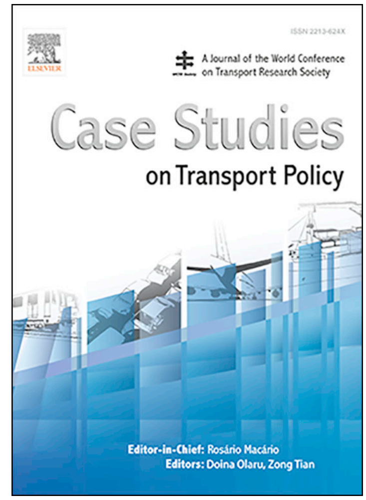
Journal Pre-proofs



Is Segmentation the Way Forward for Enhancing the Attractiveness of Urban Bus Services? Lessons Learned from Kolkata Metro City

Munavar Fairooz Cheranchery, Bhargab Maitra

PII: S2213-624X(23)00104-9
DOI: https://doi.org/10.1016/j.cstp.2023.101050
Reference: CSTP 101050

To appear in: *Case Studies on Transport Policy*

Received Date: 29 January 2023
Revised Date: 17 June 2023
Accepted Date: 16 July 2023

Is Segmentation the Way Forward for Enhancing the Attractiveness of Urban Bus Services? Lessons Learned from Kolkata Metro City

Munavar Fairooz Cheranchery

E-mail address: fairooz@nitc.ac.in; Tel.: +917557818784

Department of Civil Engineering, National Institute of Technology Calicut, Kozhikode- 673601, India

Bhargab Maitra*

*Corresponding author. Tel.: +919434040738; E-mail address: bhargab@civil.iitkgp.ac.in

Department of Civil Engineering, Indian Institute of Technology Kharagpur, Kharagpur-721302, India

Abstract: Incorporating conflicting requirements of different user groups and ensuring operational viability of bus services are the major challenges faced by transportation policymakers in developing countries like India. The paper reports an investigation on the design of urban bus services with segmentation giving due consideration to the requirements of user groups and service provider. A three-stage approach is demonstrated with reference to premium and ordinary bus services in Kolkata metro city. The design of premium service was carried out based on the choice riders' (car owners) perception, while that of ordinary service was carried out based on the perception of captive riders' (non-car owners) perception. A total of 10 routes with premium and ordinary services were selected for the study. Design was carried out for two cases namely, design with unconstrained supply of buses and design with constrained (present) supply of buses and guidelines and recommendations were given for the design of bus service with segmentation for Kolkata city. Application of the approach clearly showed that with marginal fare increment and additional supply of buses, highest level of service can be achieved without burdening the operator in terms of additional subsidy. The study offers a comprehensive methodological framework for the segmentation of urban bus services, which can be easily replicated in other cities. In addition, the valuable experience and insights shared in the study can provide practitioners with guidance and direction to develop sustainable urban bus services that align with transportation sustainability goals.

Keywords: Segmentation; urban bus transport; premium service; ordinary service; simulation model.

Abstract: Incorporating conflicting requirements of different user groups and ensuring operational viability of bus services are the major challenges faced by transportation policymakers in developing countries like India. The paper reports an investigation on the design of urban bus services with segmentation giving due consideration to the requirements of user groups and service provider. A three-stage approach is demonstrated with reference to premium and ordinary bus services in Kolkata metro city. The design of premium service was carried out based on the choice riders' (car owners) perception, while that of ordinary service was carried out based on the perception of captive riders' (non-car owners) perception. A total of 10 routes with premium and ordinary services were selected for the study. Design was carried out for two cases namely, design with unconstrained supply of buses and design with constrained (present) supply of buses and guidelines and recommendations were given for the design of bus service with segmentation for Kolkata city. Application of the approach clearly showed that with marginal fare increment and additional supply of buses, highest level of service can be achieved without burdening the operator in terms of additional subsidy. The study offers a comprehensive methodological framework for the segmentation of urban bus services, which can be easily replicated in other cities. In addition, the valuable experience and insights shared in the study can provide practitioners with guidance and direction to develop sustainable urban bus services that align with transportation sustainability goals.

Keywords: Segmentation; urban bus transport; premium service; ordinary service; simulation model.

1. Introduction

With rapid urbanization and increased purchasing power of people, vehicular volume has increased substantially in several countries (Jou et al., 2011). Emerging countries such as India observed exponential rise in private vehicle usage over the last few decades (Cheranchery and Maitra, 2017). Such a growth in vehicular volume coupled with limited road infrastructure has created a demand-supply imbalance in urban India (Agarwal et al., 2018). The resulting traffic congestion and emission have significantly contributed to the poor quality of life in cities (Kang and oh, 2016). Statistics shows that vehicular emission solely contribute to nearly 70% of air contamination in India (Rastogi et al., 2018). It has now become more imperative than ever to attract private vehicle users towards public transport for mitigating the congestion and emissions (Cheranchery and Maitra, 2018). Historically, bus is the popular and primary public transport mode in India due to its extensive coverage and affordable cost (Dandapat et al., 2017). However, poor service quality in terms of excessive crowding, delay, and long waiting time often discourages choice riders to use bus for their travel (Verma, 2015). Realizing this fact, Government formulated several policies to encourage the use of urban bus services (Ahmad and de Oliveira, 2016). As a part of Jawaharlal Nehru National Urban Renewal Mission (2005), substantial number of premium quality buses was introduced in several Indian cities to increase the attractiveness of bus service (JNNURM, 2005). However, overall scenario remains unchanged as the private car usage continues to surge in urban areas (Mittal et al., 2016).

Studies carried out in Indian context clearly indicate the need for the augmentation of bus service quality in terms of in-vehicle travel time, on-board comfort, traffic information, etc., to make it attractive to choice riders (Maitra et al., 2014). However, the cost associated with the improvement may burden both service providers and travelers. Considering the marginally weaker segment of the society (captive riders), the fare of public transport is kept low in India (Pucher et al., 2005). That has severely restricted the operating revenues of bus service, making it difficult to afford routine operation of bus service (Pucher et al., 2005). Hence, with constrained financial resources, the major focus of the Government has been to maintain the existing service without augmenting service quality (Cheranchery and Maitra, 2019). Therefore, the challenge is to enhance the quality of bus service keeping in mind the requirements of two distinctly different user groups (captive and choice riders) without burdening the Government in terms of additional financial aid to bus services.

Segmentation is defined as the process of identifying user groups or market segments that have similar characteristics, and incorporating their requirements in the service design for providing maximum benefit to the society (Elmore-Yalch, 1998). Segmentation of bus service is proposed as a solution to the aforementioned concerns in Indian cities by several researchers keeping in mind the requirements of user groups (captive riders and choice riders) and service provider (Howells and Lowe, 2018; Maitra et al., 2014). A document published CODATU suggests 16 policy recommendations for emerging countries to enhance accessibility to all. The 15th recommendation in the document was to develop a more adapted public transport supply and fares for different user groups (CODATU, 2016).

Urban travelers in India are generally classified as choice riders and captive riders based on car ownership (Ashalatha et al., 2012; Cheranchery and Maitra, 2017). While car owning travelers are considered as choice riders, the non-car owning travelers are considered as captive riders (Maitra et al., 2014). Similarly, bus service in urban India may be broadly classified as premium service and ordinary service. Premium service is offered by superior quality buses with high fare to cater to the need of choice riders. On the other hand, ordinary service is offered by low quality buses with a cost affordable to captive riders. Studies have been carried out in Kolkata city to understand the perception of choice riders and captive riders towards premium and ordinary services, respectively (Cheranchery and Maitra, 2017). Level of service standards were also established for premium and ordinary services of Kolkata city based on the perception of choice and captive riders, respectively (Cheranchery and Maitra, 2018). However, no guidelines are available for the design of premium and ordinary services utilizing the findings of aforementioned studies. Several Indian cities, such as Kolkata and Bengaluru, have already introduced premium buses. However, no guidance is available for the design of urban bus services with segmentation considering the requirements of two distinctly different user groups and service provider. A three-stage methodology is proposed here for the design of urban bus services with segmentation giving due consideration to the requirements of user groups and service provider. The work is demonstrated with reference to urban bus services in Kolkata metro city.

The reminder of the manuscript is organized into 6 sections. The initiatives taken by the Government of India to improve urban bus service is summarized in section 2. The methodology is discussed in Section 3. The study area is introduced in Section 4, while data collection is briefed in Section 5. Design of bus service with segmentation was demonstrated with reference to Kolkata city in Section 6, and the work is concluded in Section 7.

2. Literature review

The Government of India has made various efforts to enhance the quality and attractiveness of urban bus services. In this section, the initiatives taken by the Indian government to improve the urban bus service are summarized briefly.

The Jawaharlal Nehru National Urban Renewal Mission (JNNURM) was launched by the Government of India in 2005 (Choudhary, 2019). Under this mission, the government provided financial assistance to cities for the development of urban infrastructure, including the improvement of urban bus services. Many cities in India received financial assistance from JNNURM to improve their bus services, including the introduction of premium buses and the construction of bus depots and terminals. The Smart Cities Mission was launched by the Government of India in 2015 to promote sustainable and inclusive urban development. The mission aims to develop 100 smart cities in India by 2022 (Smith et al., 2019). Many smart cities under this mission have implemented various measures to improve their bus services, including the introduction of intelligent transport systems and the deployment of electric buses. The Bus Rapid Transit System (BRTS) is a high-quality bus-based transit system that provides fast, efficient, and reliable transport services. The Government of India has implemented BRTS in many cities, including Ahmedabad, Pune, and Jaipur, to improve the quality and attractiveness of urban bus services (Deng and Nelson, 2011). BRTS systems provide dedicated bus lanes, modern buses, and intelligent transport systems. The National Urban Transport Policy (NUTP) was launched by the Government of India in 2006 (Kuriakose, 2013). The policy aims to promote sustainable and inclusive urban transport systems. The policy emphasizes the importance of public transport, including urban bus services, and provides guidelines for the development of public transport systems in India.

3. Methodology

Design of bus service with segmentation aims to identify best operating scenarios for premium and ordinary bus services which are beneficial to both travelers and operators. A reduction in the Generalized Cost (sum of monetary costs of various quantitative and qualitative attributes of bus service) is considered as travelers' benefit (Dandapat et al., 2017). On the other hand, operational viability of service (typically, when the income exceeds operational expenditure) is considered as an indicator of the operators benefit. However, a majority of the service operated by the Government at present are running in financial loss and requires heavy subsidy. Therefore, in the present work, the service is assumed to be operationally viable when the income (from service) exceeds the expenditure or when there is a reduction in the subsidy requirement as compared to the present state. In essence, the design of bus service with segmentation aims to identify operationally viable premium and ordinary services which results in least GC to the traveler. The methodology adopted is discussed below.

Methodology followed for the design of bus service with segmentation includes broadly three stages as shown in Figure 1. It may again be mentioned that the design of premium service is carried out based on the requirements of choice riders and that of ordinary service is performed based on captive riders' perception.

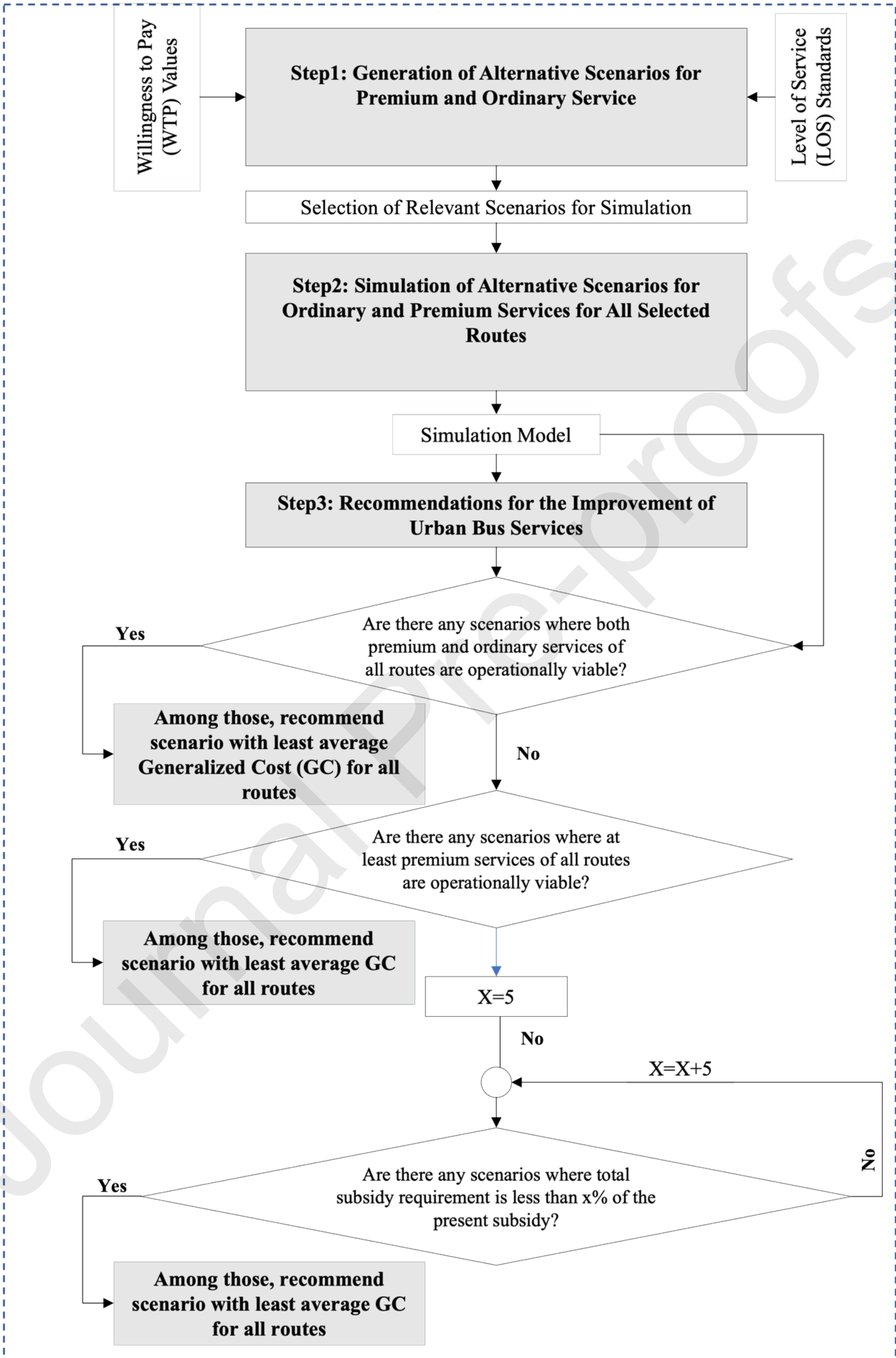

Willingness to Pay (WTP) Values
Step1: Generation of Alternative Scenarios for Premium and Ordinary Service
Level of Service (LOS) Standards
Selection of Relevant Scenarios for Simulation
Step2: Simulation of Alternative Scenarios for Ordinary and Premium Services for All Selected Routes
Simulation Model
Step3: Recommendations for the Improvement of Urban Bus Services
Are there any scenarios where both premium and ordinary services of all routes are operationally viable?
Yes
Among those, recommend scenario with least average Generalized Cost (GC) for all routes
No
Are there any scenarios where at least premium services of all routes are operationally viable?
Yes
Among those, recommend scenario with least average GC for all routes
X=5
No
X=X+5
Are there any scenarios where total subsidy requirement is less than x% of the present subsidy?
Yes
No
Among those, recommend scenario with least average GC for all routes

Figure 1. Methodology

Generation of alternative scenarios

The methodology is aimed to identify the best scenario to operate premium and ordinary services under the framework of segmentation. As bus service is characterized by several attributes such as cost, travel time and crowding level, the operational scenarios are defined as combinations of various levels of such attributes. The primary task is to select key attributes and its levels for generating larger set of scenarios. While the selection of key attributes is carried out using Revised (Importance-Performance Analysis) IPA, attribute levels are identified based on LOS standards and Willingness to Pay (WTP) values. At the end of this stage, a larger set of scenarios with key attributes and its levels is identified. However, it may not be logical and necessary to simulate all (full factorial combinations) such scenarios as simulation process is generally time consuming. Accordingly, relevant scenarios are filtered out from the larger set based on trial simulations.

Simulation of alternative scenarios

Simulation is necessary for a fair evaluation of the selected scenarios and selection of the best scenarios for the operation of premium and ordinary services. Dandapat and Maitra has developed a simulation model for bus services in Kolkata city. The model is suitably modified for the present context (Figure 2) and simulation of the selected scenarios of premium and ordinary services is carried out in this stage of the methodology. Apart from the bus service and demand characteristics, a GC model as simulation input is necessary for the scenario evaluation. Simulation of the service is expected to provide outputs such as income, expenditure, GC to passenger, number of buses required, average waiting time, and average crowding level of the simulated service.

Recommendation for the operation of bus services with segmentation

This stage of the methodology aims to recommend best operational scenarios for premium and ordinary bus services. The best scenario is selected based on GC to traveler and operational viability. The simulation outputs such as average GC to travelers, revenue generated, and expenditure are used for the selection process which is carried out in three steps (3a, 3b, and 3c) as shown in Figure 2. In step 3a, scenarios satisfying the operational viability (revenue ≥ expenditure) for both services (premium and ordinary) of all study routes are shortlisted. Subsequently, scenario resulting in least GC to traveler from the shortlisted scenarios is recommended as the best scenario under segmentation. If none of the simulated scenarios satisfy operational viability criterion for both services in all routes, then recommendation was made based on step 3b. Scenarios satisfying operational viability of premium service of all routes are shortlisted in step 3b. Subsequently, scenario resulting in least GC to travelers is recommended. If none of the simulated scenarios satisfies operational viability criterion for premium service in all routes, then recommendation was made based on step 3c. Scenarios with total subsidy requirement (combined value of premium and ordinary services) is less than a fixed percentage (say x%) of the present subsidy is shortlisted in step 3c, and recommendation was made by selecting scenario with least GC to the travelers from the shortlisted scenarios. If none of scenarios satisfies the criteria (say at x=5), higher values of x will be chosen until the criteria is met.

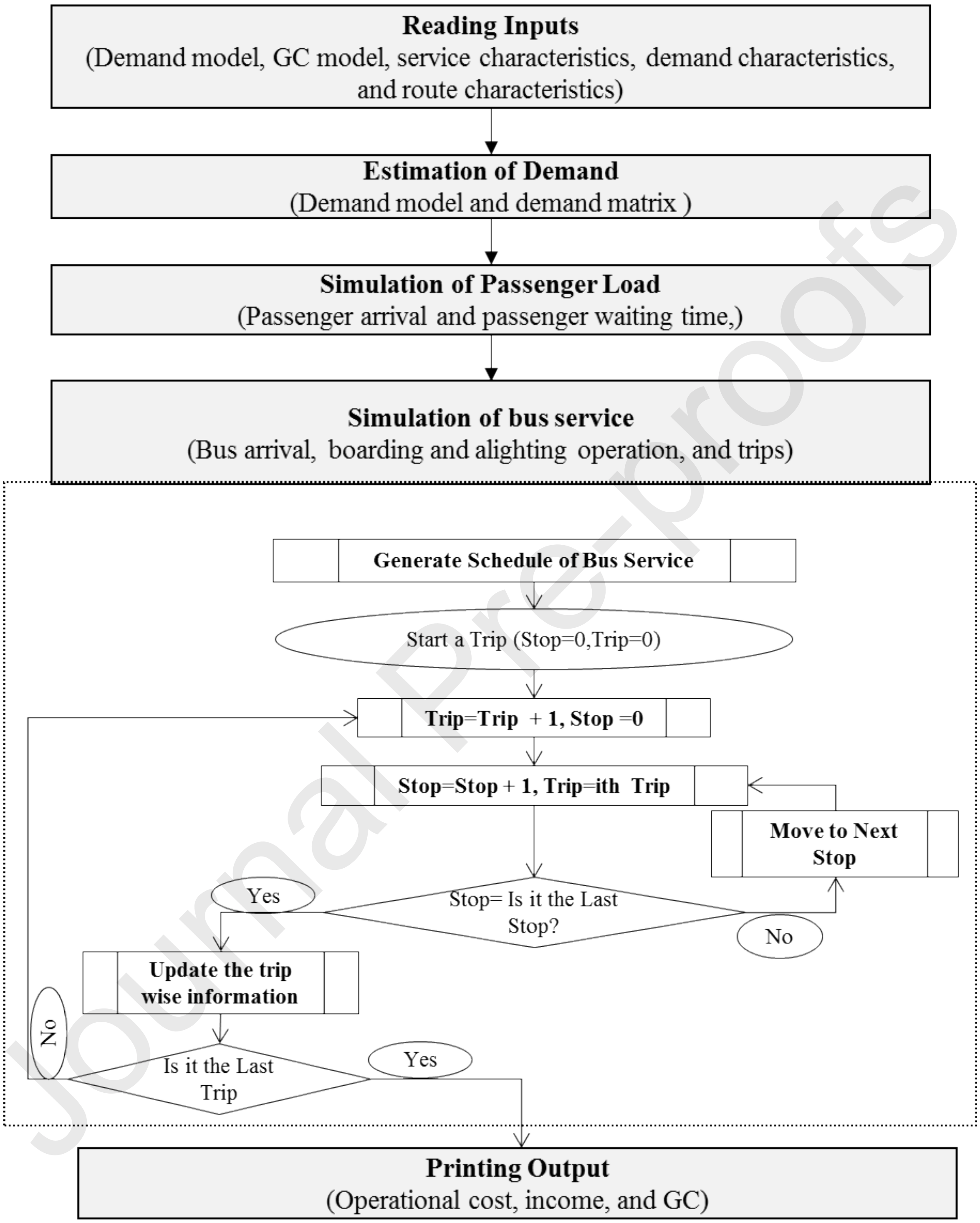


Figure 2. Simulation model

4. Study Area

Kolkata, a megacity in India is selected for the study. The city has a population density of 24,000 per square kilometer (Sen, 2020). It has limited road network which covers only 6% of the total area (Sen, 2020). With limited road space and growing travel demand, the city is experiencing severe congestion, vehicular emission, and delay. Bus is the primary mode of public transport in Kolkata. In fact, around 60% of the total passengers in Kolkata use bus for their travel (Dey, 2012). The city has extensive coverage of bus service which is predominantly served by ordinary buses. Over the years, the car ownership rate and the share of choice riders in the city has increased substantially. With an aim to attract choice riders, the Government has introduced premium buses in Kolkata city. The unique characteristics (say, traffic congestion, availability of premium and ordinary services, and extensive bus network) of bus service in the city provided an opportunity to select Kolkata as case study for the design of urban bus services with segmentation. Ordinary service in Kolkata is operated by both private and Government operators. However, the Government controls the service in terms of fare, route permit, etc., for all ordinary routes. The key operator controlling the operation of bus service in Kolkata is West Bengal Transport Corporation (WBTC). Apart from ordinary service, premium service is also operated by WBTC. In the present work, ordinary and premium services operated by WBTC are considered for the design of urban bus services with segmentation. Premium buses are a new addition to the urban transportation sector in India, featuring superior air-conditioned seating arrangements, enhanced comfort, robust security systems, and advanced information facilities. In contrast, ordinary bus services are provided at lower fares, but with reduced service quality in terms of the aforementioned attributes. A total of 10 routes were selected for the study in such a way that both premium and ordinary services are operational in those routes (Figure 3). The selected routes are Garia-Airport (R1), Ultadanga-Ecopark (R4A), Ultadanga-Saltlake (R4B), Garia-Howrah (R5), Howrah-Esplanade (R6), Garia-Ramnagar (R9B), Garia- Ballygunge (R9L), Ballygunge-Esplanade (R10), Ultadanga - Rabindra Sadan (R12), and Golpark - Bagbazar (R12DL).

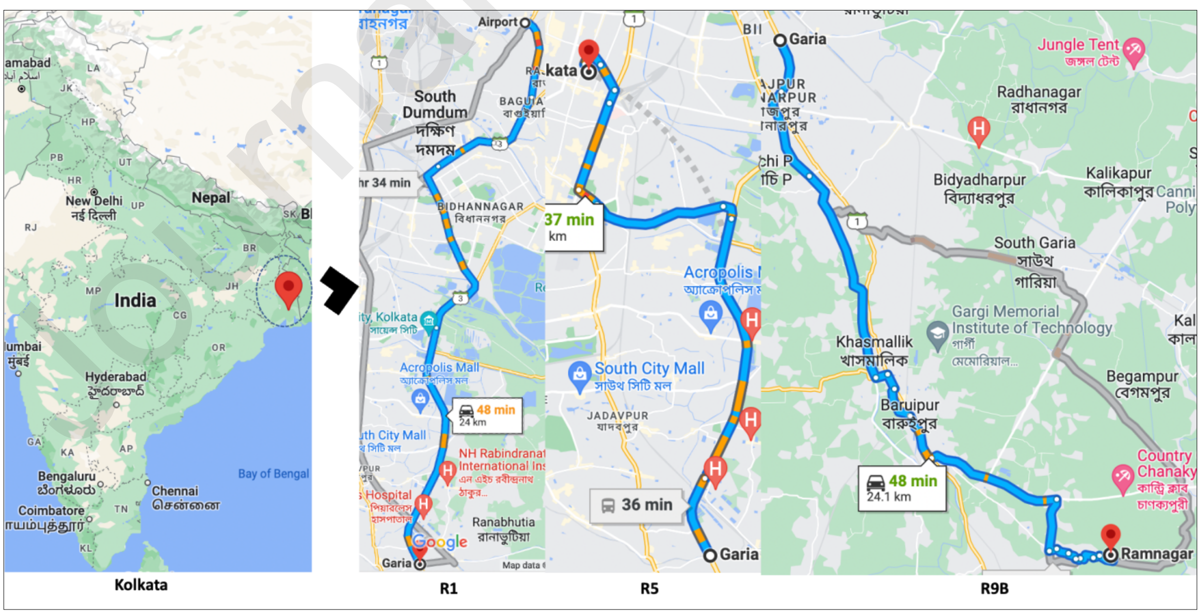


Figure 3. Study area and bus routes

5. Database

Simulation inputs include data related to service route, vehicle, cost, fare model, GC coefficients, demand model, hourly demand and origin-destination (OD) matrices of the service routes under consideration. Route related information includes route length, number of bus stops, and average spacing between bus stops. This was collected through route map and field investigations. The vehicle characteristics such as number of seats, vehicle capacity, and fuel economy were collected directly from the operator. The cost inputs include operating and non-operating cost such as Equated Monthly Installment (EMI), fixed wages of the employees, fuel and lubricant cost, and maintenance cost. The cost inputs along with fare model was collected directly from the operator. After collecting ticket data from the operator, single day demand was obtained by computing the average of one week data. The demand pattern showed substantial variation in demand across various time periods. Accordingly, it was decided to simulate the service for five time periods (6 AM to 7 AM, 7 AM to 10 AM, 10 AM to 2 PM, 2 PM to 6 PM, 6 PM to 11 PM) within the service span to account for the variation in demand. Demand and OD matrices were developed for these time periods for facilitating the simulation.

6. Design of Bus Services with Segmentation

The proposed methodology is demonstrated here for the design of urban bus service with segmentation for Kolkata city. The design was carried out for two cases namely, (i) design with unconstrained supply of buses and (ii) design with constrained supply of buses.

6.1. Selection of attributes and its levels for scenario generation

Selection of important attributes and their levels is a major task prior to the scenario generation. The study conducted by Cheranchery and Maitra (2017) listed priority attributes for enhancing the quality of ordinary and premium services of Kolkata. Cheranchery and Maitra (2017) used Revised IPA to identify key attributes for ordinary and premium bus services. The priority attributes include crowding level, service span, headway, travel time, access egress time, security, and information. The quantitative attributes and their standards from existing literature are summarized in Table 1.

Table 1. Attributes and standards based on exsitng literature

Attributes	Standards	Literature
Crowding level (passenger per seat)	<0.3 (LOS A),0.31-0.9 (LOS B, 0.91-1.50 (LOS C),1.51-2.30 (LOS D),>2.30 (LOS E).	Das and Pandit (2015), Cheranchery et al. (2021),
Service span (hour)	21 (LOS A), 21-17 (LOS B), 16-15 (LOS C), 14-12 (LOS D), <12 (LOS E)	Das and Pandit (2015), Wirasinghe et al. (2013)
Waiting time (minutes)	=0.0 (LOS A), 0.1-4.0 (LOS B), 4.1-20.0 (LOS C), 20.1-35.0 (LOS D), >35.0 (LOS E)	Das and Pandit (2015)

Delay in travel time (minutes)	0.0 (LOS A), 0.1-7.0 (LOS B), 7.0-17.0 (LOS C), 17.0-50.0 (LOS D), >50.0 (LOS E)	Das and Pandit (2015)
Cost increment (%)	<13 (Very fair), 13-19 (Fair), 19-43 (Neutral), 43-63 (Unfair), >63 (Very unfair)	Cheranchery et al. (2019)

The levels of quantitative attributes such as crowding level, service span, headway for scenario generation were fixed based on the Level of Service (LOS) standards developed by Cheranchery and Maitra (2018) as summarized in Table 2. Study also identified acceptable cost increment to choice and captive riders in terms of fairness levels (Table 2). In the present study, the levels of access-egress time and journey speed were retained at their present values as observed from the field. This is because any improvement in such attributes require interventions at the network level. The WTP values estimated by Cheranchery and Maitra (2019) as summarized in Table 3 were used for selecting the levels of qualitative attributes.

Table 2. Level of service standards for premium and ordinary services based on the choice and captive riders

Premium Service						**Ordinary Service**					
LOS	**Crowding level (Average number of**	**Service Span (Hour)**	**Headway (minutes)**	**Fairness levels**	**Cost increment (%)**		**Crowding level**	**Service Span**	**Headway (minutes)**	**Fairness levels**	**Cost increment (%)**
A	<1.0	>17	<12	Very fair	≤25	A	<1.2	>16	<16	Very fair	≤13
B	1.0-1.2	16-17	12-17	Fair	25-40	B	1.2-1.4	15-16	16-22	Fair	13-19
C	1.2-1.3	14-16	17-24	Neutral	40-64	C	1.4-1.6	12 -15	22-31	Neutral	19-43

D	1.3-1.5	11-14	24-40	Unfair	64-83	D	1.6-1.80	10-12	31-46	Unfair	43-63
E	>1.5	<11	>40	Very unfair	>83	E	>1.80	<10	>46	Very unfair	>63

6.2. Demand and Generalized Cost Model

Generalized cost and demand model are necessary for estimating the likely benefits to travelers due to improvement in service attributes and to study its impact on the ridership of bus service. The GC (Equation 1 and Table 3) and demand model (Table 4) developed by Cheranchery and Maitra (2019) for the choice and captive riders of Kolkata city were used for this purpose. The WTP values are reported in INR/minute (I USD=70.96 in 2021). The model was developed using SP and RP data collected from the travelers of Kolkata city using simple random sampling technique. A joint SP-RP model was developed using 1049 samples collected from Kolkata city (Cheranchery and Maitra, 2019). The study developed joint SP-RP model by simultaneous estimation technique in NLOGIT software. Additional details on model estimation are available in (Cheranchery and Maitra, 2019).

$$GC_{nij} = \alpha_{ae} * AT + \alpha_{wt} * WT + \alpha_{ivtt} * IVTT - \alpha_{sp} * SP + (\alpha_{sa} + \alpha_i + \alpha_c) * d_{nij} + FA_{nij} \quad (1)$$

Table 3. Generalized Cost coefficients for choce and captive riders

Coefficients	Unit	Willingness to Pay (WTP)	
		Choice riders	Captive riders
α_{ae} (Access-egress time)	INR/minute	1.50	0.30
α_{wt} (Waiting time)	INR/minute	1.26	0.43
α_{ivtt} (In-vehicle travel time)	INR/minute	1.04	0.98
α_{sp} (Span of operation)	INR/hour	2.60	1.30
α_{sa}, (Security system I)	INR/km	2.82	2.80
α_{sa}, (Security system II)	INR/km	2.39	1.80
α_{sa}, (Security system III)	INR/km	1.91	1.50
α_{i} (Information I)	INR/km	3.43	1.60
α_{i} (Information II)	INR/km	3.00	1.20
α_{i} (Information III)	INR/km	1.67	1.17
α_{c} (Crowding I)	INR/km	3.71	0.46
α_{c} (Crowding II)	INR/km	3.21	0.20
α_{c} (Crowding III)	INR/km	2.10	0.13

Security System 1: No facility to ensure security; Security System II: Bus is equipped with CCTV camera; Security System III:Waiting shed is equipped with CCTV camera; Security System IV: Both bus and waiting shed are equipped with CCTV camera; Information I: Printed schedule of bus arrival at waiting shed; Information II: Printed schedule at waiting shed and online static information; Information III: Digital dynamic information at waiting shed and static online information; Information IV: Digital dynamic information at waiting shed and dynamic online information; Crowding I: standing in overcrowded condition; Crowding II: standing in crowded condition; Crowding III: standing comfortably; Crowding IV: occupying a seat.

Table 4. Joint SP-RP model for choice and captive riders

Attributes	Coefficients	
	Choice riders	Captive riders
Access-egress time	-0.069 (-6.75)	-0.021 (-2.46)
Waiting time	-0.058 (-17.81)	-0.03 (-12.48)
In vehicle travel time	-0.481 (-11.21)	-0.68 (-15.68)
Cost	-0.0046 (-24.35)	-0.006 (-20.20)
Service span	0.12 (10.59)	0.09 (5.29)

Security system I	-1.3 (-8.70)	-2.2 (-7.34)
Security system II	-1.1 (-7.79)	-1.3 (-6.46)
Security system III	-0.88 (-6.79)	-1.1 (-6.88)
Information I	-1.58 (-11.21)	-1.13 (-6.09)
Information II	-1.38 (-8.65)	-0.87 (-4.39)
Information III	-0.77 (-5.12)	-0.81 (-4.18)
Crowding I	-1.71 (-16.97)	-0.32 (-3.44)
Crowding II	-1.48 (-12.27)	-0.14 (-1.59)
Crowding III	-0.97 (-8.59)	-0.09 (-1.12)
Constant [Ordinary Bus]	-2.87 (-19.98)	0.3 (2.6)
Constant [Premium Bus]	1.53 (8.49)	-0.087 (-1.38)
Constant [Car]	-0.71 (-8.99)	--
SP/RP Scale factor	2.41 (15.09)	2.3 (7.91)
ρ^2	0.44	0.51

6.3. Design with unconstrained supply of buses

The design was carried out in three stages as mentioned in the methodology section. In this case, it was assumed to have unconstrained supply of premium and ordinary buses. The unconstrained supply signifies the availability of unlimited number of buses to satisfy the LOS of headway and crowding.

<u>*Generation of alternative scenarios*</u>

Alternative scenarios for the improvement of bus services (premium and ordinary) were generated in this stage. This includes selection of improvement levels for quantitative and qualitative attributes of both services. The improvement levels of quantitative attributes for premium and ordinary services were selected based on the LOS standards reported in Table 2. The levels of the quantitative attributes such as service span, headway, and crowding level of premium services were fixed based on LOSA and LOS B (Table 2). In the case of premium service, levels of qualitative attributes were selected based on the top two WTP values of choice riders. Accordingly, information III and IV, security system III and IV were selected as the improvement levels for qualitative attributes of premium service. In the case of ordinary service, the levels of quantitative attributes were selected as per LOS A and LOS B established based on the perception of captive riders. However, unlike premium service, all four levels of the qualitative attributes of ordinary service were selected for the scenario generation. This is considering the fact that selecting top two levels alone with limited fare is unlikely to provide financially viable scenarios for ordinary service. The levels of access-egress time and journey speed were retained at their present values as observed from the field. Table 5 summarizes the attribute levels of premium and ordinary services selected for the scenario generation.

Table 5. The range of attributes for scenario generation

Attributes	Premium service	Ordinary service
Access-Egress Time (minutes)	Base Level	Base Level
Headway (minutes)	LOS A and LOS B	LOS A and LOS B
Average Journey Speed (km/h)	Base Level	Base Level
Fare (INR)	Corresponding to a fairness level, Very Fair and Fair	Corresponding to a fairness level, Very Fair and Fair
Service span (hours)	LOS A and LOS B	LOS A and LOS B
Crowding Level (Occupancy ratio)	LOSA and LOS B	LOSA and LOS B
Security System	Level III and Level IV	Level II, Level III and Level IV
Information	Level III and Level IV	Level II, Level III and Level IV

<u>*Simulation of alternative scenarios*</u>

All identified scenarios were simulated using the simulation model. A total of 321 scenarios were simulated for each route. The base (present) scenario and all selected improvement scenarios were simulated at this stage. The supply of premium and ordinary buses was assumed to be unconstrained, which means the required number of buses to satisfy the LOS criteria is available. The route, bus and cost related data used for simulations are presented in Table 6. As mentioned earlier, the service span for both services were classified into five periods, several rounds of simulation were carried out, and all relevant outputs were recorded before identifying a set of operationally viable scenarios.

Table 6. Key data for simulation

Model Input		**Values**		**Unit**
		Premium Service	**Ordinary Service**	
Operator's Cost				
Non-Operating cost (EMI, Insurance, etc.)		70000	33500	INR/month
Fixed wages (fixed cost)		80000	80000	
Other cost (bonus, cleaning, etc.)		7000	7000	
Fuel and lubricant costs (variable cost)		25	15	INR/km
Cost of maintenance (Tire, tube, spares, and others) (variable cost)		7	5	
Route Characteristics				
Route length		21	21	Km
Number of bus stops		26	26	_
Average spacing between bus stops		0.80	0.80	Km
Bus Characteristics				
Seat capacity		42	38	Passengers/bus
Crush load capacity		80	80	Passengers/bus
Fuel economy		3.5	4	km/litre
Additional Cost due to Security Arrangements and Information (Includes unit price, installation cost and maintenance cost)				
Security system	Installation of CCTV camera in waiting shed	16917	16917	INR/month
	Installation of CCTV Camera inside bus	10000	10000	
Information	Vinyl Board (Static Information)	7750	7750	
	Led Display (12'x8') (Dynamic Information at Bus Stop)	96667	96667	
	Website/Mobile based application (Dynamic information)	3334	3334	

Recommendation for the improvement of bus service

Although simulation was carried out for several scenarios, owing to space constraints, simulation outputs of two selected scenarios are summarized in Table 7.

Table 7. Simulation outputs of two selected scenarios

Premium service			**Ordinary service**			**Premium service**			**Ordinary service**		
Scenario: FM4_LA_I4_S4			**Scenario**: FM2_LB_I2_S3			**Scenario**: FM4_LA_I4_S4			**Scenario**: FM3_LB_I2_S3		
Route	Operational viability	Average GC to passengers	Route	Operational viability (Yes/No)	Average GC to passengers	Route	Operational viability (Yes/No)	Average GC to passengers	Route	Operational viability (Yes/No)	Average GC to passengers
R1	Yes	54	R1	Yes	92	R1	**Yes**	54	R1	**Yes**	90
R4A	Yes	68	R4A	No	150	R4A	**Yes**	68	R4A	**No**	148
R4B	Yes	69	R4B	No	118	R4B	**Yes**	69	R4B	**No**	115
R5	Yes	84	R5	No	141	R5	**Yes**	84	R5	**No**	138
R6	Yes	87	R6	No	145	R6	**Yes**	87	R6	**No**	143
R9B	Yes	82	R9B	No	138	R9B	**Yes**	82	R9B	**No**	135
R9L	Yes	54	R9L	No	93	R9L	**Yes**	54	R9L	**No**	91
R10	Yes	80	R10	No	80	R10	**Yes**	80	R10	**No**	78
R12	Yes	49	R12	No	81	R12	**Yes**	49	R12	**No**	79
R12DL	Yes	51	R12DL	No	88	R12DL	**Yes**	51	R12DL	**No**	86
Average GC=67.8			Average GC=112.6			**Average GC=67.8**			**Average GC=110.3**		

Note: It may be noted that although several scenarios were investigated, only two scenarios are presented here due to space constraints. The scenarios are designated in the form $FM_x\_L_{A/B}\_I_yS_z$, where FM indicates Fare Model and suffix x indicates the number of fare model, L_A and L_B indicate LOS A and B respectively, I refers to information and suffix y indicate level of information, and S indicate security arrangement and suffix z indicate the level of security arrangement.

Simulation of the base scenario clearly showed that none of the premium routes are operationally viable at present, and the service requires heavy subsidy to meet the operating cost. This is clearly in line with the observations of previous studies (Pai and Hidalgo, 2009; Tiwari and Jain, 2010). The results further showed that the ordinary service of Route 1 is the only operationally viable service at present. The simulation results of improvement scenarios also indicated that none of the scenarios are operationally viable for ordinary service except for Route 1. On the other hand, a few improvement scenarios were found operationally viable for premium services of all routes. Further investigations suggested that unless there is significant increment in the fare (which is not acceptable to the captive riders as per Table 2), none of the ordinary services (except Route 1) would be operationally viable for any scenarios. This is in line with the findings of previous studies in the context of ordinary bus service in Kolkata city (Dandapat et al., 2017; Cheranchery and Maitra, 2021). Therefore, it was decided to select a set of scenarios where premium services are operationally viable and the subsidy requirement is less than the present for ordinary services. Among those scenarios, the scenario with least generalized cost to the passengers were recommended for the improvement of premium and ordinary services as summarized in Table 8.

Table 8. The recommended scenario for premium and ordinary service with unconstrained supply of buses

Attributes	Premium service		Ordinary service
Headway (minutes)	≤12 (LOS A during peak hours) 12-17 (LOS B during off-peak hours)		16-22 (LOSB) during peak and off-peak hours
Average Journey Speed (km/h)	(14km/h) Base level		(13 km/h) Base level
Fare	Minimum Fare (INR)	20	8
	Maximum Distance with Minimum Fare (km)	4	3
	Fare Increment (INR/km)	2.5	0.5
Service span (hours)	18 (LOS A)		16 (LOS B)
Crowding Level (Occupancy ratio)	≤1 (LOS A)		1.2-1.4 (LOS B)
Security System	Both bus and waiting shed are equipped with CCTV camera (Level IV)		Waiting shed is equipped with CCTV camera (Level III)
Information	Digital dynamic information at waiting shed and online dynamic information (Level IV)		Printed schedule at waiting shed and online static information (Level II)

The recommended headway for each route and the corresponding number of buses required for each route are summarized in Table 9. Interestingly, the number of buses required to satisfy the recommended scenario is less than the present supply. This clearly indicate the oversupply and underutilization of ordinary buses in Indian context which is in agreement with the findings of Dandapat et al., (2017). As far as premium services are concerned, the number of buses required to satisfy the LOS criteria of headway exceeds the present supply. A total of 76 additional buses are required to satisfy the recommended scenario. It may not be practical to increase the supply by such a large number due to financial constraints. This was the main motivation for exploring the design with constraint supply of buses.

Table 9. Routewise headway and number of buses required

Route	Number of buses required				Route	Headway (minutes)			
	Premium Service		Ordinary Service			Premium Service		Ordinary Service	
	Present	Improved	Present	Improved		Present	Improved	Present	Improved
R1	14	17	16	10	R1	23	10	16	16
R4A	16	29	15	14	R4A	22	10	20	18
R4B	15	26	9	12	R4B	26	11	22	20
R5	13	21	16	11	R5	26	11	20	16
R6	14	20	16	11	R6	23	10	18	18
R9B	15	22	12	10	R9B	22	10	20	20
R9L	11	18	12	8	R9L	45	12	20	20
R10	13	23	10	10	R10	35	11	17	17
R12	13	16	20	19	R12	38	11	22	18
R12DL	14	22	9	9	R12DL	21	10	20	18
Total	**138**	**214**	**135**	**114**	**Average**	**28**	**11**	**20**	**18**

6.4. Design with constrained supply of buses

As mentioned earlier, design of bus service with segmentation was carried out with constrained (present) supply of buses.

Generation of alternative scenarios

Design with constrained supply is required only when the present supply is inadequate to fulfil the LOS requirements as per the unconstrained design. Table 9 clearly shows that the number of ordinary buses required to satisfy the unconstrained design of ordinary service is less than the present supply of ordinary buses. Hence, it is not necessary to constrain the supply of ordinary buses. Therefore, supply was constrained to present supply only for the premium service. The level of service of headway and crowding will be affected due to the limited supply of premium buses. Therefore, the challenge is to design a premium service with the best possible LOS for headway and crowding with the present supply of buses. For this purpose, the base scenario was simulated initially for all routes under the present supply of buses to categorize the routes in terms of the LOS of headway and crowding. Accordingly, premium routes were categorized as follows: routes with (i) LOS A for headway and crowding (ii) LOS A for headway and LOS B crowding (iii) LOS B for headway and LOS A for crowding (iv) LOS B for both headway and crowding (v) LOS C or below for headway and LOS C or below for crowding. The results indicated that with the present supply of buses, it is not possible to satisfy LOS A for headway and crowding for all routes. Further, the results suggested that many of the existing routes have inadequate supply of buses to ensure at least LOS B for crowding and headway. However, the results also indicated the possibility of achieving at least LOS B for crowding and headway for the selected routes subjected to a reorientation in the supply of buses among the routes. Accordingly, a fraction of the supply from routes which satisfies higher LOS either in headway, crowding or both were systematically transferred to those routes with inadequate supply to satisfy LOS B for headway and crowding. After distributing the premium buses among various routes, alternative scenarios were generated based on the levels of attributes summarized in Table 10. After eliminating several scenarios using trail simulations, a total of 321 scenarios were identified for simulation.

Table 10. The range of attributes for scenario generation

Attributes	Premium service	Ordinary service
Access-Egress Time (minutes)	Base Level	Base Level
Headway (minutes)	LOS B	LOS A and LOS B
Average Journey Speed (km/h)	Base Level	Base Level
Fare (INR)	Corresponding to a fairness level, Very Fair and Fair	Corresponding to a fairness level, Very Fair and Fair
Service Span (hours)	LOS A and LOS B	LOS A and LOS B
Crowding Level (Occupancy ratio)	LOS B	LOSA and LOS B
Security Arrangement	Level III and Level IV	Level II, Level III and Level IV
Traffic Information	Level III and Level IV	Level II, Level III and Level IV

Simulation of alternative scenarios

All identified scenarios were simulated using the simulation model. The simulation procedure as adopted in the case of unconstrained supply was followed with necessary modifications in the range of headway and crowding level. As mentioned earlier, the service span for both services were classified into five periods, several rounds of simulation were carried out and all relevant outputs were recorded.

Recommendation for the bus service

As obtained in the case of unconstrained supply, no scenario was found operationally viable for the ordinary services of all routes. However, unlike the previous case, a few scenarios were found operationally viable for two ordinary services namely, Route 1 and Route 9B. As far as premium services are concerned, a few scenarios were found operationally viable for all routes. Therefore, it was decided to select a set of scenarios where premium services are operationally viable and the subsidy requirement is less than the present for ordinary services. Among those scenarios, the scenario with least GC to passengers were recommended for the improvement of premium and ordinary services. The recommended scenario for the improvement of premium and ordinary services with constrained supply of buses is summarized in Table 11.

Table 11. The recommended scenario for premium and ordinary service under constrained supply

Attributes	Premium service		Ordinary service
Headway (minutes)	12-17 (LOS B) during peak and off-peak hours		16-22 (LOSB) during peak and off-peak hours
Average Journey Speed (km/h)	(14km/h) Base level		(13 km/h) Base level
Fare	Minimum Fare (INR)	20	8
	Maximum Distance with Minimum Fare (km)	4	3
	Fare Increment (INR/km)	2.5	0.5
Service Span (hours)	18 (LOS A)		16 (LOSB)
Crowding Level (Occupancy ratio)	1.0-1.2 (LOSB)		1.2-1.4 (LOSB)
Security System	Both bus and waiting shed are equipped with CCTV camera (Level IV)		Waiting shed is equipped with CCTV camera (Level III)
Information	Digital dynamic information at waiting shed and online dynamic information (Level IV)		Printed schedule at waiting shed and online static information (Level II)

The number of buses required to satisfy the improved is found to be less than the existing supply of buses. Therefore, additional supply of premium and ordinary buses are not required.

6.5. Impact of improvement on key parameters

This section includes a discussion on the impact of recommended improvement under unconstrained and constrained cases on parameters such as demand share of bus service, mode shift of choice riders to premium service, income of ordinary and premium services, overall GC, GC to choice riders, and GC to captive riders. The impact of improvement was estimated giving due consideration to all study routes as summarized in Figure 4. The results clearly suggest that overall, there is a substantial increase in the demand of bus services due to the recommended improvement scenarios. Such an increase may primarily be attributed to the shift of choice riders to premium service. These findings are in agreement with the findings of the study conducted by Cheranchery and Maitra, (2019). In attempt to improve the quality of premium services, Cheranchery and Maitra (2019) identified the positive impact of improved LOS on ridership and revenue. Similarly, in the present work, positive impact of recommended scenarios under unconstrained and constrained cases can be observed on revenue of premium and ordinary services, overall GC, and GC to captive and choice riders. Except for the revenue of ordinary service under constrained scenario, the magnitude of the improvement of all parameters were found substantially higher for the recommended scenario under unconstrained supply. This is also in line with the findings of Dandapat et al., (2017) in the context ordinary private buses in Kolkata city.

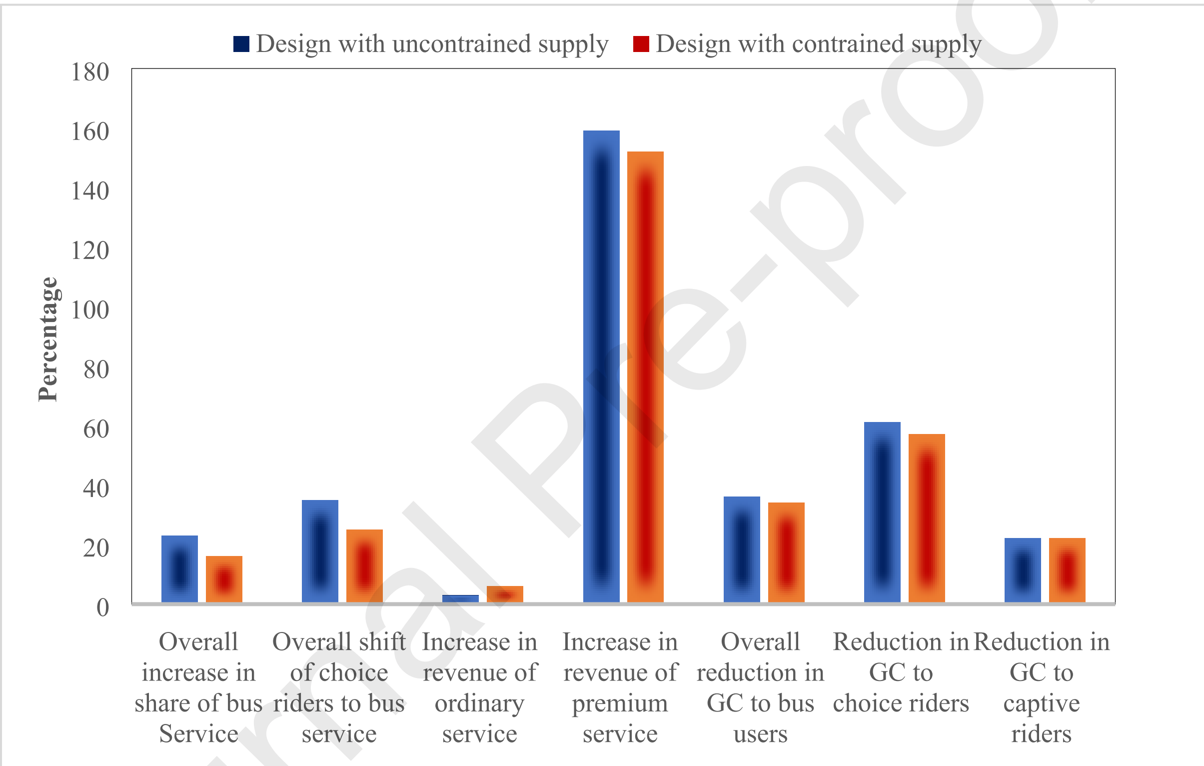


Figure 4. Impact of improvement on key parameters

6.6. Supply allocation chart for premium service

As long as additional premium buses are unavailable, the scenario recommended under constrained supply may be adopted by the practitioners. As per the availability of new premium buses, it is important to adopt the recommended scenario under unconstrained supply as it is found to give maximum benefit to both travelers and operator. The distribution of buses is a straight forward task using Table 9 only if the required additional number of buses can be acquired in single phase. However, owing to financial constraints, a complete transformation from constrained to unconstrained scenario is possible only in multiple phases based on the availability of fund to acquire additional buses. While acquiring additional buses in different phases, it is important to distribute them rationally among various routes by giving due consideration to the requirements of operators and the travelers. This further indicate that the distribution of buses among various routes must ensure operational viability and maximum reduction in GC to the travelers. A supply allocation chart (Table 12) is developed to aid practitioners for allocating the premium buses in different routes effectively.

Table 12. Supply allocation chart

Bus	**Route**	**Bus**	**Route**	**Bus**	**Route**	**Bus**	**Route**
1	R4A	20	R4B	39	R12DL	58	R12
2	R1	21	R4A	40	R6	59	R1
3	R4B	22	R9L	41	R5	60	R6
4	R4A	23	R12DL	42	R10	61	R5
5	R10	24	R9B	43	R9B	62	R10
6	R4B	25	R12DL	44	R4B	63	R9B
7	R4A	26	R10	45	R4A	64	R4B
8	R10	27	R9B	46	R9L	65	R4A
9	R4B	28	R4B	47	R12DL	66	R9L
10	R4A	29	R4A	48	R12	67	R12DL
11	R12DL	30	R9L	49	R1	68	R12
12	R10	31	R12DL	50	R6	69	R1
13	R4A	32	R6	51	R5	70	R5
14	R4B	33	R12DL	52	R9L	71	R10

15	R12DL	34	R10	53	R9B	72	R9B
16	R6	35	R9B	54	R4B	73	R4B
17	R5	36	R4B	55	R4A	74	R4A
18	R10	37	R4A	56	R9L	75	R9L
19	R9B	38	R9L	57	R12DL	76	R12DL

For this purpose, simulation was carried out by adding single bus in each study route. As the transformation begins from the constrained scenario, during simulation, all attributes (except headway and crowding) were constrained based on recommended scenario under constrained supply. The simulation outputs were recorded and the operational viability with the addition of single bus in each route was checked. After ensuring operational viability, the premium bus was finally allocated to that route which ensure maximum reduction in GC due to the addition of single premium bus. Following this procedure, a maximum reduction in GC was observed by assigning the first (additional) premium bus in Route 4A. Once a premium bus was assigned to a particular route, outputs such as waiting time, crowding level, GC, and number of bus available were updated in the database. The procedure was continued sequentially for the remaining 76 buses till the unconstrained scenario was achieved. The sequence of premium bus allocation as per the availability is summarized in Table 12. The table is expected to be useful for the policy makers and practitioners for allocating new premium buses in different routes judiciously.

7. Conclusions

A three-stage methodology for the design of urban bus service with segmentation was demonstrated incorporating the requirements of different user groups and service provider. The methodological application reveals that with additional supply of buses, the level of service of premium buses can be improved substantially to LOS A even with a marginal increment in fare. It is found that even with the existing fleet of premium buses, the level of service could be improved to LOS B by re-orienting the supply of buses among various routes. Such an improvement in premium service can enhance benefit to choice riders without putting any additional burden on the Government. On the other hand, analysis of ordinary service clearly indicate improper supply management as several routes are found oversupplied with ordinary buses, while a few are found undersupplied. This is resulting in high Generalized Cost to users and distorting the operational viability of ordinary service. The results further indicate that even with the present supply of buses, the ordinary service can be improved substantially for augmenting benefit to captive riders without burdening the Government in terms of additional subsidy. Lack of supply of buses is found to be a major bottleneck for the improvement of premium service. The deployment of new premium buses to the existing routes needs to be done judiciously in order to maximize the benefit to users. A supply allocation chart is developed to aid practitioners for allocating the premium buses in different routes effectively. The case specific findings are expected to be instrumental for the development of urban bus services in Kolkata city. However, the experience and approach presented here can be adopted in other cities for the design of bus service with segmentation considering the requirements of different user groups and service provider. The government may consider implementing a contract-based model for the provision of bus services, which can potentially improve efficiency, quality, and cost-effectiveness of urban transportation services. Further research works may be carried out in the future to explore the possibilities of such models.

References

1. Agarwal, A., Lämmel, G., & Nagel, K. (2018). Incorporating within link dynamics in an agent-based computationally faster and scalable queue model. Transportmetrica A: transport science, 14(5-6), 520-541.
2. Ahmad, S., and de Oliveira, J. A. P. (2016). Determinants of urban mobility in India: Lessons for promoting sustainable and inclusive urban transportation in developing countries. Transport Policy, 50, 106-114.
3. Ashalatha, R., Manju, V. S., and Zacharia, A. B. (2012). Mode choice behavior of commuters in Thiruvananthapuram City. Journal of Transportation Engineering, 139(5), 494-502.
4. Cheranchery, M. F., & Maitra, B. (2017). Priority areas of intervention for improving urban bus services: Experience in Kolkata, India. Transportation Research Record, 2634(1), 17-27.
5. Cheranchery, M. F., & Maitra, B. (2018). Investigating perception of captive and choice riders for formulating service standards of ordinary and premium buses in Indian cities. Transport Policy, 72, 89-96.
6. Cheranchery, M. F., & Maitra, B. (2019). Improving Ridership and Reducing Subsidy for Premium Bus Service in Kolkata Metro City. Journal of Transportation Engineering, Part A: Systems, 145(7), 04019030.
7. Cheranchery, M. F., & Maitra, B. (2021). Improving quality of ordinary bus service in Kolkata city: Integrating conflicting requirements of users and transit operator. Transport Policy, 111, 17-27.
8. Choudhary, B. K. (2019). Jawaharlal Nehru National Urban Renewal Mission (JNNURM). The Wiley Blackwell Encyclopedia of Urban and Regional Studies, 1-5.
9. CODATU (2016). The Accessibility We Need. Message from CODATU to HABITAT
10. Dandapat, S., and Maitra, B. (2015). An approach for identifying optimal service for rural bus routes. Case Studies on Transport Policy, 3(3), 287-294.
11. Dandapat, S., Cheranchery, M. F., & Maitra, B. (2017). Is fare increment desirable for ensuring operational viability of private buses?. Transport Policy, 59, 134-141.
12. Das, S., & Pandit, D. (2015). Determination of level-of-service scale values for quantitative bus transit service attributes based on user perception. Transportmetrica A: Transport Science, 11(1), 1-21.
13. Deng, T., & Nelson, J. D. (2011). Recent developments in bus rapid transit: a review of the literature. Transport Reviews, 31(1), 69-96.
14. Dey, T. (2012). Changing profile of state transport undertakings in mass transport services: A case of Kolkata city. Researchers World, 3(2), 45.
15. Elmore-Yalch, R. (1998). A handbook: Using market segmentation to increase transit ridership (Vol. 36). Transportation Research Board.
16. Gerbec, M., Samuel, R. O., and Kontić, D. (2015). Cost benefit analysis of three different urban bus drive systems using real driving data. Transportation Research part D: Transport and environment, 41, 433-444.
17. Howells, J., and Lowe, M. (2018). Innovation, market segmentation and entrepreneurship in services: The case of the hotel industry. In the Routledge Companion to the Geography of International Business (pp. 493-508). Routledge.
18. JNNURM (2005). Jawaharlal Nehru National Urban Renewal Mission Ministry of Urban Development, Government of India.

19. Jou, R. C., Chen, C. C., & Chen, Y. L. (2011). The effects of travellers' acceptance/satisfaction of unimplemented/implemented transportation demand management strategies on travel behaviour. Transportmetrica, 7(3), 201-228.
20. Kang, J. G., & Oh, H. U. (2016). Factors affecting vehicles' carbon emission in road networks. Transportmetrica A: Transport Science, 12(8), 736-750.
21. Kuriakose, P. N. (2013). A new direction in public transport in India with national urban transport policy 2006. Indian Journal of Transport Management, 37, 248-267.
22. Litman, T. (2015). Evaluating public transit benefits and costs. Victoria, BC, Canada: Victoria Transport Policy Institute.
23. Maitra, B., Dandapat, S., and Chintakayala, P. (2014). Differences between the perceptions of captive and choice riders toward bus service attributes and the need for segmentation of bus services in urban India. Journal of Urban Planning and Development, 141(2), 04014018.
24. Mittal, S., Dai, H., and Shukla, P. R. (2016). Low carbon urban transport scenarios for China and India: A comparative assessment. Transportation Research Part D: Transport and Environment, 44, 266-276.
25. Pai, M., and Hidalgo, D. (2009). Indian bus rapid transit systems funded by the Jawaharlal Nehru national urban renewal mission. Transportation Research Record, 2114(1), 10-18.
26. Pucher, J., Korattyswaropam, N., Mittal, N., and Ittyerah, N. (2005). Urban transport crisis in India. Transport Policy, 12(3), 185-198.
27. Rastogi, A., Rajan, A. V., & Mukherjee, M. (2018). A review of vehicular pollution and control measures in India. In Advances in Health and Environment Safety (pp. 237-245). Springer, Singapore.
28. Sen, S. (2020). 'Green'-ing Kolkata: Creating a Sustainable City–An Overview. ing Kolkata: Creating a Sustainable City–An Overview (July 21, 2020). International Journal of Research and Analytical ReviewsMay, 7(2).
29. Smith, R. M., Pathak, P. A., & Agrawal, G. (2019). India's "smart" cities mission: A preliminary examination into India's newest urban development policy. Journal of Urban Affairs, 41(4), 518-534.
30. Tiwari, G., and Jain, D. (2010). Bus rapid transit projects in Indian cities: a status report. Built Environment, 36(3), 353-362.
31. Verma, M. (2015). Growing car ownership and dependence in India and its policy implications. Case Studies on Transport Policy, 3(3), 304-310.
32. Wirasinghe, S. C., Kattan, L., Rahman, M. M., Hubbell, J., Thilakaratne, R., & Anowar, S. (2013). Bus rapid transit–a review. International Journal of Urban Sciences, 17(1), 1-31.

Highlights

- A three-stage approach is demonstrated for segmentation of urban bus services
- Urban bus service design is carried out for constrained and unconstrained cases
- Lack of supply is found to be a major bottleneck for premium service
- A supply allocation chart is developed to aid practitioners for allocating the premium buses

Author Contribution Statement

Munavar Fairooz Cheranchery: Conceptualization, Methodology, Software, Data curation, Writing- Original draft preparation, Visualization, Investigation.

Bhargab Maitra*:* Supervision, Software, Validation, Writing- Reviewing and Editing,