



## METHODOLOGY FOR MULTIMODAL SERVICE LEVEL ASSESSMENT IN ROMANIAN TRAFFIC CONDITIONS

Mihai Alexandru Maleanu, Sorin Patiu

*Technical University of Civil Engineering of Bucharest, Romania*

### Abstract

Public transport systems in Romanian cities operate under increasing congestion, fluctuating service reliability and heterogeneous passenger expectations. Although Level of Service (LOS) frameworks such as HCM and TCQSM provide structured evaluation procedures, their thresholds are predominantly normative and may not fully reflect user perception in specific socio-economic contexts. This paper proposes a perception-based methodology for calibrating public transport LOS thresholds under Romanian urban conditions. The approach applies the Law of Successive Intervals to transform ordinal satisfaction responses into interval-scale values and derive statistically grounded boundaries for key operational parameters. The study is based on a survey of 512 public transport users in Bucharest and focuses on headway, excess waiting time and passenger load. The resulting LOS thresholds provide locally adapted service level classifications that may support urban mobility planning and performance monitoring.

*Keywords: level of service, public transport analysis, quality of services, user perception, successive interval*

### 1 Introduction

Urban public transport systems in large metropolitan areas are confronted with increasing operational pressure generated by congestion, environmental constraints, and heterogeneous passenger expectations. While the concept of Level of Service (LOS) has been widely adopted in transport engineering since its formalization in the Highway Capacity Manual framework [1, 7], its application to multimodal and passenger-oriented systems remains methodologically challenging. Traditional LOS approaches were developed primarily to evaluate traffic flow conditions using indicators such as delay, speed and volume-to-capacity ratios [1, 2]. Although the concept was subsequently extended toward multimodal analysis through NCHRP Report 616 [3], its implementation has largely remained normative, relying on expert-defined operational thresholds rather than empirically calibrated perception boundaries. The Transit Capacity and Quality of Service Manual (TCQSM) extended LOS concepts to public transport by incorporating availability, reliability, comfort and convenience dimensions [3]. However, the thresholds defining LOS categories are generally established through expert assessment rather than empirical perception-based calibration. Several researchers have highlighted that travel time components and reliability factors are not uniformly perceived by passengers [4, 5]. In urban contexts characterized by high congestion, climatic variability and heterogeneous user expectations, direct transfer of international LOS standards may not adequately reflect perceived service quality. Bucharest represents such a case, with peak-hour congestion, variable headways and significant seasonal thermal discomfort.

Under these conditions, calibration of LOS thresholds based on passenger perception becomes necessary. The objective of this paper is to develop a methodology for deriving public transport LOS thresholds adapted to Romanian urban conditions using statistical scaling procedures applied to user perception data

## 2 Literature review

### 2.1 Existing state of practice

The research documented in NCHRP Report 616, prepared for the American Association of State Highway and Transportation Officials in support of the Highway Capacity Manual (HCM), represents one of the earliest efforts to formulate a multimodal performance evaluation framework. The HCM proposes procedures for estimating Level of Service (LOS) across multiple modes, including private automobiles, public transport, bicycles, and pedestrians [3]. Similarly, the Transit Capacity and Quality of Service Manual (TCQSM), 3<sup>rd</sup> Edition, introduces a methodology for assessing transit performance from the passenger's perspective [3, 4]. It evaluates aspects such as comfort, availability, and convenience, while distinguishing between fixed-route services and demand-responsive transit systems. Comfort and convenience are associated with factors such as passenger load, reliability, and travel time, whereas availability is measured through service hours, frequency, and network coverage [4]. However, despite offering comprehensive guidance, the manual does not explicitly address the impact of road congestion on transit performance. Moreover, a case study revealed that the TCQSM assigns equal weight to different travel time components, even though passengers may perceive these components differently in real-world conditions [5].

The service level thresholds set to date by TCQSM for public transport are based on specialist assessment rather than user perception. The importance of user perception in evaluating service quality has been emphasized by many researchers. Hence Parasuram et al, consider user perception fundamental for judging the service quality, as the passengers are ultimately bear the consequences of poor service performance [6]. In addition, several researchers have challenged whether these LOS thresholds can be universally applied, questioning their relevance and accuracy across diverse geographic settings and economic conditions. For example, the question was raised whether the level of service would have the same meaning in different geographic regions and whether distinct LOS standards or thresholds might vary across urban, suburban, and rural areas [7]. Public transport users from different countries are likely to perceive the same level of service differently, due to variations in socio-economic conditions as well as differences in service delivery.

Other research efforts have focused on applied an Importance-Satisfaction framework to determine which service attributes passengers considered most critical, based on aggregated, real-time perceptions collected through surveys conducted at multiple public transit stations [8]. In contrast, Tyrinopoulos and Antoniou analyzed variations in user-perceived satisfaction across different service levels, using an ordered probit model [9]. A different perspective is offered by using a Service Quality Index in which participants were asked to indicate their levels of satisfaction in response to a set of hypothetical service scenarios. However, this approach is highly dependent on respondents' experience regarding bus transit service level [10]. In accordance with TCQSM manual the level of service has been defined as range of values with a scale between „A” (highest) and F (lowest) and this system was used in USA to calculate service quality of transportation system [3]. Other researchers have investigated several approaches to establish LOS scale values for transportation facilities.

One such approach is the “equivalent travel time” method proposed by Mfinanga and Ochieng. This method derives LOS scale values by translating various attributes of public transport services into their equivalent travel times and subsequently classifying them into the corresponding LOS categories [11]. In accordance with the literature review the ‘Law of Successive Interval Scaling’ is the one of the most appropriate approaches for data collection especially when information is obtained thorough random field survey [12]. This method effectively overcomes the limitations associated with Arrow’s Paradox and introduces an alternative approach for assessing the extent of agreement or disagreement among groups of respondents [13].

### 3 Proposed methodology

The purpose of this article is to develop a methodology for calculating the level of service adapted to Romanian characteristics of public transport and the environment in which the service operates. Based on the field investigations conducted it is essential that any evaluation of public transport performance to reflect the needs and expectations of primary users and examine how these factors influence the decision to choose public transport. Each major urban area has distinctive characteristics – such as corporate culture, climate conditions, leadership patterns, and geographical constraints – that differentiate it from cities in other countries. For instance, Romania experiences relatively moderate winters and very hot summers. Under such climatic conditions, the availability of air conditioning in public transport vehicles becomes a significant determinant in passengers’ modal choice [2].

Based on the literature reviews a set of public transport service parameters were identified. This article mainly focuses on quantitative indicators for describing level of service scale. The parameters selected for analyses are headway of service, (frequency of transit), passenger load (passenger/seat ratio). Additional contextual parameters such as accessibility and amenities were recorded but the calibration focused on core quantitative indicators. During the research were used a combination of field studies together with an online survey. The sample size estimation is 399 participants (using a margin of error of 5% at 95% confidence) based on the number of transit users [14]. The total amount of answers was received from 512 participants to overcome any incomplete data. The questionnaire was structured into three distinct sections. In the first section are recorded data regarding regularity of uses and the period when the public transport service is used. For the second section the level of satisfaction was measured on a Likert scale of 1 to 5 (where 1 is very poor and 5 is very good). The last part of the survey has focused on gathering socio- economic data of the interviews. There were collected information about age, sex, monthly income, job activity, etc.

For this research law of successive interval scaling was used to assess the LOS thresholds for public transport users. The main advantage of this method is the possibility to convert the data into an interval scale. Hence the level of satisfaction was classified in  $k$  categories, where  $k = 1$  is very poor and  $k = 5$  is very good. Every category contains a lower boundary and upper boundary values [15]. Also, each response regarding evaluation of public transport was separated in groups, where  $j$  is the group number. For example, the headway of time for public transport was divided in seven groups, corresponding to time interval from questionnaire as is presented in table 1. Then it was calculated the number of responses for each category group ( $j$ ).

**Table 1** Number of responses for headway of time for each group (j) and each rating category (k)

No.	j	k					Total
		1	2	3	4	5	
1	< 2 min	0	0	0	40	62	102
2	2 - 4 min	0	1	23	49	94	167
3	5 - 9 min	0	6	26	32	35	99
4	10 - 14 min	15	21	25	4	2	67
5	15 - 19 min	17	9	11	1	0	38
6	20 - 30 min	12	9	3	0	0	24
7	> 30 min	13	2	0	0	0	15

The next step was to establish the cumulative proportions of responses  $p_{jk}$  for each (k) category group. The proportion of responses shows level of satisfaction for each group [16]. The method of successive intervals assumes that, for any given level of service, the response function is normally distributed along a psychological continuum divided into “m” categories. Hence, for each service level, the quantitative LOS rating is characterized by a mean and a dispersion  $\epsilon_{ji}$ . Likewise, each rating category (k) has an upper boundary defined by its own mean and dispersion  $\epsilon_{ki}$  [12, 17]. In accordance with literature review the probability  $p_{jk}$  for a passenger to appreciate a certain parameter for evaluation of public transport at or below a certain “k” category is presented on below formula [16]:

$$p_{jk} = \Phi\left(\frac{\mu_k^{UB} - \mu_j^{LOS}}{\sigma_j}\right) \tag{1}$$

where  $\sigma_j$  is standard deviation of satisfaction in group  $j$  and  $\Phi$  is cumulative distribution function of the standard normal distribution.

The methodology continues with calculations of normal deviate  $y_{jk}$  (standardized positions of satisfaction categories on an assumed underlying normal satisfaction distribution) against the corresponding proportion  $p_{jk}$  based on following formula:

$$Y_{jk} = \Phi^{-1}(p_{jk}) \tag{2}$$

The normalized mean  $\frac{\mu_k^{UB}}{\mu_k}$  can be calculated as the average as the average of  $y_{jk}$  over all groups for each category “k”, [12], using the below formula:

$$\frac{\mu_k^{UB}}{\mu_k} = \frac{\sum_{j=1}^n y_{jk}}{n} \tag{3}$$

The procedure continues with linear regression analysis between normal deviate  $y_{jk}$  and the normalized mean  $\frac{\mu_k^{UB}}{\mu_k}$ . The values  $\frac{\mu_k^{UB}}{\mu_k}$  are dependent variables, while normal deviate  $y_{jk}$  are the independent variables. In figure 1 is presented linear relationship between  $\frac{\mu_k^{UB}}{\mu_k}$  and  $y_{jk}$ , where  $\sigma_j$  is the slope of the graph and the intercept are the value of  $\mu_j^{LOS}$ , for a service factor. However, because the relationship between  $\mu_j^{LOS}$  and average service level (y) is not linear, the next step is to elaborate a regression analysis between these variables. The equation of the regression may be linear, quadratic, cubic or exponential equations.

Furthermore, Bock and Jones [17] recommend a conformity test or a chi-square ( $\chi^2$ ) for the performance of the model by computing the difference between the observed proportion in each category ( $p_{jk} - p_{jk-v}$ ) with those derived from model ( $P_{jk} - P_{jk-v}$ ).

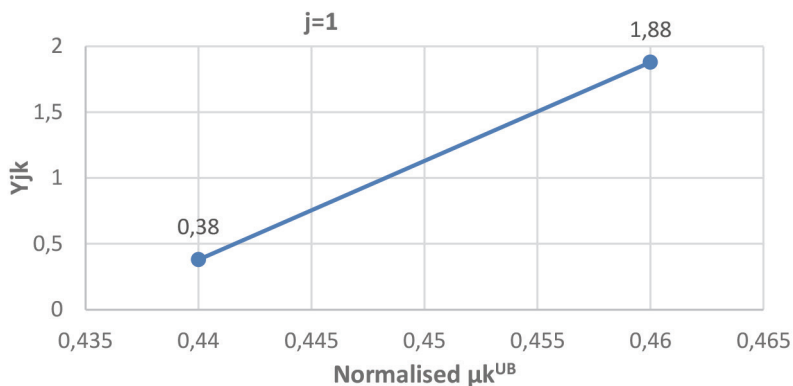


Figure 1 Linear relationship between  $\mu_k^{UB}$  and  $y_{jk}$  for  $j = 1$ , for headway of service factor

At the end, the service levels of the upper boundaries for each (k) category were calculated and the results was converted to letters using the equivalencies from the below tables, where A is the best performance and F the worst value.

Table 2 Transit level of service for headway of public transport

Level of service	LOS scale value [minutes]
A	< 3.4
B	3.5-6.9
C	7-12.9
D	13-17.4
E	> 17.5

Table 3 Transit level of service for excess waiting time

Level of service	LOS scale value [minutes]
A	< 1
B	1.1-2
C	2.1-3
D	3.1-3.9
E	> 4

**Table 4** Transit level of service for passenger load (passenger/seat ratio)

Level of service	LOS scale value [passenger/seat]
A	< 0.3
B	0.31-0.85
C	0.86-1.49
D	1.49-2.2
E	> 2.3

## 4 Conclusion

This study proposed a perception-based methodology for calibrating public transport LOS thresholds under Romanian urban conditions. By applying successive interval scaling to survey data from 512 users in Bucharest, statistically derived service boundaries were obtained for headway, excess waiting time and passenger load. The results indicate that passenger perception is strongly influenced by headway regularity and waiting time, while elevated load factors significantly reduce perceived service quality. The derived thresholds provide locally adapted evaluation ranges that may support urban mobility planning and performance assessment. Although the study was limited to Bucharest, the methodology is replicable in other cities where normative LOS standards may not reflect local perception patterns. Future research may extend the analysis to additional urban areas and integrate behavioral models linking calibrated LOS thresholds to modal choice.

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