Methodology to Determine Level of Service for Bus Transit in a Developing Country Like India

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Abstract

Service quality assessment has received increased attention amongst transport planners in recent years due to the increased importance to improve user satisfaction and patronage for public transport services. While service quality assessment reflects users' perception and acceptance of existing service quality, researchers have identified 'Level of Service' as an efficient tool to measure service quality. Researchers have established that user perception of service quality varies between individuals based on their travel needs and also between geographic regions due to difference in socio-economic conditions. While 'user perception' has been recognized as an essential component of Level of service (LOS), the LOS thresholds for public transportation that have been established by existing research are not based on user perception but on expert judgment. The present research develops an overall framework to determine LOS thresholds from user perception and also provide a measure to determine the maximum number of users from different user groups that will get satisfied at these thresholds. The framework also analyses the key service area gaps that identified by different user groups that are otherwise ignored when only the total user population is considered.

1. Introduction

Service quality assessment has received increased attention amongst transport planners in recent years due to the increased importance to improve user satisfaction and patronage for public transport services. While service quality assessment reflects users' perception and acceptance of existing service quality, researchers have identified 'Level of Service' as an efficient tool to measure service quality. The concept of level of service was first introduced by the Highway capacity Manual (HCM) in 1965 to assess the performance of highways which was later adopted for public transportation and defined by the Transit Capacity & Quality of Service Manual (TCQSM) 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" [13]. The definition clearly highlights the importance of users'/ passengers' perception while determining level of service, however, the level of service thresholds that have been established so far by the TCQSM for public transportation are not based on user perception but rather on expert judgment. The importance of 'user perception' in assessment of service quality has been highlighted by a number of researchers. Wang & Shieh [20] discussed that service quality is "an antecedent of customer satisfaction" which in turn is based on 'user perception'. According to Berry, Zeithaml, & Parasuraman 1990 [11], user perception is essential as ''customers are the sole judge of service quality'' and it is the customers who suffer the consequences of poor service quality. On the other hand Parasuraman, Zeithaml, & Berry [15] defined 'assessed service quality' as the difference between customer's expectation and perception of services delivered. Although the latest edition of the Highway Capacity Manual [19] has incorporated user perception while determining level of service for interrupted and uninterrupted transport facilities, the LOS criteria used in the manual still remain defined by experts. Moreover, researchers have questioned the applicability and validity of these LOS thresholds for all geographic or economic regions. Roess et al. [17] opined whether LOS C would mean the same in Chicago and Peoria and whether there should be separate LOS standards or thresholds for urban, suburban and rural areas. Washburn, Ramlackhan, and McLeod [21] argued that, "motorist expectations and perceived quality of service on rural freeways are distinctly different from those on urban freeways". The argument is just because Zeithaml's research in 1993 established that users' expectation on service quality is influenced by their personal needs, their past experience from service providers, their assessment of what is possible to be delivered and various situational factors

[22]. Evidently, public transport users in developed and developing countries will have different perceptions of service quality for the same service level because of their difference in socioeconomic conditions and the difference in service delivery environments between the two regions. Developing countries like India have a mixed socio-economic composition of urban riders which differs from those in developed countries. Existing research has established that user priorities for services and users' 'zone of tolerance' (ZOT) for different services varies between individuals based on the local urban environment, i.e, land use and traffic system, characteristics of location and level of accessibility etc; socio-economic characteristics of users, the demographic profile of the region, user habits and travel needs [5, 22]. The 'zone of tolerance' is a range of service level defined by the users' 'desired service' and 'minimum acceptable service' or 'adequate service' [22]. The 'desired service' is the level of service representing a blend of what customers believe 'can be' and 'should be' provided while 'minimum acceptable service' is the level of service customers are willing to accept [22]. Bus transit acts as a social welfare service in developing countries and majority of the urban travelers are dependent on bus transit. Therefore, from the point of social equity, it is essential to meet the bus transit service requirements of different user groups and achieve the maximum satisfaction level amongst all user groups. Moreover a comprehensive methodology is required that will determine the LOS thresholds for bus transit based on user perception, that can be universally adopted and applied in any economic and geographic region. The current research is focused towards developing a methodology to determine LOS thresholds for bus transit. The objectives of the research are three-fold: 1) to develop a universal methodology to determine LOS thresholds for bus transit service parameters based on 'user perception' that can be adopted for both developing and developed countries, 2) to identify the difference in user tolerance between different user groups and design a method to determine the service levels that will satisfy maximum number of users covering all user groups, and 3) to establish a method to determine the critical service area gaps in bus transit service in a given city. Urban transport planners and transit service providers will primarily benefit from this research as the research output will provide them a guideline to assess users' perception of existing transit quality, identify the key service areas that need improvement and determine the key service levels that will satisfy maximum number of users although the final service provision depends on the financial and infrastructural viability. The methodology evolved in this research has been developed using user perception data from bus transit users in the city of Kolkata, India.

2. Broad Research Framework

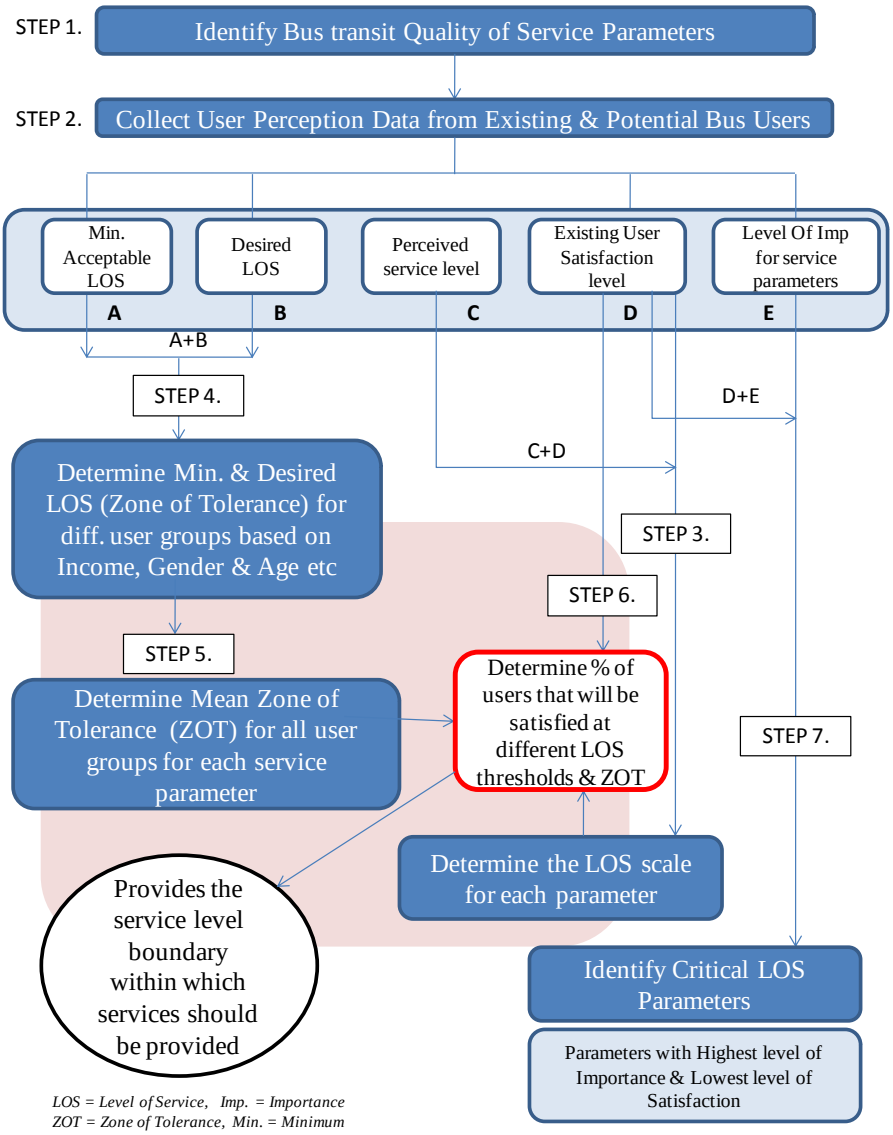

Fig. 1. Broad Research Framework

Fig. 1 shows that broad research framework 1) to determine LOS thresholds for bus transit service parameters from user perception, 2) to determine the overall zone of tolerance for different user groups, 3) to establish the maximum number of users that will get satisfied at different ser-

vice levels, and 4) to identify the critical service area gaps in existing bus transit facility. The first step in this research was to identify the bus transit service parameters that are relevant for service quality assessment for the city of Kolkata. The second step was to obtain user perception data from existing bus users and potential bus users in Kolkata on their A) minimum acceptable level of service (LOS) for different bus transit service parameters, B) desired LOS for each service parameter, C) perceived level of service from existing services, D) perceived level of importance for different bus transit service parameters, E) perceived level of satisfaction on existing service level for each service parameter. The third step was to determine the LOS thresholds for each bus transit service parameter from user satisfaction data on perceived service levels using the method of successive interval scaling (as explained in section 2.3). The fourth step in this research was to determine the mean zone of tolerance for each service parameter for each bus user group based on income, age, gender etc. followed by calculating the overall zone of tolerance, for each service parameter, covering all user groups (Step 5). The next step was to determine the percentage of all users that will get satisfied at LOS thresholds and at the overall ZOT for each service parameter. The final step in this research was to identify the critical bus transit service areas that need immediate improvement in the city of Kolkata. The results indicate the service parameters that have been prioritized not only by the total user population but also by different users and potential user groups. The method has been explained in detail in the following sections with results for bus transit services in Kolkata.

2.1. Quality-of-Service (QOS) parameters for bus transit for Kolkata

The relative importance of different bus transit quality-of-service (QOS) parameters, that influence users' perception of service quality, differ for different urban environments [1, 6, 7, 18, 22]. Thus it is important to identify the service parameters that are relevant for bus transit service quality assessment for any given city. In the current research, an initial set of bus transit service parameters were identified from literature review. This was revalidated for the Indian context through an expert opinion survey conducted amongst academicians and transport professionals across India. The experts identified a number of parameters, in addition to those identified from literature review. These additional parameters were found to be relevant for the present socio-economic condition of Indian urban environments. The method for identification of bus transit QOS parameters for India has been explained in detail in Das & Pandit [6]. This list of bus transit

QOS parameters were further revalidated for the city of Kolkata through an on board pilot survey conducted on 216 bus users as explained in Das & Pandit [7]. The final list included 22 QOS parameters including nine 'quantitative' and 13 'qualitative' parameters as shown in Table 1. Quantitative parameters are those than can be described by a quantitative service level while qualitative parameters are those whose service levels cannot be quantified but can only be perceived by users as 'good' or 'bad'.

Table 1 List of Bus Transit QOS Parameters identified for Kolkata, India

Quantitative QOS Parameters	Qualitative QOS Parameters
1. Delay in total journey time, 2. Bus stop nearness, 3. Waiting time, 4. Service hours, 5. Crowding level, 6. Seat availability, 7. Number of mode interchange, 8. On-time performance, 9. Boarding & alighting time	1. Bus design & comfort, 2. Bus stop shelter design, 3. Ticket purchasing system, 4. Bus operating & driving practices, 5. Bus driver & conductor behaviour, 6. Safety from road accidents, 7. Safety from thefts on board, 8. Safety for women on board, 9. Safety at bus stops at night, 10. Bus maintenance, 11. Cleanliness, 12. Bus stop shelter maintenance 13. Availability of information

2.2. User Perception data from bus users in Kolkata

In this step, a stated response survey was conducted on board on bus users in Kolkata, along 25 bus routes, for all working days in a week and covering peak and non peak periods. A total of 919 completed responses were obtained. The user perception data collected from survey respondents included 1) minimum acceptable level of service (LOS) for different bus transit service parameters, 2) desired LOS for each service parameter, 3) perceived level of service from existing services, 4) perceived level of importance for different bus transit service parameters, 5) perceived level of satisfaction on existing service level for each service parameter. The perceived level of satisfaction was measured on a scale of 1 to 5 (1= very good to 5= very poor) while the perceived level of importance was meas-

ured on a scale of 1 to 3 (1=very important to 3=not important). The reasons for adopting two different scales of measurement for level of importance and level of satisfaction are explained in Das & Pandit [8]. Survey respondents were also asked to state their socio-economic and demographic profile, their boarding and alighting stoppage, regularity of travel by bus, private vehicle ownership status and type of vehicle owned. In addition to this, surveyors were asked to note the time of survey, existing bus route number and existing bus type. The data so obtained were further classified into different user groups based on income, age, gender, dependency on bus (captive or choice riders), bus type, peak or non peak hour ridership and physical handicap as summarized in Table 2. Five income groups were identified for Indian urban areas, based on literature review and analysis of pilot survey results [7, 8]. Captive riders are the "transit-dependent population" [2] and were identified from the survey respondents as those riders who own no personal vehicle and are regular bus users whereas, choice riders were identified as those who travel by bus although irregularly and also own a personal vehicle. The survey questionnaire presented qualitative service parameters like 'bus design' with a number of sub-parameters. Respondents were asked to rate each sub-parameters as 'absolutely essential' and 'not so essential parameter'. The service levels against each sub-parameters were exemplified from five different bus types presently plying within the city of Kolkata: 1) Government Bus (operated by Government Organizations), 2) Old Private Bus (old model of bus operated by private players), 3) New JNNURM bus (new model of private bus designed under JNNURM scheme, 4) Mini bus (operated by private player), 5) AC bus (new bus model under JNNURM scheme but with air condition). Respondents were asked to state their level of satisfaction of a 5-point scale against each service parameter for each of the bus types mentioned above.

Table 2 Share of survey respondents in different user groups

Total sample of users	919 nos.
	% share of total users
*Captive riders	70
**Choice riders	30
Income Groups	**% share of total users**
< Rs 4000 per month	12
Rs 4000-8000 per month	21
Rs 8000-15000 per month	92
Rs 15000-30000 per month	58
> Rs 30000 per month	17
Gender	**% share of total users**
Male	72
Female	28
Age	**% share of total users**
< 30 years	31
31-55 years	65
> 55 years	4
Physically Handicapped population	0.5
Time of the Day	**Total no. of respondents**
Morning Peak hour	249
Evening Peak hour	73
Non Peak hour	602

2.3. LOS Thresholds from User Perception for total user population

2.3.1. LOS Thresholds for Quantitative Service parameters

The current research adopted the 'Law of Successive Interval Scaling', developed by Thurstone in 1952 [3] and used by Correia et al [4] to establish LOS thresholds for passenger airport terminals from user satisfaction data. The major advantage of the 'law of successive interval scaling' is that it converts ordered categorical data into an interval scale. The law of successive intervals is based on the idea of a scale continuum that can be di-

vided into a number of category boundaries. Every survey respondent has a unique perception of scale value for a given service attribute that can be placed between two category boundaries. Likewise there can be k number of categories of observation. The lower boundary of the first category is minus infinity, and the upper boundary of the last category is plus infinity. With the use of a mean scale value or mean LOS rating and a discriminal dispersion for the mean scale value, the upper boundary for each category is determined. The method assumes a homogeneous sample and a normal distribution of responses to obtain the discrimnal dispersions. Finally, by assuming a causal relationship between user perception of LOS rating and the actual physical measure, the LOS scale boundaries are determined. The method has been explained in detail in Das & Pandit [9]. The results of the LOS thresholds that have been developed for the quantitative bus transit service parameters for the city of Kolkata, using 'law of successive interval scaling' have been show in Table 3 to Table 10.

Table 3. LOS Thresholds for waiting time

LOS Category	LOS Thresholds (minutes)
A	= 0.0
B	0.1-4.0
C	4.1-20.0
D	20.1-35.0
E	>35.0

Table 4. LOS Thresholds for Service Hours

LOS Category	LOS Thresholds (hours)
A	>21
B	21-17
C	16-15
D	14-12
E	<12

Table 5. LOS Thresholds for Bus stop nearness

LOS Category	LOS Thresholds (meters)
A	<70
B	71-200
C	201-700
D	701 -1500
E	>1500

Table 6. LOS Thresholds for Crowding level

LOS Category	LOS Thresholds (passengers/seat)
A	<=0.3
B	0.31-0.90
C	0.91-1.50
D	1.51-2.30
E	>2.30

Table 7. LOS Thresholds for Seat

Table 8. LOS Thresholds (No. of

Availability	
LOS Category	LOS Thresholds (%)
A	100.0
B	99.9-70.0
C	69.9-50.0
D	49.9-10.0
E	<10.0

transfers)	
LOS Category	LOS Thresholds
A	0
B	1
C	2
D	3-4
E	>4

Table 9. LOS Tresholds for on-time Performance

LOS Category	LOS Thresholds (%)
A	>=90.0
B	89.9-80.0
C	79.9-50.0
D	49.9-20.0
E	<20.0

Table 10. LOS Thresholds for delay

LOS Category	LOS Thresholds (minutes)
A	0.0
B	0.1-7.0
C	6.9-17.0
D	16.9-50.0
E	>50.0

Table 3 and Table 10 show that LOS A is zero units for 'waiting time' and 'delay in total journey time'. This means that a waiting time of <4 minutes, or a delay of <7 minutes can be perceived as LOS A or LOS B by bus users in Kolkata. This overlap in threshold boundaries has occurred due to the inability of bus users in Kolkata to distinguish between 'very good' or 'good' level of service for service levels <4 minutes of waiting and <7 minutes of delay.

2.3.2. LOS Thresholds for Qualitative Service parameters

Limited research exists today that quantifies LOS thresholds for qualitative service parameters except in the domain of pedestrian facility wherein a weighted average score index has been used as LOS criteria and grouped into regular intervals defining LOS scales [16]. The present research adopts the weighted average scoring technique and combines it with the 'law of successive interval scaling' as explained in Correia et al. [4] to develop LOS thresholds for qualitative bus transit parameters like 'bus design'. 'Bus Design', for example, had 18 sub-parameters. The average weighted score was calculated for each sub-parameter for each of the five bus types as shown below (see Eq. 1.1).

$WS_{jk} = [\sum(I_{ji} \times S_{jik})^{n}_{i=1}] / n$……..……...(1.1)

Where,

WS_{jk} = Average weighted score for sub parameter j for bus type k

I_{ji} = Level of importance given to sub-parameter j by respondent i

S_{jik} = Level of satisfaction given to sub-parameter j by respondent i for bus type k

n= total number of respondents

The sum total of the average weighted scores for all sub-parameters (see Eq. 1.2) gave the average weighted score for each bus type as shown in Table 11.

$WS_k = \sum (WS_{jk})^{m}_{j=1}$……(1.2)

Where,

WS_k = Total weighted score for bus type k

m = total number of sub parameters

Table 11 shows that the average weighted scores for sub-parameters 1 to 9 are same across all bus types. This is because these elements are not present in any of the bus categories and hence have been given the same level of satisfaction by the respondents for all bus types. Finally the law of successive interval scaling was used to determine the LOS thresholds for 'bus design' as shown in Table 12.

Table 11 Total Weighted Score for Different Bus Types

Sl. no	Bus design Sub-parameters	New JNNURM Bus	AC bus	Government Bus	Old Pvt. Bus	Mini bus
1	Separate entry & exit doors	1.38	1.38	1.38	1.38	1.38
2	Wheelchair entry	1.49	1.49	1.49	1.49	1.49
3	Availability of racks	1.46	1.46	1.46	1.46	1.46
4	Availability of magazines/ news-papers	1.15	1.15	1.15	1.15	1.15
5	Availability of music system	1.15	1.15	1.15	1.15	1.15
6	Availability of priority seats for elders/ disabled	1.65	1.65	1.65	1.65	1.65
7	Seat segregation for men & women	1.57	1.57	1.57	1.57	1.57
8	Bus stop arrival announcement fa-cility	1.33	1.33	1.33	1.33	1.33
9	Availability of CCTV surveil-lance	1.39	1.39	1.39	1.39	1.39
10	Comfortable seat design and space	6.69	7.41	4.82	3.60	3.65
11	Appropriate seat-ing arrangement & leg-space	6.70	7.16	4.74	3.69	3.49
12	Comfortable Standing-space layout	6.38	6.77	4.69	3.73	3.19
13	Appropriate de-sign of handrails	5.90	6.47	4.34	3.47	3.37
14	Low floor height of bus	5.89	6.36	4.29	3.58	2.68
15	Appropriate tech-nology to reduce jerks	6.64	7.40	3.99	2.89	3.02
16	Appropriate size & design of win-dows	6.78	7.32	4.68	3.23	4.13
17	Availability of sunscreen / cur-tain for windows	6.78	7.32	4.68	3.23	4.13
18	Overall ventila-tion mechanism inside bus	6.78	7.32	4.68	3.23	4.13

Table 12 LOS thresholds for Bus design

LOS Grade	Weighted Score
A	>75.1
B	63.0-75.1
C	49.3-62.9
D	38.3-49.2
E	<38.2

Table 12 shows that any weighted score above 75.1 is considered as LOS A and a range of score between 62.9 and 75.1 is LOS B. hence, according to this scale, the New JNNURM bus and the AC bus is considered as LOS B and LOS A respectively by users in Kolkata.

2.4. Overall Zone of Tolerance (O_{ZOT}) for different user groups

2.4.1. Quantitative Service parameters

Researchers have established that user perception of service quality and the 'zone of tolerance' for different service levels vary between individuals [5, 7, 22]. In order to ensure social equity amongst all user groups, it is important to meet the service requirements of different user groups. In the present research the zone of tolerance for each user group was analysed and compared for different service parameters. After establishing the zones of tolerance for different user groups, the overall zone of tolerance (O_{ZOT}) was calculated as an average of the zones of tolerance of all user groups considered in the research as shown in Table 13 for waiting time. Table 13 shows that lowest 'desired service' for waiting time is for the handicapped users (6 minutes) while the lowest 'minimum acceptable service' for waiting time is for the income group >Rs 30000 per month (12.8 minutes). Therefore if one was to consider a zone of tolerance from 6 to 12.8 minutes of waiting time, almost all user groups will be satisfied. However, this method could lead to over weightage to a particular user group. Moreover, any bias caused by over representation of any particular user group in the survey cannot be eliminated in this method. Hence, it was found judicious to consider an average zone of tolerance covering all user groups, i.e, Overall Zone of Tolerance, which not only eliminates the bias but also provides a more feasible range of service levels for the service providers.

The Overall Zones of Tolerance (O_{ZOT}) for the other bus transit service attributes for Kolkata have been summarized in Table 14.

Table 13 Mean Zone of Tolerance for different user groups and Overall Zone of Tolerance (O_{ZOT}) for Waiting time in Kolkata

User Group	Min Acceptable LOS (minutes)	Desirable LOS (minutes)
Dependency on public transport		
Captive	18	8
Choice	15	8
Income		
<4k	17	9
4-8k	19	8
8-15k	17	8
15-30k	17	10
>30k	13	8
Gender		
Male	17	8
Female	17	8
Age		
<30yrs	17	8
31-55yrs	17	8
>55yrs	15	8
Physically handicapped	20	6
Time of the Day		
Morning Peak	15	8
Non Peak	18	8
Evening Peak	18	10
Overall Zone of Tolerance (O_{ZOT})	17	8

Table 14 Overall Zone of Tolerance (O_{ZOT}) for different bus transit service attributes in Kolkata

Service Attribute	Overall Min Acceptable LOS	Overall Desirable LOS
Bus stop nearness	461 meters	237 meters
Delay in total journey time	19 minutes	4 minutes
Crowding level	1.3 passengers/seat	0.8 passengers/seat
Seat availability	60 %	90%
On-time performance	60%	90%
Number of mode transfers	2	0
Service hours	15 hours	19 hours
Boarding-alighting time	1.7 minutes	2.5 minutes

2.4.2. Qualitative Service parameters

Unlike quantitative service parameters, the minimum acceptable and desired service level for qualitative service parameters cannot be quantified. However, the minimum acceptable service for qualitative service parameters can be defined as a group of sub-parameters that are considered an absolute necessity by users. For example, in the current research, from amongst a list of 18 sub-parameters for 'bus design', users were asked to choose those parameters that they considered as 'absolutely essential'. Table 15 summarizes the sub-parameters for 'bus design' that have been selected maximum number of times as minimum acceptable service by different user groups. This list of parameters represents the overall minimum acceptable service for 'bus design' covering all user groups. The detailed method for selection of minimum acceptable service for qualitative parameters has been explained in Das & Pandit [10].

Table 15 Overall Minimum Acceptable Service for Bus Design covering all user groups

Sl. No.	Sub-Parameters for Bus design
1	Availability of priority seats for elders/ disabled
2	Seat segregation for men & women
3	Comfortable seat design and space
4	Appropriate seating arrangement & leg-space
5	Comfortable Standing-space layout
6	Appropriate technology to reduce jerks
7	Appropriate size & design of windows
8	Availability of sunscreen / curtain for windows

2.5. Percentage of Users satisfied at different service levels

It is in the interest of transit service providers and transport planners to determine the service levels that will satisfy maximum number of users and yet maintain social equity. While the Level-of-Service thresholds represent the perception of all users about service quality, the overall zone of tolerance for each service parameter ensures that the service requirements of all user groups are met. After establishing the LOS thresholds and the overall zone of tolerance for each service parameter, the current research used the user satisfaction data to determine the percentage of users that will get satisfied at each LOS threshold and within the overall zone of tolerance. For example, Figure 2 shows that 67% of users will get satisfied at minimum acceptable service, i.e, 17 minutes of waiting time while 81% of users will get satisfied at desired service, i.e, 8 minutes of waiting time. If the transit service providers wish to increase the user satisfaction, then they need provide service levels better than the desired service level, i.e waiting time should be less than 8 minutes. Moreover, it can be seen from Fig. 2 that the overall ZOT lies within the range of LOS C, i.e, 'average' in service quality from user perception. This means that in order to improve user perception of service quality from LOS C to LOS B/A, waiting time should be less than 4 minutes which will also increase the percentage of users satisfied (>88%). The percentage of users satisfied at different service levels for the other quantitative bus transit service attributes for Kolkata are summarized in Appendix A.

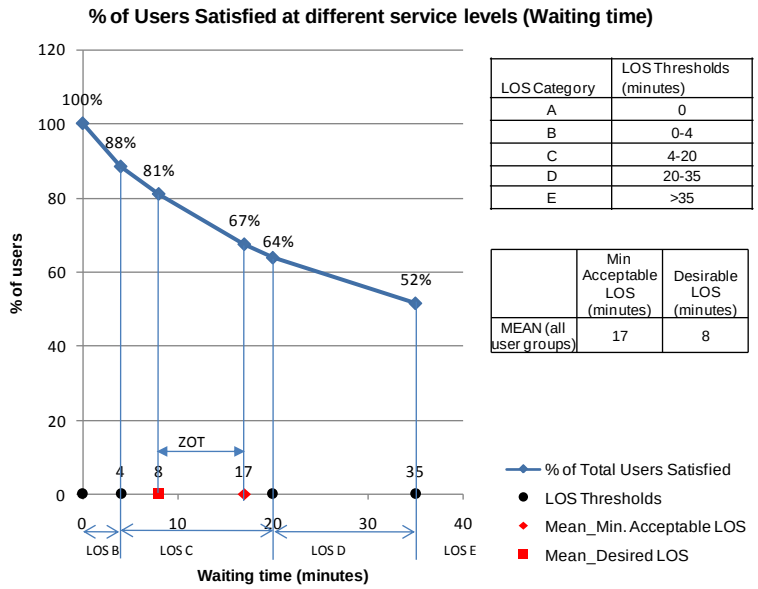

Fig 2. Percentage of users satisfied at different service levels (waiting time)

Fig. 3 shows the percentage of users satisfied at different service levels represented by the weighted average scores for different sub-parameters for bus design.

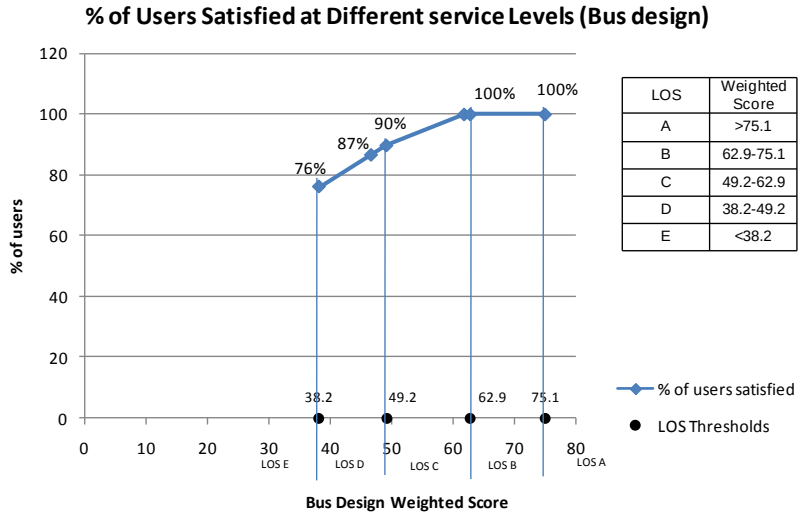

Fig. 3 Percentage of users satisfied at different service levels (bus design)

2.6. Determination of Critical Parameters

While it is important for transit service providers and transport planners to determine what service levels should be provided that will satisfy maximum number of users, it is also important to diagnose the critical service areas within the existing system that need immediate improvement. Researchers believe that users' priority for different services differ between different user groups based on their travel needs and expectations. Hence, it is important to analyse the key service requirements of different user groups and their perception of service area gaps in the existing system. The current research adopted an importance-satisfaction analysis tool to identify the key service area gaps that need to be addressed for improving transit performance [12, 14]. The advantage of this method is that, it not only identifies the service parameters that influence users' overall perception of service quality but, also 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. The method requires the plotting of users' stated level of importance against their stated level of satisfaction as shown in Table 16.

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Table 16 Importance-Satisfaction Chart/ Index

<table>
<tr><td colspan="3" rowspan="3"></td><td colspan="3">IMPORTANCE</td></tr>
<tr><td>Very Imp.</td><td>Moderately Imp.</td><td>Not Imp.</td></tr>
<tr><td>1</td><td>2</td><td>3</td></tr>
<tr><td rowspan="5">SATISFACTION</td><td>Very Good</td><td>1</td><td rowspan="2">Factors that will help retain loyalty</td><td rowspan="2">Need to be maintained</td><td rowspan="2">Exceeding expectations</td></tr>
<tr><td>Good</td><td>2</td></tr>
<tr><td>Average</td><td>3</td><td>Semi critical parameters: Should be improved for higher perceived value</td><td>Do have significant effect on users' perception</td><td>Factors do not influence perceived value</td></tr>
<tr><td>Poor</td><td>4</td><td rowspan="2">Critical parameters: Needs urgent improvement</td><td rowspan="2">Semi critical parameters : Should be improved for higher perceived value</td><td rowspan="2">Less important from service delivery point of view</td></tr>
<tr><td>Very Poor</td><td></td></tr>
</table>

Table 17 summarizes the critical and semi-critical service parameters that have been identified by different bus user groups and potential user groups

in Kolkata. The results show that while the total user population identified a few parameters as critical and semi-critical parameters, a number of parameter have been found both critical and semi-critical by different user groups in addition to those identified for the total user population. This clearly implies that different user groups prioritize different service parameters that affect their assessment of overall service quality.

3. Conclusion

The current research presents an overall methodology to determine LOS thresholds for bus transit service parameters from user perception that can be adopted and applied to any given city, thus accommodating the difference in user perception of service quality between different economic and geographic regions. The results clearly indicate that user perception of service quality and user zone of tolerance differ between different user groups. Hence, from the point of view of social equity it is important to consider the service requirements of different user groups while designing bus transit services. This research provides a guideline to determine the critical services that need improvement considering all user groups and also provides a method to determine the percentage of users that will get satisfied at different service levels, thereby assisting transport planners and service providers to design services that will satisfy maximum number of users amongst all user groups. Moreover, this research applies the 'law of successive interval scaling' along with a weighted score technique to define LOS thresholds for qualitative bus transit service. However, this research is limited to developing LOS thresholds for individual service parameters. Future research can be directed towards developing a methodology to determine an overall LOS scale for bus transit services from user perception.

Table 17 Critical and semi-critical parameters for different user groups in Kolkata

	Critical Parameters	**Semi Critical Parameters**
Total Users Population	• Boarding-alighting time • Safety from thefts on-board • Cleanliness	• Bus service hours • Bus stop nearness • On-time performance • Waiting time • Seat Availability • Crowding level • On-board safety from road accidents • Safety for women on board • Bus maintenance • Bus stop shelter maintenance
User Groups	**Parameters found Critical in addition to those for Total User Population**	**Parameters found Semi-Critical in addition to those for Total User Population**
Captive Riders	• Bus stop shelter maintenance	
Choice riders		• Total journey time
Income Groups		
<Rs 4000 per month	• Safety for women on board • Driving practices	• Safety & security at bus stops at night • Total journey time
Rs 4000-8000 per month	• On-time performance • Total journey time • Bus stop shelter maintenance	• Safety & security at bus stops at night
Rs 8000-15000 per month	• Bus stop shelter maintenance	
Rs 15000-30000 per month		• Safety & security at bus stops at night • Total journey time
>Rs 30000 per month	• Safety for women on board	• Safety & security at bus stops at night • Total journey time • Driving practices

Age Groups		
<30 years	• Bus stop shelter maintenance	• Total journey time • Safety & security at bus stops at night
31-55 years		
>55 years	• On-time performance	• Total journey time • Driving practices
Gender		
Male		
Female	• Bus stop shelter maintenance	
Handicapped population	• Crowding level • Safety & security at bus stops at night • Driving practices • Bus maintenance	• Total journey time • Bus driver behaviour • Bus stop shelter maintenance
Bus types		
State Bus	• Bus stop shelter maintenance	
Old Private Bus		• Bus design • Safety & security at bus stops at night
Mini Bus	• Bus stop shelter maintenance	• Total journey time • Bus design • Safety & security at bus stops at night
New JNNURM Bus		• Total journey time
AC Bus	• Waiting time • Seat Availability	
Surface Transport Mini	• Crowding level	• Total journey time

Bus	• safety for women on board • Bus stop shelter maintenance • Bus maintenance	• Bus stop shelter design • Safety & security at bus stops at night
Time of the Day		
Morning Peak	• Crowding level • Total Journey time • Bus maintenance • Bus stop maintenance	
Non Peak		
Evening Peak		• Total Journey time • Security at night at bus stops
Non bus users	• On-time performance • Waiting time • Seat Availability • Crowding level	• Total journey time

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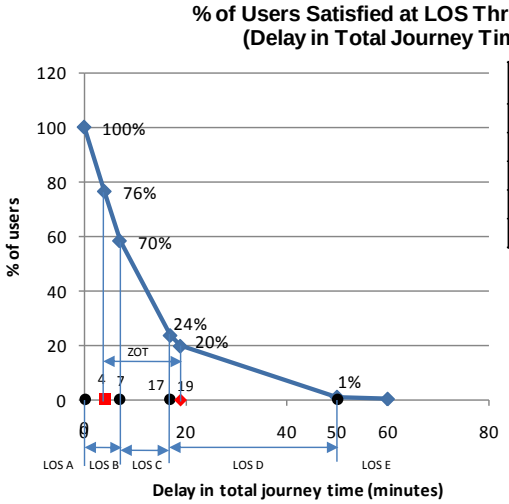
Appendix A – Percentage of users satisfied at different service levels for different quantitative service attributes in Kolkata

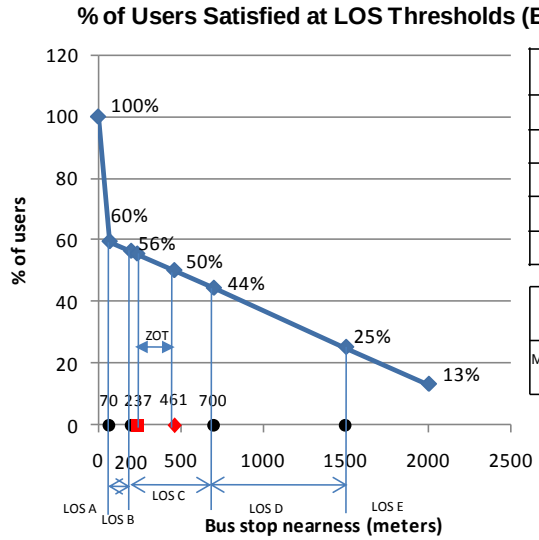


LOS Category	LOS Thresholds (minutes)
A	0
B	0-7
C	7-17
D	17-50
E	>50

	Min Acceptable LOS (minutes)	Desirable LOS (minutes)
MEAN (all user groups)	19	4

% of Total Users Satisfied
Mean_Min. Acceptable LOS
Mean_Desired LOS

Fig. A.1 Percentage of users satisfied at different service levels (delay in total journey time)

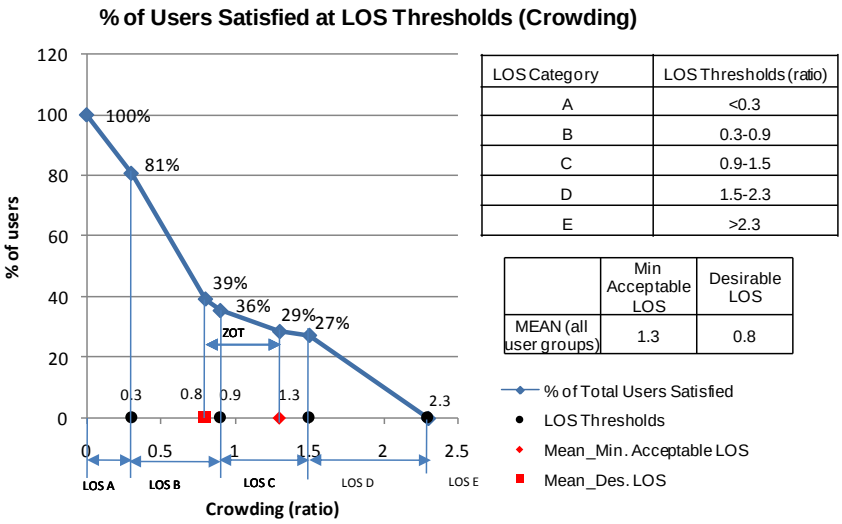


LOS Category	LOS Thresholds (meters)
A	<70
B	70-200
C	200-700
D	700 -1500
E	>1500

	Min Acceptable LOS (meters)	Desirable LOS (meters)
MEAN (all user groups)	463	235

% of Total users satisfied
LOS Thresholds
Mean_Min. Acceptable LOS
Mean_Desired LOS

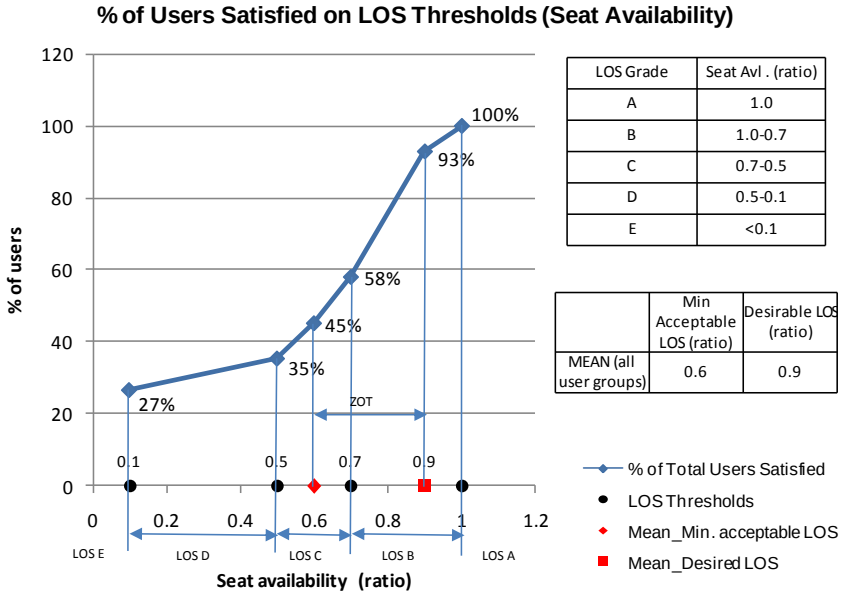
Fig. A.2 Percentage of users satisfied at different service levels (bus stop nearness)



LOS Category	LOS Thresholds (ratio)
A	<0.3
B	0.3-0.9
C	0.9-1.5
D	1.5-2.3
E	>2.3

	Min Acceptable LOS	Desirable LOS
MEAN (all user groups)	1.3	0.8

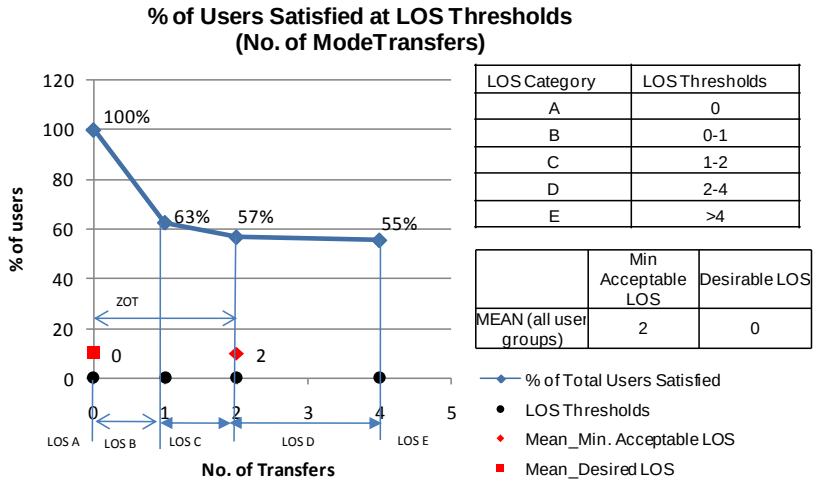
Fig. A.3 Percentage of users satisfied at different service levels of crowding level described as number of passengers per seat



LOS Grade	Seat Avl . (ratio)
A	1.0
B	1.0-0.7
C	0.7-0.5
D	0.5-0.1
E	<0.1

	Min Acceptable LOS (ratio)	Desirable LOS (ratio)
MEAN (all user groups)	0.6	0.9

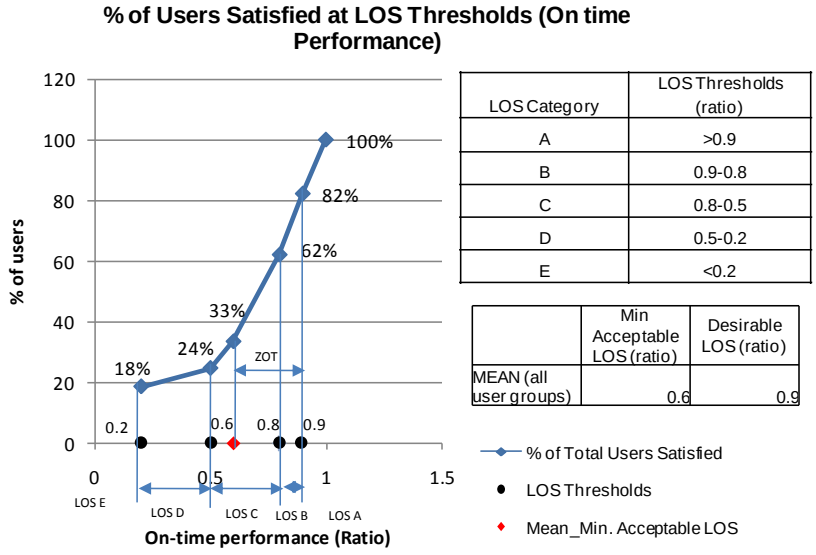
Fig. A.4 Percentage of users satisfied at different service levels (seat availability)



LOS Category	LOS Thresholds
A	0
B	0-1
C	1-2
D	2-4
E	>4

	Min Acceptable LOS	Desirable LOS
MEAN (all user groups)	2	0

Fig. A.5 Percentage of users satisfied at different service levels (Number of mode transfers)



LOS Category	LOS Thresholds (ratio)
A	>0.9
B	0.9-0.8
C	0.8-0.5
D	0.5-0.2
E	<0.2

	Min Acceptable LOS (ratio)	Desirable LOS (ratio)
MEAN (all user groups)	0.6	0.9

Fig. A.6 Percentage of users satisfied at different service levels (on-time performance)

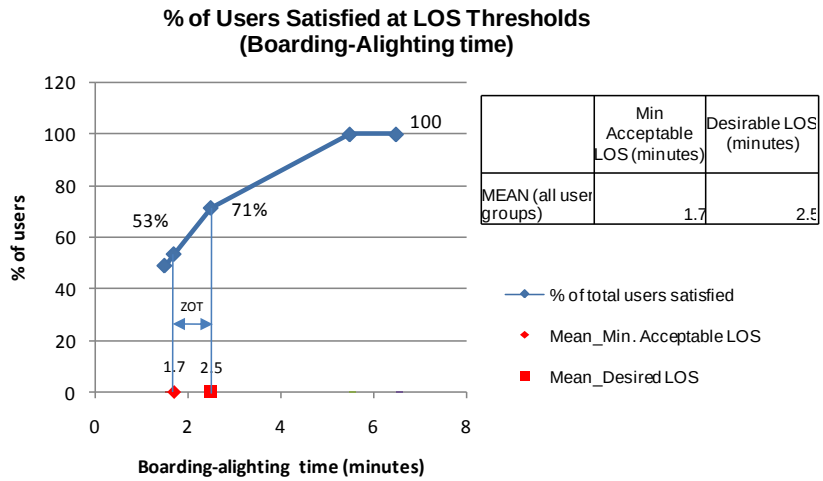


Fig. A.7 Percentage of users satisfied at different service levels (boarding-alighting time)

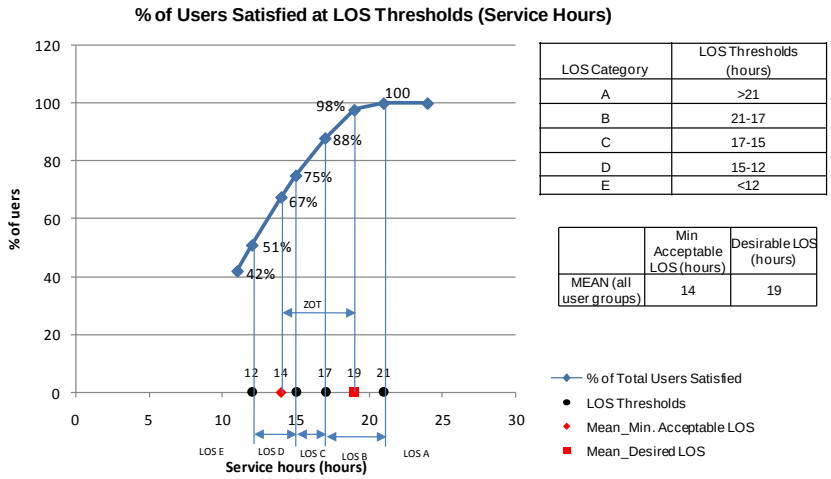


Fig. A.8 Percentage of users satisfied at different service levels (service hours)