the form of ‘franchising’ or ‘privatization competition’ and at the same time subsidising the private operators through payment on the basis of bus kilometre travelled instead passenger kilometre as stipulated in the contract or tender. This requires the formation of an agency responsible for overall management and consortiums of private owners forming a corporate entity which could participate in the auction process along with bigger companies for different ‘clusters’ of route or areas of the city.

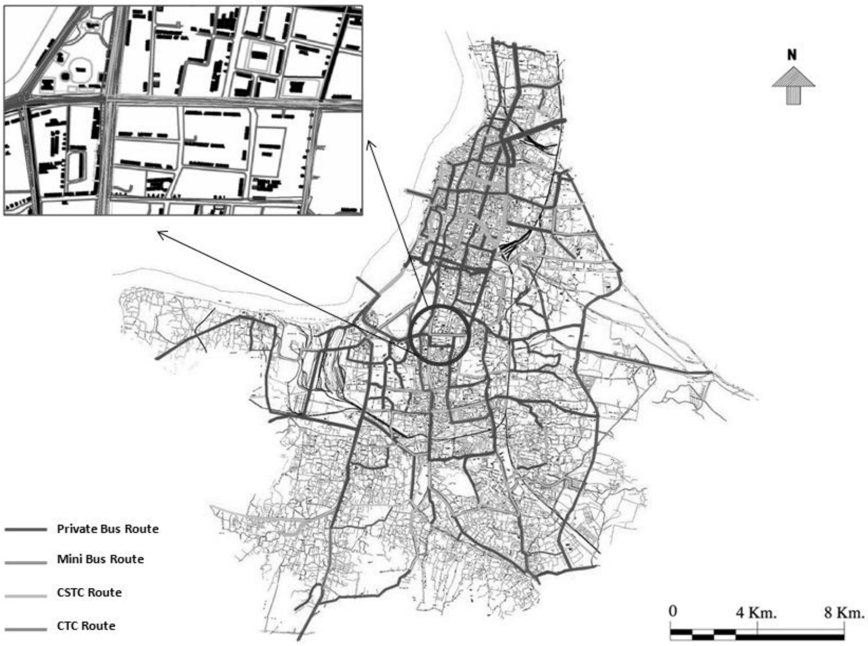

Fig. 2: Bus routes in Kolkata [25]

In the present study, data were collected both from primary survey and secondary sources such as KMDA (Kolkata Metropolitan Development Authority), Motor Vehicles Department, Kolkata, NATMO (National Atlas and Thematic Mapping Organization), Census of India, Kolkata Police Department, Transport Department Government of West Bengal etc. and nongovernmental sources such as Bengal Bus Syndicate, Joint Council of Bus Syndicate in Kolkata etc. Primary survey was conducted to collect data on road characteristics such as road width, presence of median and right turns, traffic volume, modal split, volume/capacity ratio, surrounding land use, etc. for major traffic arteries and bus transit characteristics such as bus route origin, destination and travel path, bus transit ridership, bus occupancy, bus fleet size & frequency, bus stop locations, fare structure etc. for all bus routes in Kolkata. This data were organized in GIS (Geographic Information system) format using MapInfo software. In addition, spot speed surveys at different locations and corridor speed delay surveys were conducted for bus and other vehicles. An extensive survey was also conducted for obtaining boarding alighting count of bus passengers at bus stops for different bus routes on two corridors namely, Garia to B.B.D.Bag (Fig. 6) and Joka to B.B.D.Bag(Fig. 4,5), with B.B.D.Bag being the CBD of Kolkata and for obtaining user satisfaction data on existing service levels. Respondents were asked to state the level of importance and their level of satisfaction on the existing service levels for different bus transit service parameters along with the minimum acceptable service level and desired service level for each quantitative service parameter to determine their zone of tolerance (ZOT). The perceived satisfaction level was measured on a scale of 1 to 5 (1= very good to 5= very poor) and the perceived importance level was measured on a scale of 1 to 3 (1=very important to 3=not important) as per the convenience of the users found during a pilot survey in Kolkata [8]. The final survey was conducted randomly on board along 4 and 5 bus routes along the 'Garia-B.B.D.Bag' and 'Joka-B.B.D.Bag' corridor respectively resulting in a collection of 59 and 116 completed responses respectively.

Fig. 3: Metro railway routes in Kolkata

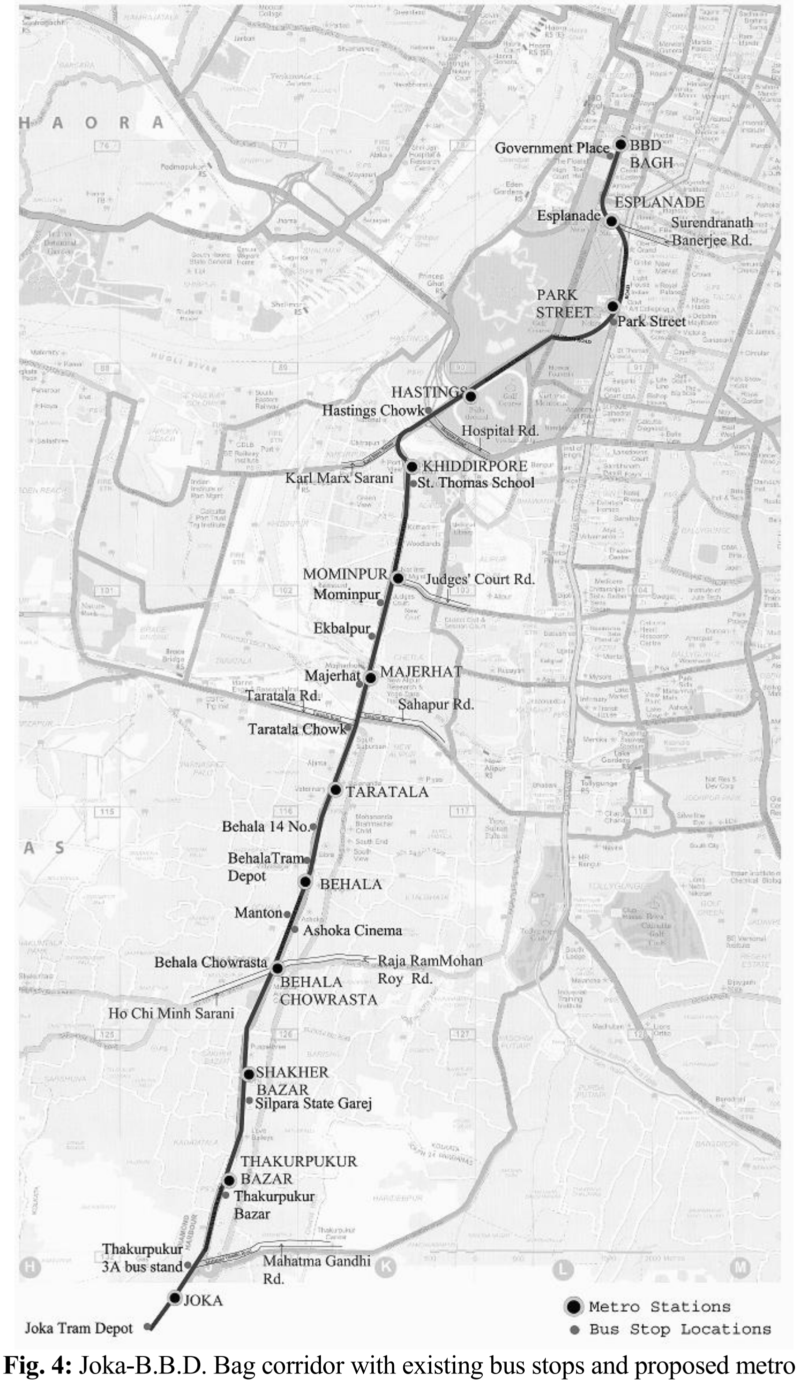

Fig. 4: Joka-B.B.D. Bag corridor with existing bus stops and proposed metro rail stations

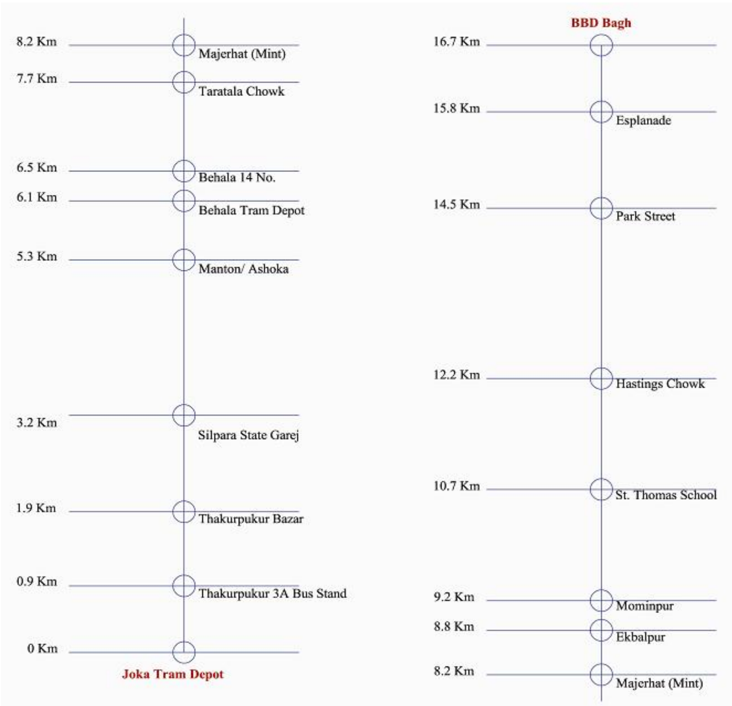

Fig. 5: Joka-B.B.D. Bag corridor bus stops and intermediate distances

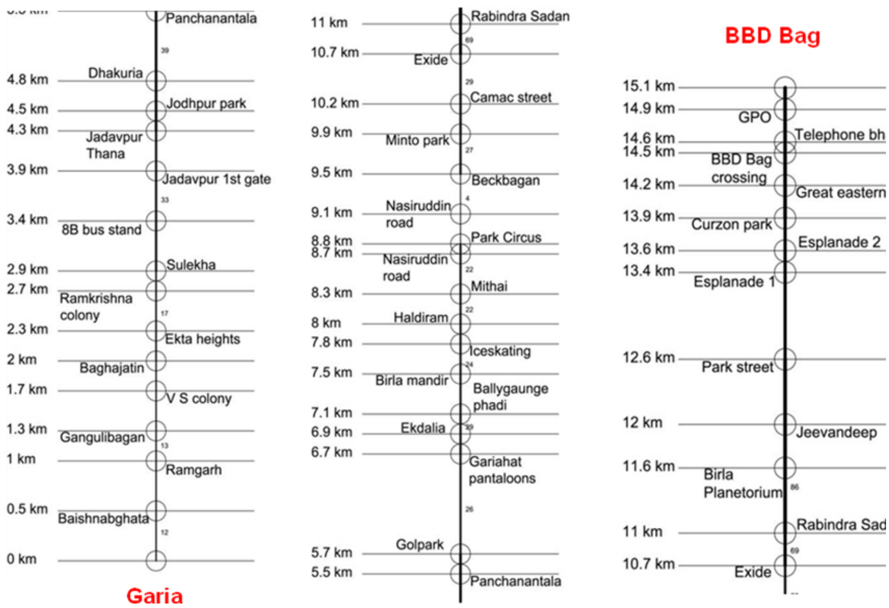

Fig. 6: Garia-B.B.D. Bag corridor bus stops and intermediate distances

5. Broad Framework and research methodology

The present research involves six major steps as shown in Fig. 7.

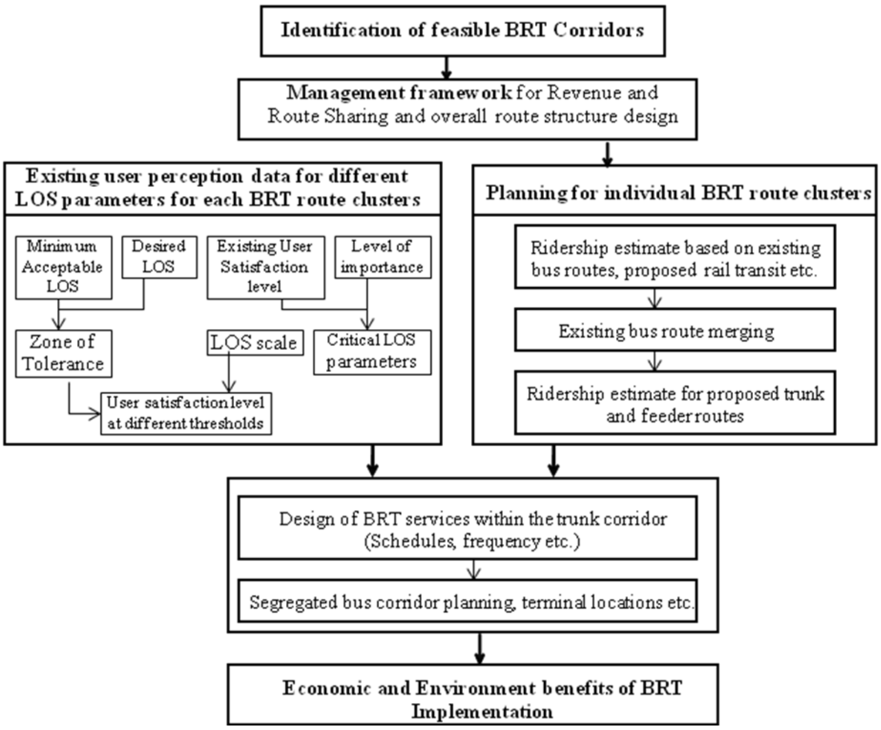

Fig. 7: Broad Framework

In Kolkata, bus routes have developed over time in response to the passenger travel demand and these were used to determine the major travel demand directions and the corridors through which these demands are met. Next, feasibility for implementing BRT along these corridors were examined in terms of right of way (existing and future), number of major junctions and delay, existing volume by capacity (V/C) ratio etc. to arrive at the final list of feasible BRT corridors. The detail methodology has been discussed by Maparu and Pandit [18]. The proposed BRTS route clusters in Kolkata along the selected corridors were determined based on the existing fully and partly overlapping bus routes along these corridors and their travel demand direction [25].

Next, a management framework for revenue and route sharing is proposed in line of the cluster approach followed in Delhi to ensure a smooth transition of bus transit services to BRT services. As discussed earlier, privatization in the form of 'franchising' is proposed for the BRTS operation in Kolkata along with the participation of the public operators as in the case of Delhi. However, the system of 'privatization competition' may also be considered after few years once the BRTS operation has attained maturity. A new agency is also proposed which would be responsible for the overall management of BRTS operations in the city. In addition to corridor management, awarding contracts, marketing, generation of time schedules etc. This agency would be made responsible for fare recovery both from public and private operators and distribution of payment to the same on the basis of bus kilometre travelled instead passenger kilometre as stipulated in the contract or tender. The existing private operators could be combined to form consortiums having a corporate identity and a professional management team to participate in the auction process for running BRTS services along the BRTS route clusters. As an added incentive and also considering the existing permits this consortium of private operators may be awarded the tender for running BRT services for the first contract period after which proper auctions including bigger private companies could be undertaken.

The third step involves ridership estimates for each BRT route cluster based on ridership of existing bus routes, route rationalization in the form of existing bus route merging and finally ridership estimate of the proposed trunk and feeder routes within the cluster. Peak hour bus ridership of existing bus routes has been considered for calculating ridership for each BRT route cluster and the modal shift resulting from improved LOS of bus service due to BRT implementation has been kept out of the scope of work. However, future proposals for rail transit and its effect on BRT ridership were also considered. The detail methodology has been discussed by Pandit and Maparu [25, 19]. Implementation of BRTS without route rationalization leads to reduced efficiency and increased congestion [13]. The need for route rationalization has also been identified for Delhi BRTS [2, 11]. In the present research, the route merging policy and route rationalization was formulated by first categorizing the different overlapping bus routes along the proposed BRTS route. Four categories were proposed, namely, 'trunk BRT', 'feeder BRT', 'combined BRT' and 'non BRT'. "'Trunk BRT' bus routes are defined as those which are completely within the BRT corridor. 'Feeder BRT' routes serve passenger in the trunk service from its surroundings. 'Combined BRT' routes are those which are partially within the trunk corridor. 'Non-BRT' bus routes have none or a very insignificant portion within the trunk corridor"[25]. Based on the above categorization, an existing overlapping bus route was determined to be a 'trunk BRT' if most of its passengers was found to be travelling within the BRT route. Similarly, an existing bus route found to be having a large overlapping part and a small non-overlapping part with few passengers is divided into 'trunk BRT' for the overlapping part and 'feeder BRT' for the non-overlapping part. In case of bus route having a considerable non-overlapping part but still with many passengers boarding and alighting within the BRT route, then it is determined to be 'combined BRT' which have to follow BRTS regulation for the overlapping part. Finally, existing overlapping bus routes were determined to be "non BRT" if it was found to have little overlap and insignificant number of passengers boarding or alighting within the BRT route. To determine the passenger loading at different links, i.e., number of passengers travelling from one stop to another within the corridor, bus passenger O-D (Origin-Destination) matrix was created for all existing bus routes fully or partly overlapping with the proposed BRT route cluster using the passenger boarding-alighting count data at bus stops obtained during primary survey [19]. Due to the lack of high quality base O-D matrix, first null base transfer O-D matrix was prepared and subsequently the Proportional Distribution method was applied to arrive at the passenger O-D matrix. The detail methodology has been discussed by Pandit and Maparu [19]. Then, based on the adopted route merging policy and route rationalization final bus passenger O-D matrix was created for the trunk corridor and the feeder routes.

In the next step, existing user perception data for different LOS parameters for each BRT route cluster is analyzed to determine the critical LOS parameters (Highest level of importance and the lowest level of satisfaction), zone of tolerance (ZOT) and user satisfaction level (% of users satisfied at different LOS and ZOT thresholds) to determine the appropriate service level boundaries within which new BRTS services should be provided. The service parameters used in this research were identified from literature review and validated in the Indian context through an expert opinion survey [7] and further validated for the city of Kolkata through a pilot survey conducted on 219 bus users [8] and shown in Table 3. The Level of service thresholds for different bus transit service parameters adopted in this research was developed from user perception data on perceived service levels using the 'Law of Successive Interval Scaling', developed by Thurstone in 1952 [3] and subsequently used by Correia et. al. [6] to develop LOS thresholds for passenger airport terminals from user satisfaction data. The detail methodology has been discussed by Das and Pandit (2013)[10]. Next, the average minimum acceptable service and desired service for each service parameter within each BRT route cluster was computed using user perception data of the existing bus routes overlapping with the proposed BRT route cluster.

This mean zone of tolerance (ZOT) bounded by the minimum acceptable and desired level of service establishes the range of service level that service providers should consider while designing their services in addition to financial feasibility. In addition, to LOS thresholds and ZOT, a new measure called 'user satisfaction level (USL)' is also introduced which could be used to determine the share of users satisfied at existing service levels within each of the BRT route clusters. In the current research, the cumulative number of users who rated services either 1 (very good), 2 (good) or 3 (average) within the overall satisfaction scale of 1 to 5 (1= very good to 5= very poor) were considered as 'satisfied' users. Finally, to diagnose the critical service areas that need immediate improvement in these BRT route clusters, the current research adopted an importance-satisfaction analysis tool [14,17] that helps service providers to categorize service areas into groups of service attributes that need to be prioritized immediately and those that can be improved at later stages for improving transit performance in each of the BRTS route clusters. The analysis requires users' stated level of importance to be plotted against their stated level of satisfaction for different service attributes. Table 1 summarizes the different categories of service attributes based on the level of users' stated level of imporatance and satisfaction.

Table 1. Importance satisfaction analysis

Importance (Imp) & Satisfaction (Satisf.) Level	Service attribute categories
Imp (1)+Satis. (4/5)	Critical Parameters (Should be improved immediately)
Imp (1)+Satis. (3)	Service levels should be improved for higher perceived value
Imp (2)+Satis. (4/5)	Service levels should be improved for higher perceived value
Imp (2) +Satis. (1/2)	Good: Needs to be maintained
Imp (2)+Satis. (3)	No impact on users
Imp (3) +Satis. (1/2)	Exceeding expectation
Imp (3) +Satis. (3/4/5)	Not important

**Imp = Level of importance, Satis. = Level of satisfaction*

Finally, using the user perception data and the bus passenger O-D matrix created for the trunk corridor and the feeder routes, BRT services could be designed in terms of schedules, frequency and other service parameters. The methodology to determine segregated or open corridors, improvement of speed and reduction in travel time for both buses and other vehicles for the proposed BRTS corridors has been discussed in detail in Pandit and Maparu [25, 19]. This paper presents the broad framework for bus transit reform and redesign for the city of Kolkata based on user perception and does not include the detail BRTS service designs (schedules, frequency etc.) and the economic and environmental benefits of BRTS implementation.

6. Results and discussion

Fig. 8 shows the proposed BRTS routes in Kolkata. A total of eight trunk routes is proposed with overlaps in certain stretches of the corridors. Each of these BRTS routes is also supported by feeder services. Using regression modelling, it was found that, speed improvement of vehicles in the mixed lanes was only possible for roads with 3 lanes or more in each direction after the implementation of segregated corridors for buses. Accordingly, segregated corridors were proposed only for a part of the BRTS route limited to stretches with three or more lanes and lane markings for buses in the rest of the route [25,19]. The BRTS system is also designed to be 'open' with access to all types of buses considering the passenger travel demand along these corridors.

Two of these BRTS route clusters namely, 'SCM-Gariahat-AJC-JLN' route with origin at Garia and destination at B.B.D. Bag and 'DH-Strand' route with origin at Joka and destination at B.B.D. Bag were taken up for detail design. In case of the proposed 'SCM-Gariahat-AJC-JLN' route, out of all overlapping existing bus routes, 35 routes (2 CSTC, 1 CTC, 19 private and 13 Mini bus routes) were identified to cater to the existing passenger travel demand. These 35 routes were further categorized into, 9 'trunk BRT', 4 'Trunk and feeder BRT', 13 'Combined BRT' and 9 'non BRT' bus routes. As discussed earlier, these 26 'trunk BRT', 'Trunk and feeder BRT' and 'Combined BRT' bus routes could be combined to form a cluster of bus routes which can be auctioned to a single service provider which may be a consortium of existing private operators or a bigger private company. Table 2 shows the results of route merging for some of these bus routes.

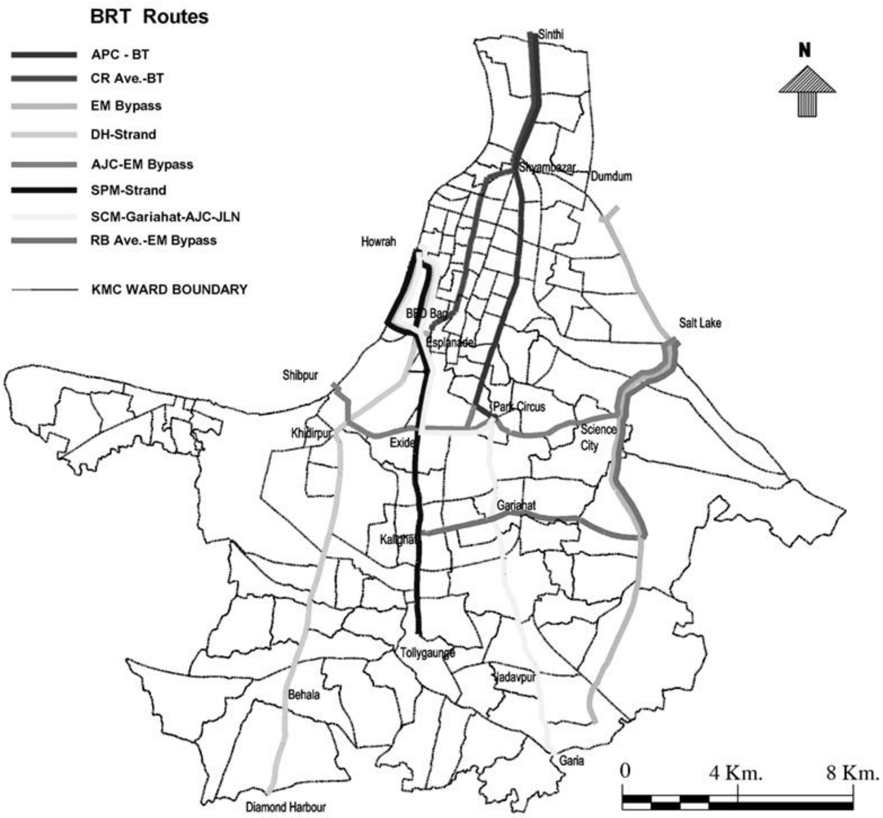

Fig. 8: Proposed BRT routes in Kolkata [25]

In case of the proposed 'DH-Strand' BRTS route, out of all overlapping existing bus routes, 44 routes (9 public, 27 private and 8 Mini bus routes) were identified to cater to the existing passenger travel demand. These 44 routes were further categorized into, 8 'trunk BRT', 12 'Trunk and feeder BRT', 11 'Combined BRT' and 13 'non BRT' bus routes. A metro rail corridor is also proposed along the same route and the results of the modal shift analysis resulting from implementation of rail transit showed that some of the bus routes will undergo considerable loss in ridership which further justifies the need for clustering of bus routes and overall reform and redesign of the bus transit system.

Table 2. Results of route merging along the 'SCM-Gariahat-AJC-JLN' BRTS route

Existing Route (Origin-Destination)	Existing Route No.	Type	Route merging	Remarks & Results
Garia- BBD Bag	101	Mini	Trunk BRT	A very small portion of the route is outside the trunk corridor.
Garia- Howrah	5	CSTC	Trunk BRT	This route follows the proposed BRT route.
Garia Station-Sealdah	45B	Private	Combined BRT	Only a part of the route is overlapping with the BRT route.
Joinpur-Aurobindo setu	M8	Mini	Feeder BRT, Trunk BRT	The route is merged with the BRT route service and the southern part of the route after Garia will have feeder service.
Garfa-Thakurpukur	SD4	Private	Non BRT	Most of the passengers on this route have an origin and/or destination outside the trunk corridor.

Fig. 9 – 14 shows the ZOT and USL for three service parameters namely 'service hours' , 'waiting time' and 'crowding level' for the two BRTS route clusters. Similarly, other service parameters such as 'bus stop nearness', 'no of transfers', 'seat availability' etc. were also analyzed. The results show a difference in the ZOT and the USL in these two BRTS route clusters. For example, the users of the 'SCM-Gariahat-AJC-JLN' BRTS route cluster show a lower tolerance i.e., 15-18 hours of daily service requirement compared to 14-17 hours of daily service requirement for the users of the 'DH-Strand' BRTS route cluster as shown in Fig. 9 and 10. On the other hand, the percentage of people satisfied at the minimum acceptable level of service (service hours) in Fig. 8 and 9 show that, while 91 percent of the people are satisfied in the 'SCM-Gariahat-AJC-JLN' BRTS route cluster, only 78 percent of the users are satisfied at the 'DH-Strand' BRTS route cluster at this LOS level. Thus, in addition to ZOT, USL could be a key determinant for determining appropriate service levels in the proposed BRTS routes. While the difference in ZOT and USL values in the two BRTS route clusters reflect the different user composition, and the different land use and urban setting of the two BRTS route clusters, it also highlights the need for consid-

ering different service levels for different service parameters in different BRTS routes.

Table 3 shows the results of the importance-satisfaction analysis for the two BRTS route clusters. While, ‘safety from thefts on board (theft)’ was found to be critical in both the clusters, ‘bus stop shelter maintenance’, ‘boarding-alighting time’, and ‘cleanliness on board’ was found to be critical in the ‘SCM-Gariahat-AJC-JLN’ BRTS route cluster and ‘Safety & security at bus stops at night’ and ‘safety for women on board(misconduct)’ was found to be critical in the ‘DH-Strand’ BRTS route cluster. ‘Bus service hours’, ‘bus stop nearness’, ‘on-time performance’, ‘waiting time’, ‘seat availability’, ‘crowding level’, ‘on-board safety from road accidents’, and ‘bus maintenance’ services were found to be in need of improvement in order to improve the overall perception of bus transit services amongst users of the ‘SCM-Gariahat-AJC-JLN’ BRTS route cluster. While, ‘seat availability’ and ‘crowding level’ was not found to have any impact on the users of the ‘DH-Strand’ BRTS route cluster, ‘total journey time’ and ‘bus maintenance’ were found to be in need of improvement in addition to the factors mentioned above for the ‘SCM-Gariahat-AJC-JLN’ BRTS route cluster.

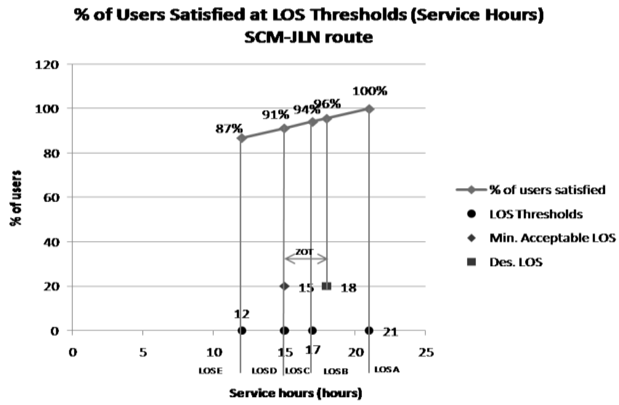

Fig. 9 User satisfaction level for ‘Service hours’ (SCM-JLN route)

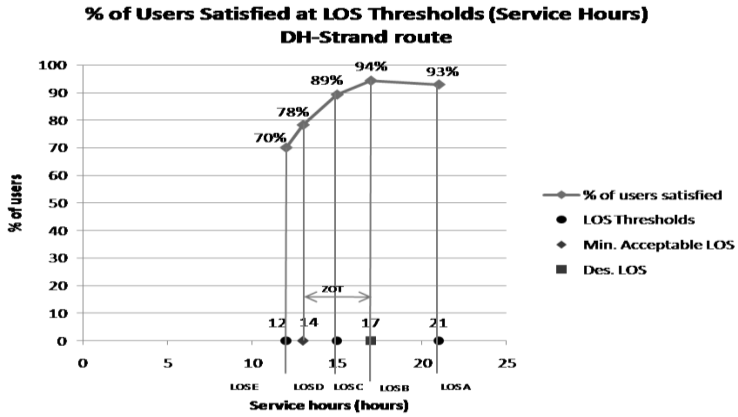

Fig. 10 User satisfaction level for 'Service hours' (DH-Strand route)

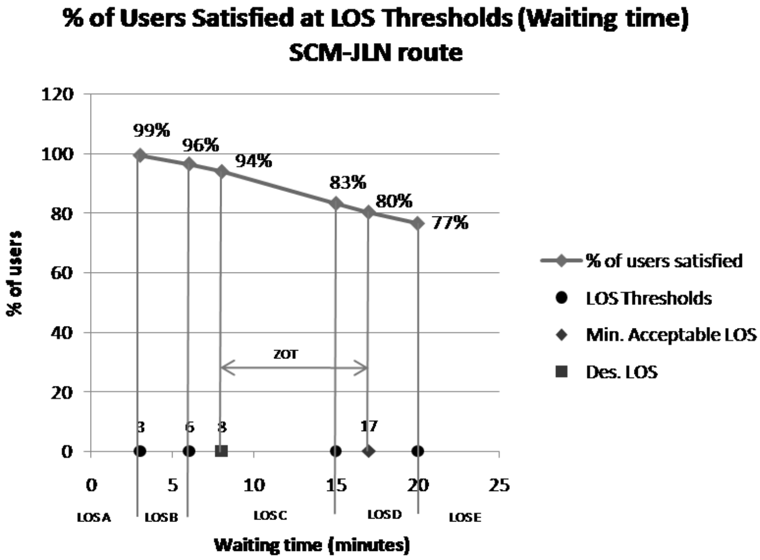

Fig. 11 User satisfaction level for 'Waiting time' (SCM-JLN route)

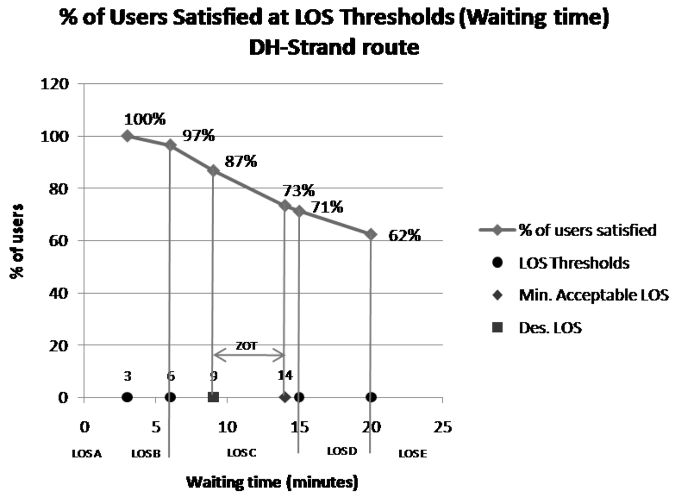

Fig. 12 User satisfaction level for 'Waiting time' (DH-Strand route)

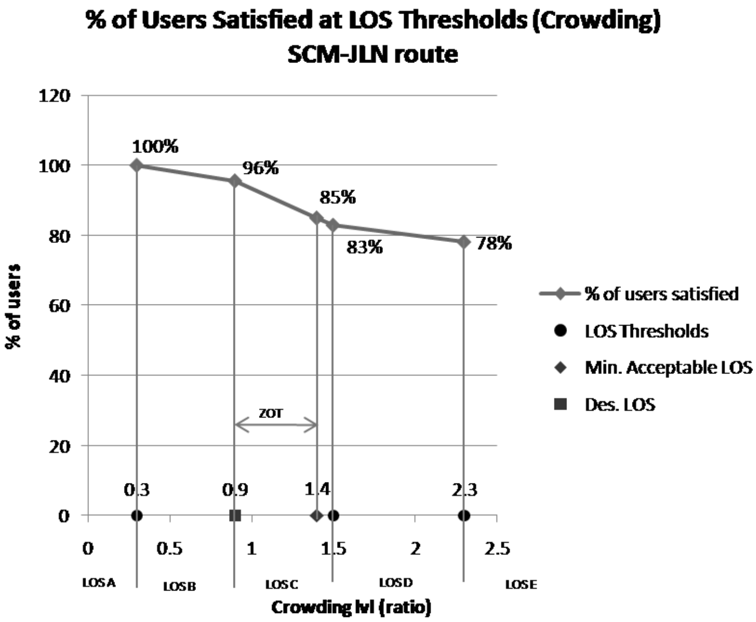

Fig. 13 User satisfaction level for 'Crowding' (SCM-JLN route)

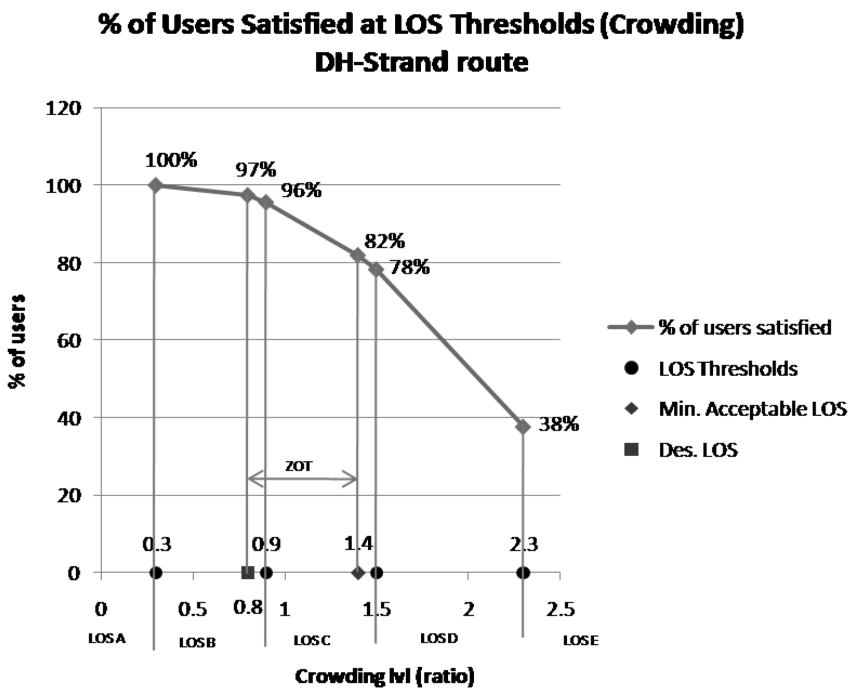

Fig. 14 User satisfaction level for ‘Crowding’ (DH-Strand route)

Table 3. Importance Satisfaction analysis for LOS parameters

	SCM-Gariahat-AJC-JLN route			DH-Strand route		
Service parameters	Importance	Satisfaction	Critical	Importance	Satisfaction	Critical
Bus service hours			√			√
Bus stop nearness			√			√
On-time performance			√			√
Waiting time			√			√
No. of mode interchange			≥			≥
Seat Availability			√			x
Crowding level			√			x
B/A time			©			x
Total journey time			x			√
Bus design			x			x
Bus stop shelter design			x			x
Road accidents			√			√
Thefts			©			©
Misconduct			x			©
Security at night			x			©
Bus driver behavior			≥			x
Driving practices			x			x
Ticket purchasing system			x			x
Bus maintenance			√			√
Cleanliness			©			x
Bus stop maintenance			©			√
Information			x			x

Legend:

Level of Importance

1	Very Important	
2	Moderately Important	
3	Not Important	

Level of Satisfaction

1	Very Good	
2	Good	
3	Average	
4	Poor	
5	Very poor	

Service attribute categories

Critical Parameters (Should be improved immediately)	©
Service levels should be improved for higher perceived value	√
Service levels should be improved for higher perceived value	√
Good: Needs to be maintained	≥
No impact on users	x
Exceeding expectation	≥
Not important	x

Results of the importance satisfaction analysis, in conjunction with the ZOT and USL values established in this research could be used to design appropriate service levels for the proposed BRTS routes. The final service levels, frequency setting, schedule of these proposed BRTS routes could be set using an optimization routine which however is not covered in the present paper. The present paper is limited to the development of a broad framework for bus transit reform and redesign using user perception data.

7. Conclusions

The proposed framework for improving the LOS and bus transit efficiency in Kolkata through the implementation of BRTS could be used as a template for reform and redesign of bus transit systems in similar cities. The existing system of bus transit operations is proposed to be transformed to a 'franchising' system through the implementation of BRTS and clustering of existing bus routes. Even though, BRTS has been proposed for some of the high travel demand corridors, existing bus services in other low travel demand routes/corridors is yet to be rationalized. Integration of BRTS operation in between different routes, detail scheduling of 'trunk BRT' and 'feeder BRT' services and BRTS infrastructure development are kept out of the scope of the present research.

Acknowledgement

The authors would like to thank the Sponsored Research & Industrial Consultancy (SRIC) cell of Indian Institute of Technology, Kharagpur for funding this study.

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