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Paper title: **Passengers' perspective of bus service quality in Bangkok: an ordered probabilistic modeling approach**

Author(s) name(s): Kasem Choocharukul, PhD

Organization(s): Department of Civil Engineering, Faculty of Engineering
Chulalongkorn University

Contact details:
Postal address: Department of Civil Engineering, Faculty of Engineering
Chulalongkorn University
Bangkok 10330, THAILAND
Telephone: (66 2) 2186578
Facsimile: (66 2) 2517304
email: Kasem.C@eng.chula.ac.th

Abstract (200 words):
Bus services provided by the Bangkok Mass Transit Authority (BMTA) can be plausibly viewed as a viable solution to the traffic congestion problem in Bangkok. Given the fact that the service has recently been enhanced with the ISO 9001: 2000 quality management system, it is still questionable if the system is acceptable from passengers' viewpoints and how they perceive the bus service operations. In addition, measures of effectiveness to be used during the planning process have not been conclusively established for describing bus quality of service in terms of passengers' perspective. These issues could lead to a poor transit planning and inefficient transit operation. In this study, a methodology was developed to investigate whether the current procedures outlined in the Highway Capacity Manual (HCM) and the Transit Capacity and Quality of Service Manual can be applicable and transferred to Bangkok area. A quality of service measure was proposed based on the probabilistic models developed in the present study, utilizing both observational data as well as travel survey information. The findings of this research are expected to further the understanding of passengers' perspective of bus service quality and the proposed quality of service measure can be potentially applied in transit planning as well as operation and management.

Introduction

For decades, public mass transportation system has played a vital role in enhancing people-moving capacity and can be plausibly viewed as a viable solution to the traffic congestion problem. In Bangkok and its perimeters, bus services are provided by the Bangkok Mass Transit Authority (BMTA) under the jurisdiction of the Ministry of Transport. As of 2002, the BMTA operates 3,655 buses, serving a total of 106 routes and covering a total service distance of 867,039 kilometers per day. Approximately 2.2 million passengers use the service daily (BMTA, 2003).

Given the significance of public mass transportation, a critical issue for transit engineers, planners, and operators is how to establish an acceptable service quality for transit riders. Since 1999, the level of service (LOS) concept given in the Transit Capacity and Quality of Service Manual (TCQSM) has been adopted for transit system in North America as a qualitative measure representing transit performance (TRB, 1999). Analogous to the LOS concept for highway system outlined in the Highway Capacity Manual (HCM, TRB 2000), the fixed-route transit LOS is defined by six letter grades from A through F with A representing the highest quality and F representing the lowest quality based on a particular aspect of transit service.

According to Chapter 2 of the TCQSM, the quality of service measures passengers' point of view of two main characteristics, i.e., transit availability and transit quality (TRB, 2003). Transit availability refers to the degree to which transit is available to given locations and times, whereas transit quality denotes passengers' comfort and convenience. Although both characteristics constitute passengers' perception of transit quality of service, the latter is heavily influenced by passengers' perspectives and hence is more difficult to justify due to different assessment from each individual. Table 1 lists the current TCQSM's quality of service framework incorporating a total of six measures of transit quality of service: three measures for transit availability and three measures for transit comfort and convenience.

In the present study, we attempted to investigate quality of service related to comfort and convenience factors from passengers' standpoint. The transit quality provided to passengers, particularly on passenger load, will be of primary focus. The passenger load refers to the degree of passenger crowding on a transit vehicle, or in other words, the ability to find a seat on a transit vehicle. Typically, the load factor, i.e., the occupancy of the vehicle relative to the number of seats is used to identify and assess this aspect. When the load factor exceeds 1.0, it can be implied that all seats are occupied and there remains some standees on the transit vehicle. Table 2 shows the current LOS criteria to evaluate passenger load. It can be observed from the table that all passengers can sit at levels of service A though C, while at LOS F more than one-third of the total passengers are required to stand inside the vehicle. Like the load factor, standing passenger area, a measure described by standing floor area per passenger, can also be used to justify the passenger load LOS when a transit vehicle is designed to accommodate more standees than seated passengers (TRB, 2003).

Table 1: TCQSM's quality of service framework (TRB, 2003)

Categories	Service Measures		
	Transit Stop	Route Segment	System
Availability	Frequency	Hours of Service	Service Coverage
Comfort & Convenience	Passenger Load	Reliability	Transit-Auto Travel Time

Table 2: TCQSM's fixed-route passenger load LOS (TRB, 2003)

LOS	Load Factor (p/seat)	Standing Passenger Area (m^2/p)	Comments
A	0.00-0.50	> 1.00	No passenger need sit next to another
B	0.51-0.75	0.76-1.00	Passenger can choose where to sit
C	0.76-1.00	0.51-0.75	All passengers can sit
D	1.01-1.25	0.36-0.50	Comfortable standee load for design
E	1.26-1.50	0.20-0.35	Maximum schedule load
F	> 1.50	< 0.20	Crush load

A review of the extant literature indicated that the current LOS thresholds for determining each of the service measures in the TCQSM are mainly based on the collective judgment of the TCRP Project A-15A team and panel. One key element that has not been adequately addressed is how transit users perceive the quality of service. Since LOS is widely used as a basic performance measure to evaluate the planning, design, and operational aspects of transit services, it is critical to consider to what extent this measure reflects passengers' point of view.

This exploratory paper aims to examine fundamental issues related to the operational quality of transit service. The findings are expected to further the understanding of passenger perspectives of transit service quality. The objectives of the present study are twofold. First, a methodology was developed to verify whether the current procedures outlined in the TCQSM can be applicable and transferred to Bangkok area. In particular, the load factor, a service measure for comfort and convenience, will be tested and compared to what transit users in Bangkok perceive in reality. This process can be accomplished by examining the probabilistic models developed in the present study, which utilizes both observational data as well as travel survey information. Secondly, it was hypothesized that besides the so-called passenger load, a number of other factors could have strong influences on service quality from passengers' viewpoint as well. Hence, the present study additionally sought to identify such factors.

Methodological approach

The relationship between load factor and user-stated LOS was investigated in the present study with the objective of establishing criteria utilizing passengers' perspectives. If the derived load factor thresholds were found to be statistically similar to the ranges in the TCQSM, then it could be implied that transit user perceptions had been appropriately incorporated in the TCQSM, even for the samples outside North America. On the other hand, a significant difference in load factor thresholds would reflect a potential problem in transferability of the current LOS designation to transit services in Bangkok area.

A bus onboard survey was selected as a means to acquire relevant data, which included passengers' attitudinal components on the quality of service and their associated socio-economic characteristics. The obtained data can be considered as revealed-preference (RP) data since passengers' preferences were revealed through their choices describing their actual travel behavior. This survey approach was found suitable for the present study because respondents would not have time to forget the characteristics of their trips (Cambridge Systematics, 1996). In addition, other operational aspects of bus services such as boarding information and the number of available seats or standees could be collected at the same time.

The questionnaire survey form was comprised of two distinct sections. The first section consisted of questions related to participants. In order to classify the responses statistically, information on socio-demographic attributes such as gender, age, occupation, education, income, and vehicle ownership was requested. The second section of the questionnaire was designed to examine passengers' perspectives on the degree of bus service quality they viewed during the survey, in addition to information related to their trip characteristics. To test the hypothesis that the load factor criteria of bus service outlined in TCQSM is consistent to bus riders in Bangkok, this section of the questionnaire survey asked participants to assign the condition they experienced a LOS from A through F, according to two key factors: the level of crowdedness and the overall quality of service. While the level of crowdedness can be directly related to the load factor, the overall quality of service was supplementally asked to verify the degree of discrepancies in user-stated LOS.

Assembled results from data collection were used in a statistical model development to establish a link, via a relevant econometric analysis, between passengers' point of view and the current LOS specifications.

Data collection

Initially, an inventory of the number of transit routes in Bangkok was considered. Bus route number 62 in Bangkok was identified as the case study for the present paper based on the fact that both regular (non-air-conditioned) and air-conditioned buses are available and the service has recently been certified with the ISO 9001: 2000 quality management standard. Note that to achieve such standard, several requirements are needed, for example, the cleanliness of the vehicle, the on-time service, and the courtesy of ticket takers and bus drivers. As a fixed-route service in the downtown area of Bangkok, bus route number 62 operates from 4:30 a.m. to 11:00 p.m. daily with service headway of approximately 10 minutes during off-peak hours and 5 minutes during peak hours. The regular buses cost 4 Baht (about AUS$0.15), while the fare structure for air-conditioned buses vary between 8 and 16 Baht (about AUS$0.30 - AUS$0.60) depending on the distance. A typical BMTA bus can seat 35 passengers and can carry up to approximately 35 additional standees.

A pilot survey was conducted prior to the actual surveys to detect any problem that might occur in the design of the questionnaire. Once the final survey design has been established, a group of surveyors was asked to ride the sampled bus trip and randomly interview passengers, both sitting and standing, as they boarded the bus. Since responses from passengers might vary by time-of-day, the survey was conducted for both peak and off-peak periods during typical weekdays.

Data analysis

This section summarizes the results obtained from the questionnaire survey. Table 3 summarizes socio-economic characteristics of 195 surveyed bus passengers. Due to missing responses to certain questions in the survey, the total number of respondents reported is not the same for each attribute. According to Table 3, it can be observed that approximately one-third of the total respondents were male, and the majority were in the 21 to 30 age group, constituting about half of the total respondents. The majority of subjects identified themselves as workers or employees, while nearly 30% of the surveyed passengers were students, and the remaining subjects were classified as "others". In terms of passengers' highest education level, nearly 50 percent of subjects had at least a college degree.

Table 3: Summary of socio-economic attributes of surveyed passengers

Socio-Economic Attributes	Levels	Number of Responses
Gender	Male	64 (32.8%)
	Female	131 (67.2%)
Age	< 21	38 (19.6%)
	21-30	104 (53.5%)
	31-40	28 (14.5%)
	41-50	16 (8.0%)
	> 50	8 (4.0%)
Occupation	Students	57 (29.2%)
	Employees/Workers	99 (50.8%)
	Others	33 (17.4%)
Highest Education	< High School	17 (8.7%)
	High School	69 (35.4%)
	College	26 (13.3%)
	Graduate Level	67 (34.4%)
	Postgraduate Level	3 (1.5%)

Table 4 reports the operational aspects of surveyed buses. The total passengers in a vehicle were found to range from 7 to 83 for regular bus and from 6 to 54 for air-conditioned bus. As many as 48 regular-bus passengers and 19 air-conditioned-bus passengers were found standing during the peak periods. These figures can be converted to the TCQSM's load factor of 2.37 and 1.54, respectively, given a fixed seating capacity of 35 seats per bus. Based on the surveyed operational aspects, specifically the load factor, all levels of service A through F can be observed from the collected data.

Table 4: Summary of operational aspects of surveyed buses

Attributes	Regular Bus		Air-Conditioned Bus	
	Minimum	Maximum	Minimum	Maximum
Number of Sitting Passengers	7	35	6	35
Number of Standing Passenger	0	48	0	19
Load Factor	0.20	2.37	0.17	1.54

Modeling approach

To determine how transit riders perceive LOS, a statistical approach was needed to predict the probability of discrete data (LOS A, B, C, D, E, and F). Since the analysis involved ordinal ratings, the proper methodology to develop a measure of transit quality was to utilize ordered probability models. Although unordered probability models such as standard multinomial discrete models were possible, efficiency would be lost because the ordered nature of the variable would be ignored and treated as nominal data (Amemiya, 1985).

Ordered probability models are derived by defining an unobserved variable, z, that is used as the basis for modeling the ordinal ranking of data, in this case LOS rankings. Given a sample of n observations, let z be the dependent variable of theoretical interest that satisfies

$$z = \beta\mathbf{X} + \varepsilon \qquad (1)$$

where **X** denotes a vector of independent variables that determines the discrete ordering for each observation (in this case only the load factor), β is a vector of estimable parameters, and ε is a random error term. Let y be the observed LOS data, consisting of 6 categories. The relationship between y and z for each observation can be shown as follows:

$$\begin{aligned} y &= 1 && \text{if } z \le \mu_1 \\ y &= 2 && \text{if } \mu_1 < z \le \mu_2 \\ y &= 3 && \text{if } \mu_2 < z \le \mu_3 \\ y &= 4 && \text{if } \mu_3 < z \le \mu_4 \\ y &= 5 && \text{if } \mu_4 < z \le \mu_5 \\ y &= 6 && \text{if } z \ge \mu_5, \end{aligned} \qquad (2)$$

where $\mu_1, \mu_2, \ldots, \mu_5$ are the estimable thresholds that separate each level of y. If ε is further assumed to be standardized normally distributed across observations with mean = 0 and variance = 1, i.e., $\varepsilon \sim N(0, 1)$, an ordered probit model estimating cumulative normal distribution of y from low to high has the form:

$$\begin{aligned} &\Phi^{-1}\{P(y=1)\} = \mu_1 - \beta\mathbf{X} \\ &\Phi^{-1}\{P(y=1) + P(Y=2)\} = \mu_2 - \beta\mathbf{X} \\ &\ldots \end{aligned} \qquad (3)$$

$$\Phi^{-1}\{P(y=1) + P(y=2) + \ldots + P(y=5)\} = \mu_5 - \boldsymbol{\beta}\mathbf{X}, \text{ and}$$
$$P(y=1) + P(y=2) + \ldots + P(y=6) = 1.$$

Or equivalently,

$$\begin{aligned}
P(y=1) &= \Phi(\mu_1 - \boldsymbol{\beta}\mathbf{X}) \\
P(y=2) &= \Phi(\mu_2 - \boldsymbol{\beta}\mathbf{X}) - \Phi(\mu_1 - \boldsymbol{\beta}\mathbf{X}) \\
P(y=3) &= \Phi(\mu_3 - \boldsymbol{\beta}\mathbf{X}) - \Phi(\mu_2 - \boldsymbol{\beta}\mathbf{X}) \\
P(y=4) &= \Phi(\mu_4 - \boldsymbol{\beta}\mathbf{X}) - \Phi(\mu_3 - \boldsymbol{\beta}\mathbf{X}) \\
P(y=5) &= \Phi(\mu_5 - \boldsymbol{\beta}\mathbf{X}) - \Phi(\mu_4 - \boldsymbol{\beta}\mathbf{X}) \\
P(y=6) &= 1 - \Phi(\mu_5 - \boldsymbol{\beta}\mathbf{X}),
\end{aligned} \tag{4}$$

where $\Phi(t)$ represents the cumulative standard normal density function:

$$\Phi(t) = \int_{-\infty}^{t} \frac{1}{\sqrt{2\pi}} \exp\left(\frac{-x^2}{2}\right) dx \quad .$$

Model estimation

The model explaining the relationship between load factor and stated LOS was calibrated using maximum likelihood method. The ORDERED procedure available in LIMDEP 7.0 (Greene, 1995) was utilized for this purpose. In this case, the load factor, the occupancy of the vehicle relative to the number of seats, is the only explanatory variable of interest in the model, thus

$$z = \boldsymbol{\beta}\mathbf{X} + \varepsilon = \beta_0 + \beta_1 \times LOAD + \varepsilon \tag{5}$$

where

LOAD	= TCQSM's load factor, and
β_0, β_1	= estimable parameters.

The model estimation results are shown in Table 5. Three distinct models were estimated, covering a sample set for regular-bus passengers, a sample set for air-conditioned-bus passengers, and a combination of both datasets. Values given in parentheses denote the corresponding t-statistics for the estimated parameters. Since z includes a constant term β_0, one of the thresholds is not identified. Therefore, the first threshold, μ_1, was normalized to zero without loss of generality. Note that the last threshold (μ_5) for Model 2 could not be estimated because of the lack of sufficient observations in LOS F. From Table 5, the load factor parameters β_1 are statistically significant, implying that the load factor influences the perceived LOS for bus commuters. The positive sign for β_1 intuitively indicates lower or worse LOS as load factor increases. All of the threshold criteria show high statistical significance.

Table 5: Model estimation results

Independent Variable	Model 1 REG	Model 2 AIR	Model 3 ALL
Constant (β_0)	-0.140 (-0.58)	0.004 (0.02)	-0.107 (-0.68)
Load Factor Parameter (β_1)	1.296 (5.45)	1.178 (4.24)	1.301 (7.85)
Threshold μ_2	0.791 (4.26)	0.747 (5.47)	0.769 (6.96)
Threshold μ_3	1.231 (5.62)	1.502 (8.60)	1.413 (10.41)
Threshold μ_4	2.325 (7.45)	2.562 (12.24)	2.476 (14.17)
Threshold μ_5	3.129 (7.73)	n/a	3.436 (11.28)
Number of observations	78	117	195
Log likelihood at zero	-133.337	-181.252	-322.617
Log likelihood at convergence	-113.918	-169.355	-287.022
ρ^2	0.15	0.07	0.11

* In this table, the three letter acronyms refer to subgroups of the sample: REG = passengers in regular buses, AIR = passengers in air-conditioned buses, and ALL = all passengers in both subgroups.

To compare the estimated results to the TCQSM load factor ranges, thresholds defining levels of service from the ordered probit models can be readily computed using the following equation:

$$\text{Load Factor Threshold} = \frac{\mu_i - \beta_0}{\beta_1} \qquad (6)$$

where i = 1,2,3,4,5 and $\mu_1 = 0$.

Given five parameters for μ_i, five cut-off values were obtained for six levels of service. The estimated threshold values, along with the corresponding TCQSM load factor LOS designations, are presented in Table 6 and graphically in Figure 1. Note that the perceived load factor range in Model 2 cannot be estimated for LOS A because passengers barely perceived the best condition they found on the bus as LOS A. Similar explanation can be justified for LOS F, resulting in merely 4 perceived levels of service in Model 2. According to Table 6 and Figure 1, it is apparent that the perceived load factor ranges derived from a sample of transit riders in Bangkok do not follow the TCQSM criteria. Specifically, load factor values in levels of service A and B seemed to be lower than those in TCQSM criteria. In addition, transit riders perceived a larger load factor value for LOS E, e.g., up to an average load factor value of 2.72, implying that the current cutoff for LOS F or "crush load" condition at 1.50 may be significantly underestimated when passengers' perspectives are taken into account.

Table 6: Comparison of load factor LOS criteria

LOS	Perceived Load Factor Range			
	Model 1 REG	Model 2 AIR	Model 3 ALL	TCQSM
A	0.00-0.11	n/a	0.00-0.08	0.00-0.50
B	0.11-0.72	0.00-0.63	0.08-0.67	0.51-0.75
C	0.72-1.06	0.63-1.27	0.67-1.17	0.76-1.00
D	1.06-1.90	1.27-2.17	1.17-1.98	1.01-1.25
E	1.90-2.52	> 2.17	1.98-2.72	1.26-1.50
F	> 2.52	n/a	> 2.72	> 1.50

* In this table, the three letter acronyms refer to subgroups of the sample:
REG = passengers in regular buses, AIR = passengers in air-conditioned buses,
and ALL = all passengers in both subgroups.

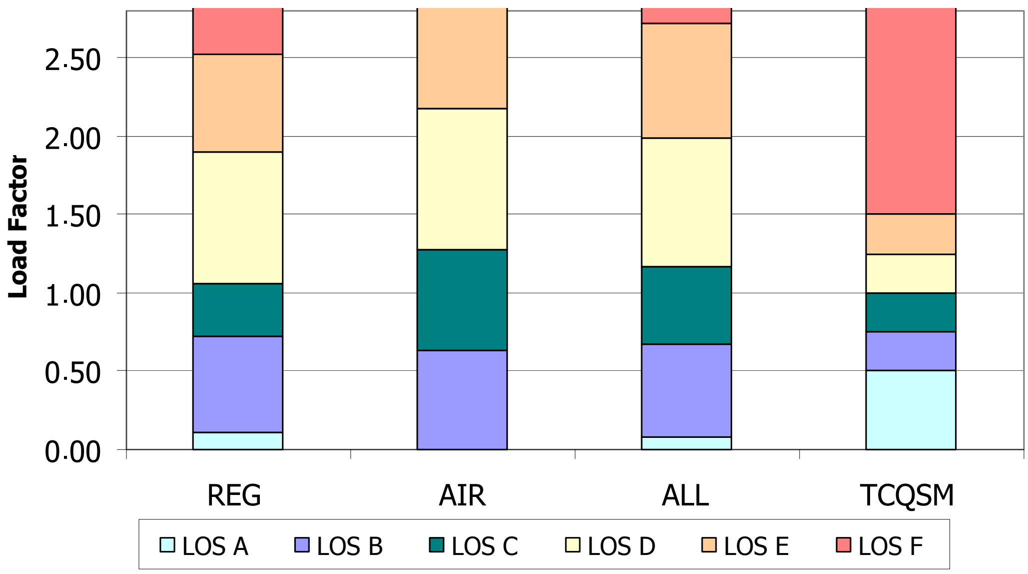

Figure 1: Graphical comparison of load factor LOS Criteria
* In this table, the three letter acronyms refer to subgroups of the sample:
REG = passengers in regular buses, AIR = passengers in air-conditioned buses,
and ALL = all passengers in both subgroups.

This finding provides support of the implication that while the load factor, an aspect of comfort and convenience, influences the perceived LOS on bus services, the current designations of threshold values in the TCQSM may not replicate what travelers, especially those in Bangkok, perceive. It can be further implied from this study that the TCQSM measures may be too restrictive and that the so-called "crush load" may be higher than the TCQSM values, because transit riders did not discern LOS F or crush load until load factor reached 2.72 on average.

Overall quality of service and load factor LOS from passengers' perspectives

The analysis presented in the preceding section represents the LOS obtained from passengers considering only the load factor or the degree of crowdedness inside the bus. When asked to rate the overall quality of service in terms of perceived LOS from A through F, it was found that passengers perceived differently. This section presents the comparison between the perceived LOS based on two criteria, the overall quality of service and the level crowdedness. To make the levels of service quality comparable, an equal distance between two adjacent levels was assumed. Specifically, "1" was assigned for LOS A, "2" for LOS B, "3" for LOS C, "4" for LOS D, "5" for LOS E, and "6" for LOS F. The higher mean value would indicate a worse condition in terms of service quality.

A correlation analysis was initially conducted to measure strength of linear association of two LOS criteria asked during the survey, based on the level of crowdedness and the overall quality of service. Although correlation at up to 99 percent confidence interval was found between two criteria, Figure 2 below, plotting perceived overall LOS versus the means of the corresponding load factor LOS values, explains one interesting point. From passengers' perspectives, the load factor LOS was perceived differently from the overall LOS. Thus, using the load factor as a sole measure to rate the overall LOS would not be justified according to passenger perceptions. In fact, the load factor values can only explain a fraction of the variations in responses to the perceived LOS. Also, it can be realized from the figure that the load factor LOS was found to be worse when compared to the overall LOS. Such findings were found to be consistent among all six levels of service.

A careful examination of the questionnaire survey results showed that, besides the level of crowdedness, commuters in Bangkok would take into account other factors pertaining to their perceptions of the bus's overall quality of service as well. Such factors include, but are not limited to, the outside traffic condition, courtesy of bus officers, and the condition of the bus.

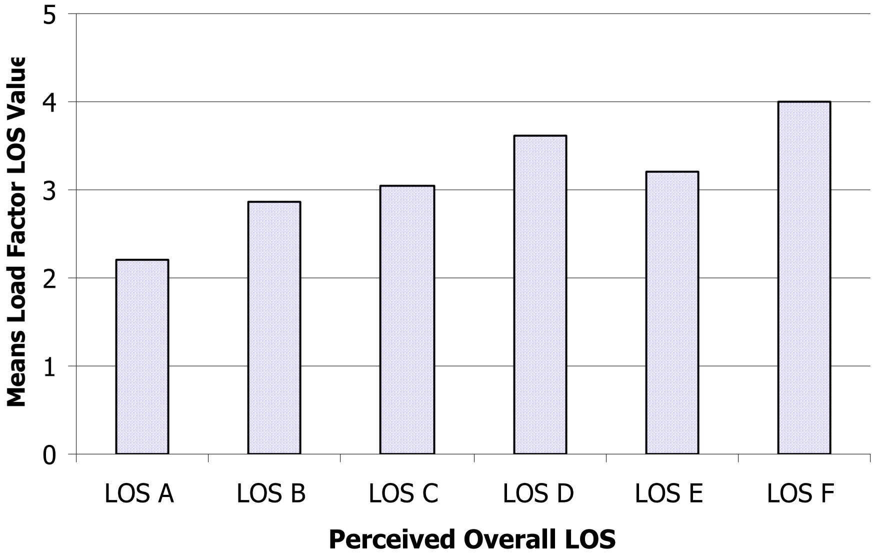

Figure 2: Plot of average means load factor LOS values v.s. perceived overall LOS

Summary and conclusions

This paper demonstrates a means for determining transit service quality from passengers' perspectives. To achieve this, 195 bus riders in Bangkok were asked to rate the service quality as they boarded the bus. Combined with the bus operational data collected simultaneously, such revealed preferences were statistically analyzed and compared with the current TCQSM standard. Econometric modeling was used to develop a set of ordered probabilistic models estimating the load factor, a service measure of comfort and convenience based on the level of crowdedness.

Several inferences can be drawn on the basis of the results of the present study, it appeared that the LOS concept outlined in TCQSM did not fit well for Bangkok commuters and the current load factor ranges seemed to be overstated because, with the exception of LOS A and B, the perceived load factor ranges were found to be higher than the current TCQSM standard. In addition, the TCQSM's current load factor range of LOS F conditions did not appear to be perceived by commuters as the "crush load" that this LOS supposedly represents. In other words, transit riders are more likely to tolerate poor service quality than is stated in the TCQSM.

The understanding of the relationship between service quality and passengers' perceptions will allow transit engineers and planners to better accommodate the demand on transportation facilities and more efficiently allocate scarce transportation resources. Acknowledging the difficulty in incorporating such factors into transit service quality, this study nevertheless shows a promising result that the issue in transferability of the current LOS designation to transit services outside of North America should be revisited. It should also be noted that although the LOS can only be considered as a tool for evaluating transit service quality in terms of some particular aspects.

While the present study establishes the need for quantitatively assessing passengers' perceptions in specifying transit service quality, an expanded sample of commuters should be collected to make definitive conclusions regarding traveler perceptions. In addition, there are, still, many factors that could be considered and investigated, depending on local needs and goals to progressively develop a full-fledged commuter-oriented measure.

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References

Amemiya, T. (1985). Advanced Econometric. Harvard University Press, Cambridge, MA.

Bangkok Mass Transit Authority (2003). "Annual Report 2002". Bangkok, Thailand.

Cambridge Systematics, Inc. (1996). "Travel Survey Manual." Prepared for U.S. Department of Transportation and U.S. Environment Protection Agency.

Greene, W. H. (1995). *LIMDEP Version 7.0 User's Manual.* Econometric Software, Inc., Plainview, NY.

Transportation Research Board (1999). *Transit Capacity and Quality of Service Manual*. TRB, National Research Council, Washington D.C.

Transportation Research Board (2000). *Special Report 209: Highway Capacity Manual*. TRB, National Research Council, Washington D.C.

Transportation Research Board (2003). *TCRP Report 100: Transit Capacity and Quality of Service Manual – 2nd Edition*. TRB, National Research Council, Washington D.C.