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# Determination of Level of Service for bus transit using method of successive interval scaling in Mumbai City

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**Abstract**

Study of commuters' attitude towards public transport and their perception of existing service quality for different service attribute of public transport have gained immense importance for determining appropriate public transport service level. In this context, level of service (LOS) is identified as a vital tool to measure service quality, as per users' perception, ranging from LOS A to LOS F which denotes 'the best' to 'worst' levels. However, the LOS existing benchmarks are defined as per the expert's judgment. Method of 'Successive Interval Scaling' is used to develop LOS values for bus service as per users' perception which converts ordered categorical scale into an interval scale. Service attributes are selected which are considered important for bus transit and LOS for each attribute is evaluated based on users' opinion. The results obtained in this study for the city of Mumbai highlights the difference in LOS values between users' perception and experts' opinion given by Ministry of Urban Development in India (MoUD), India and the Transit Capacity & Quality of Service Manual (TCQSM).

*Keywords: level of service; attributes; perception; commuters; successive interval scaling; Mumbai;*

## 1. INTRODUCTION

In order to counter the challenges of environmental pollution and increase trends in private vehicle ownership, transport planners of developing countries are becoming more concerned about improving existing conditions of public transport (Neirotti et al. 2014). Most of the urban population in India is still depend on public transport mainly bus but poor service quality of bus have increased the use of two-wheeler, car or Paratransit (Singh 2005). It is therefore essential to improve the service of the bus based on users' perception to attract more passengers and retain the existing patronage (Badami and Haider 2007; Wall and McDonald 2007; Lai and Chen 2011; Mokonyama and Venter 2013)

In the measurement of service quality, the importance of users' perception has highlighted by several researchers (Das and Pandit 2012; Lee and Lin 2005; Kuo et al.

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2009; Ryu and Han 2010; Han and Hyun 2015; Hill and Alexander 2017). Based on the demographic profile, socio-economic characteristics, past experience from service providers, users' personal needs and habits and various situational factors, users' perception varies person to person (Kooti et al. 2016; Das and Pandit 2013). Based on this it can be suggested that users' perception of service quality may differ between trip makers of developing and developed countries because of their differences in the socio-economic composition of travelers, service delivery environment and their varied travel expectations and needs (Neirotti et al. 2014; Lucas 2012).

Users' perception of service quality has been measured by various approaches summarized by Mahmoud and Hine 2013. 'Perception-based measure' is the first approach that evaluates "level of satisfaction". For example, an overall evaluation of service quality was compared with existing service levels by Dell'Olio et al. 2010. To identify the attributes that passengers found important were analyzed using importance-satisfaction (I-S) analysis by Yoh et al. 2011. This technique was collective-in-the-moment perceptions, surveyed at bus stops. The ordered probit model was used by Tyrinopoulos and Antoniou 2008 to measure the variability of users' perception on different service levels. On users overall perception of service quality, the importance of different service attributes have been analyzed by the second approach "weighted perception measure" (Mahmoud and Hine 2013). Researchers used a number of statistical techniques in this approach like quadrant analysis (Martilla and James 1977), structure equation Modelling (De Oña et al. 2013; Golob 2003), ordered probit/logit models (Joewono and Kubota 2007), factor analysis (Tyrinopoulos and Antoniou 2008), analytical hierarchy process (AHP) (Mahmoud and Hine 2013) and impact score (Lee et al. 2009). A measure of future service quality cannot be provided by these approaches, but users' perception on service quality can be provided by these approaches. The multivariate discrete distribution, weighted means, and a generalized linear model were combined by (Lee et al. 2009) to form a method that can form a relationship between users' overall satisfaction level and users' satisfaction rating for individual attributes of service. Service quality index (SQI) was developed by Hensher and Prioni 2002 which uses a stated preference experiment. In this model, against hypothetical service levels, trip makers state their level of satisfaction. In developing countries like India, this method cannot give realistic results. This is because trip makers in developing countries cannot make correct decisions based on hypothetical scenarios because they have little experience with service levels compared to developed countries. The models discussed above cannot predict users' perception on future service levels. They provide only probability of users' satisfaction against a given satisfaction (Del Castillo and Benitez 2013) or measure of relative importance of various attributes on users perception (Mahmoud and Hine 2013). Service levels that will dissatisfy or satisfy a trip maker are of keen interest to service providers. For example, if a service provider can predict whether a trip maker will consider a waiting time of 15 minutes or 20 minutes 'very good', 'good' or 'bad', then accordingly he will make the schedule for the system.

Against the actual service levels, measurement of users' perception of service quality is measured by an effective concept of level of service (LOS) identified by researchers. It measures the present as well as future service quality (Hunter-Zaworski 2003; TRB 2010). Users' perception is categorized into a number of levels or grades by LOS tool represented by 'very good', 'good', 'average', 'poor' and 'very poor'. The order of scale of trip makers' level of satisfaction is the same as that of a number of levels. A higher number of LOS categories is provided by a higher order of scales which

ensures higher accuracy in measuring trip maker perception of service quality. The trip maker's perception measurement is less complicated by LOS instrument as in this method the users are allowed to state their level of satisfaction against the perceived service levels. although very few researchers have established and quantified LOS thresholds for public service transport attributes, including the Ministry of Urban Development in India (MoUD) and the Transit Capacity & Quality of Service Manual (TCQSM), these are based on experts judgment not on trip makers perception (Hunter-Zaworski 2003; MoUD, India 2009). In this study, the law of successive interval scaling is applied to the data collected from bus users in Mumbai to develop LOS scales.

## 2. STUDY AREA

After surveying all the bus depots in Mumbai regarding bus routes coverage, passenger ferrying density, and location of the bus depot, Wadala bus depot was selected as case study area. Wadala bus depot is one of the biggest bus depots in Mumbai which is located centrally in Mumbai Island with an area of 31500m$^2$ and parking facility of 300 buses. It operates 24 bus routes having the fleet size of 169 buses operated by 934 staff. As shown in Fig. 1 showing Wadala bus depot location and different bus routes originating from Wadala depot, it clearly indicates that Wadala is well located in the center of Mumbai and bus routes are widespread across southern, eastern and western suburbs of Mumbai including Navi Mumbai as shown in Fig. 1.

Onboard, the survey was conducted on bus commuters for 10 days including weekends and peak and off-peak hours. Firstly demographic/socioeconomic survey was conducted followed by average service level survey and service attribute rating survey. A total of 315 samples were conducted out of which 307 samples of valid responses were collected.



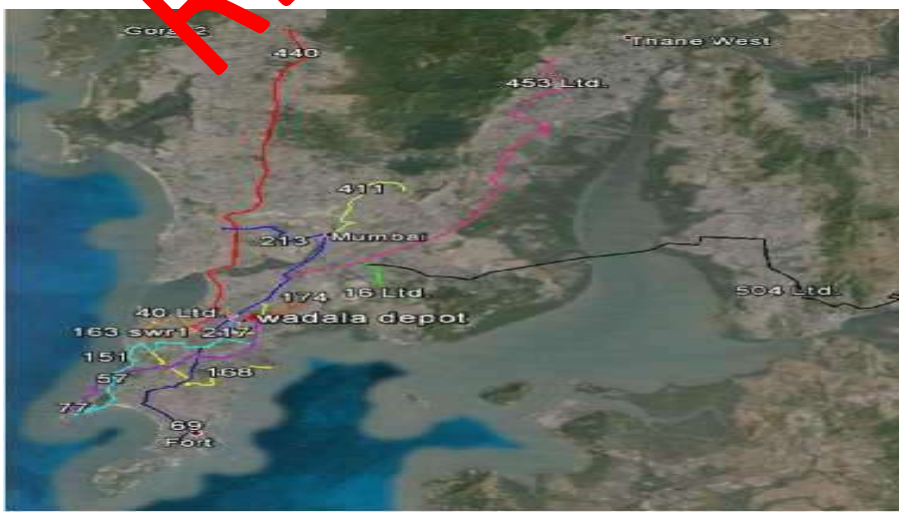


Fig. 1: Wadala bus depot and its bus routes.

## 3. RESEARCH METHODOLOGY

While a general user perception of the level of service of current urban transit may give generous contribution to systems performance. It might be increasingly helpful for service providers to realize what the key components are in transit system that should be improved and what services should be given. Hence to evaluate LOS scales and overall

satisfaction the key attributes need to be identified. In this paper data was collected based on perceived level of services not on actual service levels because of difficulty occurred in getting actual service levels.

The Method of successive interval scaling is used which is based on a scale continuum idea can be divided into number of boundary intervals. A unique perception of scale value is for every trip maker for each service attribute that can be placed between two category boundaries. For example if there is k number of categories of observation then the lower boundary is minus infinity and upper boundary plus infinity. The upper boundary for each category is determined by using mean LOS rating or mean scale value for each category and a discriminal dispersion for mean scale value. To obtain the discriminal dispersions the method assumes a normal distribution and homogenous samples. At last by using normal deviates against the proportions of responses, the proportion of response rating a particular service level is estimated. Bock and Jones (1968) have explained the detailed mathematical procedure. Finally by assuming a causal relationship between actual physical measure and user perception of LOS rating, LOS scale boundaries are determined.

The literature available highlighted that different service requirements are for different trip makers and hence have different service quality perceptions (Zeithaml et al. 1993; Dantas et al. 2001). There is a significant influence by the share of respondents on LOS scale if total user population is used for user perception averaging. For instance, share of female riders is higher in developed countries than developing countries in public transport riders. To determine LOS scales in both developing and developed countries, the results of users' perceptions, therefore, may underestimate the female rider perception in developing countries. Therefore a separate LOS scales for public transport have been developed. In this paper, for individual service attributes, perception of total user population was considered and a single LOS scale was developed, that can be easily applied by service providers at any point in time. For different quantitative bus transit service attributes in Mumbai the trip makers' were asked to state their perceived level of service and rate against perceived service theirs satisfaction levels on a categorical scale of 1 to 5 (1=very good; 5=very poor). Level of satisfaction on a five-point scale was found to be comfortable for respondents leading to five LOS categories from LOS A to LOS E. For different bus transit service attributes for Mumbai city, based on users' perception service levels, LOS scale values were determined using method of successive interval scaling described as below.

This method is developed on service quality to calculate its benchmark of bus transit across five graded rating categories based on users' perception. The method is divided into two parts, first part consist of developing average weighted score given to each range of all the selected attributes by finding out the importance given by users according to the rating given to different ranges of each of attribute, the commuters were surveyed and their perception was recorded. In the second part, the law of successive interval scaling is applied on average weighted score obtained for each range of given attribute and the range which commuters prefer the most, attributes have a rating pattern as "1", "2", …, and "5" the commuter must select only one for each attribute. The average weighted score is calculated as follows,

$$\mu_k^{UB} = \frac{1}{n}\sum_{j=1}^{n} y_{jk} \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where $\mu_k^{UB}$ is the average weighted score calculated as given in equation 1, $y_{jk}$ is

response given by commuter corresponding to each service level range (*j*) and rating category (*k*), *n* is the total number of responses corresponding to particular service level group.

After calculating average service level the next step is to evaluate successive interval scaling, the following steps were given below to determine LOS of the bus plying in Mumbai across five grades from LOS A (highest) to LOS E (lowest). The main difference about this method is it converts qualitative service attribute into numerically weighted value and then derives a user perception interval scale or LOS scale to measure users' perception on different service attribute groups.

The following are the steps involved in the Law of Successive Interval Scaling (Bock and Jones 1968):

1) We have to separate the existing service levels i.e. average weighted score for five attributes given by commuters responds in the group (*j*) where *j* is service level range.

2) Responses were obtained against each rating category (*k*) of each attribute. (Where *k* = 1, 2… 5).

3) To calculate cumulative values *pjk* for each of the service group (*j*) and for each of the rating category (*k*).

4) Calculation of normal deviates $y_{jk}$ for each of the corresponding pjk.

5) To calculate $\mu_k^{UB}$ as the average of $y_{jk}$ service group for each category *k*. This is the conversion of interval scaling into categorical scaling.

6) Regression analysis is to be conducted between $\mu_k^{UB}$ *and* $y_{jk}$ for each of the service group (*j*) to get mean LOS rating $\mu_j^{LOS}$ for each of the service groups.

7) To build a relationship between mean LOS rating ($\mu_j^{LOS}$) and the average weighted value for each range of attributes.

8) Lastly to get values from average weighted values and mean LOS rating ($\mu_j^{LOS}$) we get corresponding service level values by putting values of $\mu_k^{UB}$ in the quadratic equation. The values thus obtained are the LOS scale developed for the regular bus in Mumbai. The methodology flow chart is shown in Fig. 2.

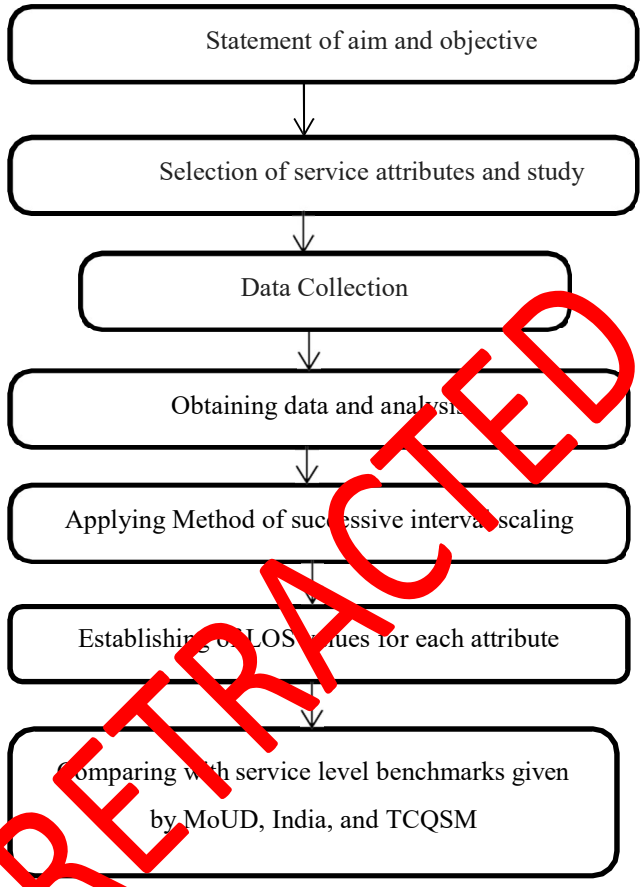




Fig. 2: Methodology flowchart.

## 4. DATA COLLECTION

The survey was conducted in person for continuous 10 days including weekends and covering both peak and off-peak hours. In the following manner survey was conducted:- In this survey, all the basic information was collected such as age, ridership, gender, income groups, and occupation, do they regularly use the bus, is taxi or cab preferred over the bus, what are the fare comparisons, etc.

Secondly, the commuters have to mention the average service level by responding to their views for service level range and rating the five different service attributes ranging from 1 (very good) to 5 (worst) as per their convenient range preferred. The demographic profile of trip makers is shown in Table 1.

Table 1: Commuters socioeconomic characteristics in Mumbai

| Total samples of users | 307 nos. |
|---|---|
| *Ridership* | |
| Captive riders | 209 |
| Choice riders | 98 |
| *Gender* | |
| Male | 190 |
| Female | 117 |
| *Age* | |

| | |
|---|---|
| <25 | 86 |
| 25-55 | 205 |
| >55 | 16 |
| *Income groups* | |
| <Rs.10000/month | 9 |
| Rs.10000-20000/month | 43 |
| Rs.20000-30000/month | 83 |
| >Rs.30000/month | 101 |
| Homemaker or students (those with no income source) | 71 |

In this study, the on-board survey was conducted on bus commuters in Mumbai for all ten days including weekends, covering peak and off-peak periods and only on regular buses plying in Mumbai. The sample size measured for this study was 315 samples out of which only 307 responded considering 80% response rate and 95% confidence level which were totally based on bus users' perception in Mumbai. The total bus user population in Mumbai was evaluated to be around 4.2 million commuters in the year 2016. The captive riders were chosen from the information in view of the following criteria: 1) commuter is a regular bus user and 2) the commuter does not have a personal mode of transport. Likewise, selections of choice rider are 1) Commuter has their personal vehicle; 2) Commuter hardly travels by bus and 3) commuter ride by taxi cab or another transport mode.

Respondents or commuters were surveyed from across all age, income, gender groups and various socioeconomic groups. This gave us the entire views regarding service of the bus in Mumbai in this demographic survey first point is ridership whether the commuter has their personal vehicle which can be used by them for their regular use and office work or they have no personal vehicle due to less income and have to depend entirely on public transport. Second is the gender group i.e. how many males or females make use of public bus transport in Mumbai. Age group reveals the various age grouped people take a public bus in the city it indicates that Mumbai's bus benefited all peoples in Mumbai. There is an income group which is the most important group in this survey; it clearly indicates the various people from laborer to the high-class person who can use the bus and sharing the same platform. It means though there is a vast income gap between peoples, the bus is used by them. The income class is divided into four categories income of person having a salary less than 10k, between 10k to 20k, 20k to 30k, above 30k and finally homemakers and students. Homemakers and students do not have their income source. This demographic survey has given a vast variety and different groups of commuters residing in Mumbai city. Each respondent is unique in them and has contributed their respond for evaluating the Level of Service of bus in Mumbai city.

## 5. PRELIMINARY ANALYSIS

In this survey, a passenger or commuter should mention their view regarding the five service attributes given to them. Each service attribute is divided into certain specific ranges depending on the type of service and convenience of service level. The respondents have to respond to rating category given as 1 (very good) to 5 (worst) for only one service level group. The respondents can respond depending on their experience of using bus service, so it is independent and irrelevant to each other. Some

may find certain service level groups as very good and the same service level group may be worst for the other respondent. The following are the data obtained after conducting a survey on commuters in Mumbai based on five different service level attributes:-

5.1) Service Hours

Table 2: Responses representing the rating category for each service hour group.

| Sr.no. | Service level group(hours) | Rating category 1 | 2 | 3 | 4 | 5 | Total responses |
|---|---|---|---|---|---|---|---|
| 1 | >20 | 29 | 34 | 7 | 4 | 3 | 77 |
| 2 | 16-20 | 21 | 39 | 23 | 11 | 2 | 96 |
| 3 | 12-16 | 6 | 5 | 16 | 27 | 14 | 68 |
| 4 | 0-12 | 2 | 6 | 10 | 17 | 31 | 66 |

5.2) No. of Mode Transfer

Table 3: Responses representing the rating category for each mode transfer.

| Sr.no. | Service level Group | Rating category 1 | 2 | 3 | 4 | 5 | Total responses |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 23 | 34 | 12 | 8 | 1 | 78 |
| 2 | 1 | 19 | 41 | 21 | 6 | 2 | 89 |
| 3 | 2 | 6 | 12 | 31 | 16 | 7 | 72 |
| 4 | 3 | 1 | [illegible] | 18 | 10 | 8 | 39 |
| 5 | 4 | 1 | 2 | 5 | 15 | 6 | 29 |

5.3) Average Travel Time

Table 4: responses representing the rating category for each travel time group.

| Sr.no. | Service level group(kmph) | Rating category 1 | 2 | 3 | 4 | 5 | Total responses |
|---|---|---|---|---|---|---|---|
| 1 | 20-30 | 7 | 24 | 10 | 4 | 2 | 47 |
| 2 | 15-20 | 12 | 37 | 23 | 12 | 3 | 87 |
| 3 | 10-15 | 1 | 12 | 78 | 28 | 2 | 121 |
| 4 | 0-10 | 1 | 7 | 9 | 23 | 12 | 52 |

5.4) Waiting Time

Table 5: responses representing rating category for waiting time service group

| Sr. no. | Service level groups(min.) | Rating category 1 | 2 | 3 | 4 | 5 | Total responses |
|---|---|---|---|---|---|---|---|
| 1 | 0-3 | 9 | 15 | 6 | 3 | 2 | 35 |
| 2 | 3-6 | 8 | 29 | 22 | 8 | 5 | 72 |
| 3 | 6-9 | 11 | 24 | 39 | 9 | 3 | 86 |
| 4 | 9-12 | 5 | 13 | 14 | 3 | 2 | 37 |
| 5 | 12-15 | 3 | 7 | 10 | 3 | 1 | 24 |
| 6 | 15-20 | 2 | 4 | 7 | 5 | 1 | 19 |
| 7 | 20-25 | 1 | 3 | 8 | 4 | 2 | 18 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 8 | 25-30 | 1 | 1 | 3 | 4 | 7 | 16 |

5.5) Loading density or passenger density

Table 6: responses representing rating category for passenger density service group.

| Sr.no. | Service level group(passengers/seat) | Rating category 1 | 2 | 3 | 4 | 5 | Total responses |
|---|---|---|---|---|---|---|---|
| 1 | 0-0.5 | 9 | 28 | 16 | 8 | 3 | 64 |
| 2 | 0.5-1.5 | 13 | 64 | 28 | 9 | 4 | 118 |
| 3 | 1.5-2.5 | 2 | 26 | 54 | 12 | 2 | 96 |
| 4 | 2.5-3.0 | 1 | 5 | 7 | 13 | 3 | 29 |

The explanation and method evaluation of attribute Service Hours are elaborated below. Table 2 is used for linking the evaluation process data with the main response table data.

Table 7: Table representing the cumulative proportion of responses for each service level group

| Sr.no. | Service level group(hours) ($j$) | Rating Category 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| 1 | >20 | 0.3766 | 0.8181 | 0.9091 | 0.9611 | 1 |
| 2 | 16-20 | 0.2187 | 0.62[illegible] | 0.8646 | 0.9792 | 1 |
| 3 | 12-16 | 0.088[illegible] | 0.[illegible]515 | 0.3968 | 0.7938 | 1 |
| 4 | 0-12 | 0.[illegible]303 | 0.1213 | 0.2728 | 0.5303 | 1 |

The cumulative values for each service level group corresponding to each rating category are represented by Table 7.

Table 8: Normal deviates ($y_{jk}$) for each service level group ($j$) i.e. service hours

| j ↓ k → | Service level group(hours) | Rating Category 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| 1 | >20 | -0.32 | 0.91 | 1.34 | 1.76 | 3.99 |
| 2 | 16-20 | -0.78 | 0.32 | 1.1 | 2.04 | 3.99 |
| 3 | 12-16 | -1.35 | -0.99 | -0.26 | 0.82 | 3.99 |
| 4 | 0-12 | -1.87 | -1.17 | -0.61 | 0.08 | 3.99 |
| $\sum y_{jk}$ | | -4.32 | -0.93 | 1.57 | 4.7 | |
| Average ( $\mu^{UB}_{K}$ ) | | -1.08 | -0.2325 | 0.3925 | 1.175 | |
| c=(0.2325+0.3925) =+0.08 Normalized mean ($\mu^{UB}_{k}$) | | -1.16 | -0.3125 | 0.3125 | 1.095 | |

Table 8 represents normal deviates. According to a normal distribution, $\mu_k^{UB}$ is linearly

related with standard normal deviates hence forth linear regression between $\mu_k^{UB}$ and $y_{jk}$ will give an estimate of $\mu_j^{LOS}$ and the standard deviation $\sigma_j$. The normalization of the average value is done in order to gain more accuracy and narrowing the errors incorporated in process as in the user perception type survey the chances of occurring error are very high.

Table 9: $\mu_j^{LOS}$ values for each service group ($j$) and corresponding average service level (service hours)

| Sl. No. | Service level group | Average Service level (Hours) | $\mu^{LOS}$ - Mean LOS rating |
|---|---|---|---|
| 1 | >20 | 20.633 | -0.967 |
| 2 | 16-20 | 16.428 | -0.522 |
| 3 | 12-16 | 13.9[illegible] | 0.415 |
| 4 | 0-12 | 10.78[illegible] | 1.013 |

Table 9 average service level is obtained directly from the survey conducted for average service group for each attribute and $\mu_j^{LOS}$ mean LOS rating is obtained from graph plotted between Normalized mean v/s service levels for each service level group. The $\mu_j^{LOS}$ value is the intercept value obtained from SPSS software; the graphs are mentioned in Fig. 3 and Fig. 4.

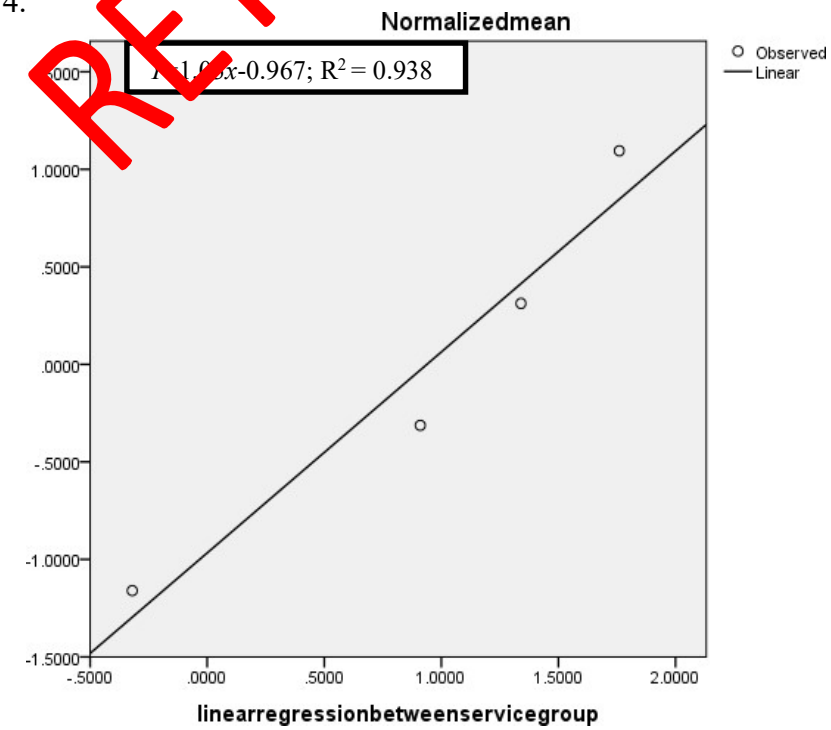


Fig. 3: the linear relationship between $\mu_k^{UB}$ and $yjk$ when $j = 1$

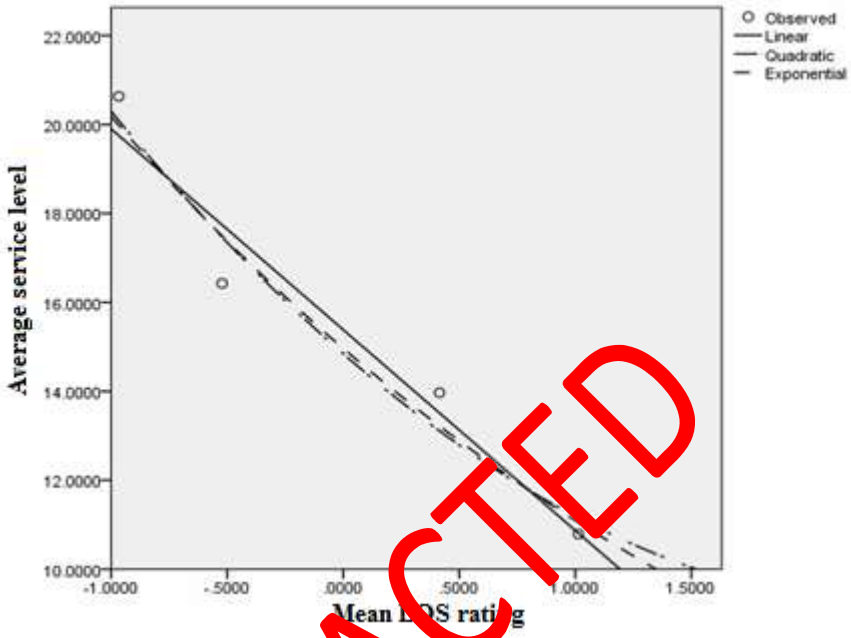




Fig. 4: Curve estimation between mean LOS ratings $\mu_j^{LOS}$ and average service level for service hours

Figure 3 shows a linear relationship between $\mu_k^{UB}$ and $y_{jk}$; when j=1. The value of the intercept (-0.967) represents the mean LOS rating $\mu_j^{LOS}$ for service group j=1. Similarly, the graphs were plotted for j=2, 3 and 4 and the intercept value is obtained for the respective terms from SPSS software. Only for j=1 chat or graph is provided here. Normalized mean is taken as a dependent variable and service level group is taken as an independent variable in SPSS software and curve estimation linear regression is carried out.

There is a causal relationship between the average service level and mean LOS rating $\mu_j^{LOS}$ as shown in Table 9. The casual relationship between mean LOS ratings $\mu_j^{LOS}$ and average service level may not be linear always. Therefore, it is important to study the task of the best curve fitting to establish the most accurate appropriate and casual relationship as shown in Fig. 4. This method of curve fitting eliminates the outliers and establishes a mathematical relationship that best fits all data points tested by the $R^2$ value. However, the mathematical relationship that will be chosen at the end is not based on maximum $R^2$ but it will be based on by testing the performance of the curve using the data points beyond the maxima and minima. If the curve fit gives inappropriate results then it may be rejected. Table 10 elaborates the results of various curve fittings between average service levels and mean LOS rating $\mu_j^{LOS}$ for total service hours for which the organization serves. In Table 10 all types of curve estimation are shown with their respective $R^2$ value. The maximum $R^2$ is for an exponential curve with significance value 0.019 and df = 2. But, the curve gave unrealistic results on predicted values also the parameter coefficient was not found

significant for the exponential curve. The quadratic equation gives the realistic answers thus, the relationship between the average service level for 'service hours' and mean LOS rating $\mu^{LOS}$ was explained by quadratic function as shown in equation 2

Quadratic Equation: $y = 0.899x^2 - 4.553x + 14.844$… ……. (2)

Where $y$ = average service level and $x$ = mean LOS rating $\mu_j^{LOS}$

After equating the values of $\mu_k^{UB}$ normalized mean in the quadratic equation 2 we get the corresponding service level for each normalized mean as shown in Table 11.

Table 10: Model Summary and Parameter Estimates for curve estimation in Fig. 4

| Dependent Variable: Average Service Level | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Equation | Model Summary | | | | | Parameter Estimates | | |
| | $R^2$ | F | df1 | df2 | Sig. | Constant | b1 | b2 |
| Linear | .948 | 36.156 | 1 | 1 | .027 | 15.385 | -4.515 | |
| Quadratic | .957 | 11.032 | 2 | 1 | .08 | 14.844 | -4.553 | .899 |
| Exponential | .962 | 50.031 | 1 | 2 | .019 | 14.965 | -.299 | |

Note: The independent variable is Mean LOS Rating.

Table 11: Upper boundary for each category (service hours)

| Category (k) | $\mu_k^{UB}$ normalized mean | Corresponding service level (hours) |
|---|---|---|
| 1 | -1.16 | 21.33 |
| 2 | -0.3125 | 16.354 |
| 3 | 0.3125 | 13.508 |
| 4 | 1.095 | 10.936 |

Table 12: LOS Scale value for "service hours" (round off)

| LOS Category | LOS scale values (hours) |
|---|---|
| **A** | **>21** |
| **B** | **16-21** |
| **C** | **13-16** |
| **D** | **12-13** |
| **E** | **<12** |

## 6. RESULTS AND DISCUSSION

The rounded-off values for service hours as per Table 12, No. Of modes of transfer, Avg. Speed, Waiting time and Passenger Density is given in following Table 13, which is close to the nearest integer. Using the method of successive interval scaling, the LOS values for each attribute have been estimated for Mumbai, based on user perception.

The results are compared with the estimated values with the already established Service level benchmarks given by Ministry of Urban Development, Government of India (MoUD, India) and Transit Capacity & Quality of Service Manual (TCQSM).
The following is the comparison of established service level benchmarks and LOS values obtained from users' perception:-

Table 13: LOS Values for bus transit service attributes in Mumbai

| LOS category | Service hours (hours) | | No. Of modes of transfer | | Avg. Speed (kmph) | | Waiting time (minutes) | | Passenger Density (passenger /seat) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | LOS values | TCQSM | Los values | TCQSM | Los values | MoUD, INDIA | LOS values | MoUD | LOS values (passenger /seat | MoUD |
| A | >21 | 19-24 | 0 | 0 | ≥19 | ≥20 | 0.0 | ≤4 | ≤ 0.7 | ≤1.5 |
| B | 16-21 | 17-18 | 1 | 1 | 16-19 | 15-20 | 0.1-4.0 | 4-6 | 0.7-1.1 | |
| C | 13-16 | 14-16 | 2-3 | 2 | 11-16 | 10-15 | 4.1-24.0 | 6-10 | 1.1-1.8 | 1.5-2 |
| D | 12-13 | 12-13 | 3-4 | 3 | 8-11 | <10 | 24.1-30 | >10 | 1.8-2.6 | 2-2.5 |
| E | <12 | 4-11 | >4 | 4 | <8 | | >30 | | >2.6 | >2.5 |
| F | | 0-3 | | | | | | | | |



6.1) **Service hours (hours)**

Table 13 shows service hours greater than 21 hours is considered as LOS A, i.e. service quality is good in developed as well as in developing counties as per TCQSM. User perception has an average response for service hours between 16 to 21 hours and 13-16 hours that is LOS B and LOS C respectively. This is because most of the trip makers' average working hours lie in this zone only. However, level of service is poor for bus users in Mumbai when service hours fall below 12. That means currently a minimum of 12 hours of daily bus services are at least required for users in Mumbai which also varies accordingly to service operators and bus routes.

**6.2) No. of mode transfer (number)**

As shown in Table 13, LOS A and LOS B are considered well by trip makers because Most of the people are satisfied with 0 transfers that is when trip maker will reach to destination using only one mode. In any public bus transport system, a user or a commuter demands that he or she should have zero number of transfers from origin to destination because as the number of transfer increases satisfaction level decreases. By considering the widespread web of Mumbai bus the need of transfer is pretty much low.

**6.3) Average travel speed (kmph)**

As shown in Table 13 the average speed of bus is almost similar by comparing service level benchmarks given by user's perception and by Ministry of Urban Development, India. A satisfies the users with speed of 19 kmph followed by LOS B having an average speed of 16-19 kmph which is considered good because users will prefer that

mode which will reach destination as soon as possible. In some congested areas the average speed of bus may be lowered to 11 to 8 kmph which is LOS C and LOS D. At times the speed may reduce below 8 kmph which is LOS E. Speedy route buses ply only on expressways so they have higher LOS value as compared to lower LOS which plies in narrow streets of Mumbai.

### 6.4) Waiting time (minutes)

The results in Table 13 shows that passenger in Mumbai perceives zero minutes of waiting time to be the best LOS and demonstrate a maximum for 30 minutes of waiting time. This may be because work trip makers want to reach at workplaces on time. The range of LOS C perceived by users has been estimated to be a bit larger as compared to another interval i.e. 4.1-24.0 minutes. The people in Mumbai could not differentiate between LOS A and LOS B when waiting time is <4 minutes. This further implies that in such cases, the four-level categorization is done.

### 6.5) Passenger density/Loading density (passenger per seat)

Table 13 shows that bus users in Mumbai consider a crowding level of ≤ 0.7 passengers per seat as good LOS i.e. LOS A. this maybe because every trip maker has keep comfort at higher priority. The crowing level of 0.7-1.1 is demanded by most of the commuters which is LOS B. User perception of service level starts degrading when crowding level starts falling below 1.1 to 1.8. As crowding level further degrades i.e. greater than 1.8 till 2.6 the service becomes unacceptable. In case of any unwanted occasion, the crowding level may be more than 2.6, which is highly unacceptable.

## 7. Comparison of LOS scale values with that of TCQSM and MoUD, India guidelines.

In this paper the LOS values established for bus users' in Mumbai have been compared with established guidelines of TCQSM and MoUD in India. Although inn this paper the LOS values are established on five point scale but the TCQSM uses six-point scale and MoUD is established on four-point LOS scale.

Passenger loading or loading density and service hour's attributes were found comparable with the TCQSM. The LOS scale comparison between the established LOS in this this study and TCQSM values reported by Associates et al. (2003).

The difference between expert judgment and user perception was analyzed by comparing LOS scale values with those established by MoUD, India. The panel of experts has established MoUD guidelines on LOS values for public transport for Indian urban roads. The waiting time was found to be comparable with MoUD, India (2009).

## 8. CONCLUSION

Determination of Level of Service as per users' perception is gaining a huge response as it states the actual situation provided to the commuter by the transport organization body. Though there are some established service level benchmarks given by MoUD, India, and TCQSM which is totally based on expert judgment while the scenario is completely different as per commuter's perception.

In this study overall framework is established for the Level of Service for bus transit service based on user perception using Method of Successive Interval Scaling and demonstrates this method on the user perception data obtained from users survey. LOS

has been identified as a useful tool by various researchers and government bodies to measure and monitor service quality. Total five attributes were selected for measuring service level they are service hours, no. of mode transfer, average travel speed, waiting time and passenger density. Service Hours were analyzed and as per user perception service of more than 21 hours is considered as LOS A while most of the commuters are satisfied with 16- 21 hours of service. As a good transport service, there should be zero transfer of bus which is considered as LOS A and most people consider 1 or 2-3 as a transfer which is LOS B and LOS C respectively. But LOS B i.e. 1 no. of transfer is considered good by most of the users for bus. The average travel speed of the bus is ≥19 kmph which is registered as LOSA while most of the buses travel with an average speed of 11-16 kmph as LOS C as per the majority of users. People with no time demand zero waiting time as LOS A while most of the users are happy with waiting time up to 4 minutes which is LOS B during rush hours and LOS C 5.1-25.0 minutes during off-peak hours. Passenger density is considered LOS A with ≤0.7 which is only at off-peak hours, while most of the commuters are satisfied with 0.7-1.1 as LOS B and 1.1-1.8 as LOS C.

Comparing the user perception data with established benchmark values we conclude that some of the service levels are considered convenient but there is variation between users' view and expert opinion recommended in MoUD, India, and TCQSM.



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