LOS EVALUATION OF IMPROVED BUS SERVICES IN DHAKA CITY

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Abstract: Level of service-quality provided by two improved bus services operating along a single route of Dhaka City was comparatively measured using a level-of-service (LOS) model which consisted of five performance measures (PMs), namely travel time, waiting time, load factor, regularity of service, and comfort. Six service categories, A through F, with boundary values, were defined for each of the five PMs. The defined MOE (measure of effectiveness) index for each PM, for both the bus services, was measured and judged against the defined LOS categories for the pertinent PM to find its operating LOS score and LOS category. These LOS scores were then combined together through applying weights of the corresponding PMs found from the passengers' attitude survey results in order to obtain aggregate LOS scores for each of the bus services.

Key words: Level of service (LOS); LOS category; LOS score, Performance measure (PM); Measure of effectiveness (MOE).

1. INTRODUCTION

Responding to the Bangladesh Government's newly declared deregulated fare policy for improved bus services, one private operator (Bangladesh Metro Bus Co. Ltd.) introduced an improved bus service - the Premium Bus Service (PBS) - with air conditioning facilities and all-seated accommodation primarily on a single route, Uttara-Motijheel-Uttara, of Dhaka city in January, 1997. Another private operator (S. S. Engineering Works and Automan Ltd.), taking few buses from the Government owned organization BRTC (Bangladesh Road Transport Corporation) on lease basis, introduced one other improved service - the BRTC City Service (BCS) - with all seated accommodation along the same route. In order to find the quality of service actually provided by these so-called improved bus services, a level-of-service or "LOS" model, adapted and extended from Quium and Tanaboriboon (1994), was applied in 1998. Whereas the Quium and Tanaboriboon model made use of four Performance Measures (PMs), namely travel time, waiting time, load factor and regularity of service, the adapted model included one more variable, the in-vehicle comfort, or simply comfort. The presented LOS evaluation procedure gives a methodology for evaluating bus service quality and for finding areas or aspects warranting improvements.

2. LITERATURE REVIEW

Use of the LOS concept in public transportation is relatively of recent origin; it started in the mid seventies of 20th century. Previously researchers had paid more attention on system performance (in terms of efficiency and effectiveness) than on issues related to quality of service offered. The LOS concept, as a tool for evaluating service quality, had been earlier used successfully in context of highways; researchers later extended it to other areas of transportation, including transit systems. Noted contributors to early developments of the

LOS concept in transit evaluation are Botzow (1974), Alter (1976), Allen and DiCesare (1976), and Bakker (1977). Quium (1993) has given detailed description of the relevant developments.

Botzow (1974) first applied the LOS concept to assess quality of public transit system. Variables used by Botzow for measuring quality of service were speed, delay, and comfort factors associated with the vehicles, including density, acceleration, jerk, temperature, air flow, and noise. He adopted the conventional six levels of service (A through F), defined boundary conditions for each level of the selected criteria, and determined weights of the selected variables in terms of points based on an opinion survey Following Botzow, Alter (1976) developed a different model using only those variables related to service generation and operation, and excluding variables related to facility or equipment standard. He selected six LOS indicators, viz. accessibility, travel time, reliability, directness of service, frequency of service, and passenger density, and proposed a five-point grading scale and weightings for the indicators to determine a composite score. Khisty (1989) used for his LOS model similar variables, but included two new variables of individual cost and public information and gave new interpretation for the variable reliability in terms of breakdowns of service. For measuring certain indicators, viz. frequency and passenger comfort, he relied upon passengers' opinion rather than using a parameter representing the variable that could be measured on a nominal or ratio scale.

Considering all the predecessors' works in developing LOS measures and models, Quium and Tanaboriboon (1994) developed a new LOS model with four indicators or performance measures, namely travel time, waiting time, load factor and regularity of service, which reflected demand aspects of bus service. The PMs selected for the Quium-Tanaboriboon model (also for the extended model presented here) are considered from users' point of view; are (mainly) operations oriented, rather than facility or equipment oriented, so that the bus operators could manipulate the levels of service through operational changes, if desired.

3. DESIGN OF THE LOS MODEL

3.1 Basic Concept of the Model

LOS models nowadays are usually used for transit performance evaluation, in particular, for evaluating the quality of service provided by a transit mode. Level of service is an overall measure of almost all service elements that affect the transit mode (here bus) users. The basic concepts and aspects of the LOS model are given in a nutshell below.

Measure of effectiveness (MOE) is a parameter that best describes the quality of certain operating characteristics. LOS performance measure (PM) is a combination of selected indicators or MOEs. A group of PMs is carefully selected and levels or categories of services of these selected PMs are then defined. Having defined the service levels, boundary values of the MOEs for each level of service are established by considering available standards, passengers' attitude, etc. The measured MOE index value for each PM is judged against the corresponding defined service categories in order to find the actual operating service level, or LOS category and LOS score provided. The LOS scores thus obtained against individual PMs are then combined together through an aggregation method (described later) to obtain overall LOS score (and LOS category) for a bus service.

3.2 Theoretical Design of the Model

3.2.1 Selection of performance measures (PMs)

The rationale of selecting the PMs and the LOS evaluation procedure that was followed in this study are described below.

LOS, in general, involves two types of parameters - operational performance elements and transportation hygiene factors. The first type includes travel time, waiting time, level of occupancy (load factor) and regularity of service, or reliability. The second type involves riding comfort, cleanliness, crew behaviour, protection against environmental elements, etc. Riding comfort is concerned with the make and design of the vehicle and very difficult to define and measure. Indeed, it is pertinent to very sophisticated cars and not to public vehicles in the Third World countries. Protection against environmental elements is usually not adequate for any bus service, which are almost in the same poor status and need not evaluation in any comparative study.

However, in-vehicle comfort is a factor of prime interest to most of the users of improved bus services. Although in-vehicle comfort is generally effected by so many factors, for the sake of convenience and simplicity it was defined in this research work to be contributed by four major elements, namely cleanliness, crowdiness, temperature and crew behaviour. It is apparent that if these four components are kept in desirable conditions, in-vehicle comfort is ensured. Thus, a group of five PMs, namely travel time, waiting, load factor, regularity of service and comfort was selected for the LOS model. Six levels or categories of service, A through F, were considered for each of the five selected PMs. These levels were measured on an equal interval 5-point scale, with the highest point of 5 for level A and 0 point for level F. The assigned points for the other levels were: 4 for B, 3 for C, 2 for D, and 1 for E. Boundary values for these six service levels (MOEs) were established considering available standards, passengers' attitude and rationality.

The PM comfort, a synthetic variable according to the definition, was assessed through evaluation of its four constituents, namely cleanliness, crowdiness, temperature and crew behaviour through the passengers' attitude survey.

The required parameter values were measured from field surveys and data obtained from PBS operator and BRTC sources. The results of a passengers' attitude survey were applied to define the six service levels for the two PMs, namely travel time and waiting time. The service levels of the other three PMs, namely load factor, regularity of service and comfort were defined by considering physical standards and rationality.

The LOS category of a PM was determined by comparing its actual value or the value of its MOE with the established service levels. An aggregation methodology (namely, weighted-sum) was followed to combine the separate LOS categories against the selected PMs. A weighting system (use of AHP to consolidate weightages assigned to individual PMs by the respondents of attitude survey) was also followed to reflect the relative significance of the selected PMs. The aggregated LOS category gave the overall service quality provided by a bus service.

3.2.2 Definitions and measurement techniques of MOE indices of the PMs

Travel time

Results of passengers' attitude survey were used in defining the six service levels of the travel time PM as well as in measuring its MOEs. In doing so, mini bus service, operating on the same route, was considered to be a competitor of PBS (and BCS), and PBS (and BCS) travel time was compared with mini bus travel time. Mini bus service was chosen for comparison, because of its widespread usage in all routes of the city. MOE index for this PM was defined as ratio of the difference between travel times of PBS (or BCS) and minibus service, plying on the same route, and the mini bus travel time. PBS and BCS- passengers were asked about their expectations of relative travel times by PBS or BCS and the mini bus service operating on the same route. In particular, passengers were asked about their opinions regarding how faster (or slower) PBS (or BCS) compared to a mini bus would be acceptable to them. A wide range of options about the acceptable level of relative speed for the PBS and the BCS compared to a minibus in percent form was given to the passengers for selection according to their expectation. A graph of speed of PBS and BCS, relative to minibus service, vs. cumulative percentage of passengers who mentioned the choice (Fig. 1) was drawn for interpolation of the relative speed against a particular percentage of passengers. Acceptable levels of MOE to defined minimum percentages of passengers were applied as the criteria to establish boundaries of the six service levels for the travel time PM. The LOS category distribution for this PM was thus formed.

Waiting time

Quality of bus service is closely concerned with the extent of waiting time. There exists many methods, both direct and indirect, to measure or estimate passengers' waiting times. But several investigators reported that collecting data on actual waiting times was not a feasible proposition mainly due to the reason that a huge number of bus stops would have to be surveyed. Secondly, as the same stop may be used by several bus routes, it is difficult to conduct such a survey due to passenger identification problems. Hence, waiting time in this research work was estimated by an indirect method applicable for randomly arriving passengers. The following empirical formula given by Bowman and Turnquist in 1981 was applied.

$$w = h/2\,(1 + cv^2\,(h)) \qquad \ldots (1)$$

where w = mean passenger waiting time,
h = mean headway, and
cv(h) = coefficient of variation of headway.

The headway data were collected for both the PBS and the BCS, and the mean passenger waiting times were calculated therefrom. The calculated mean passenger waiting time was taken as the MOE index for the waiting time PM.

Results of passengers' attitude survey were employed in defining the six service levels of the waiting time PM. Passengers' were asked about the maximum waiting times acceptable to them with few options. The reported acceptable maximum waiting times were plotted against cumulative percentage of passengers who chose the options (Fig. 2) with a view to interpolate acceptable maximum waiting time for any particular percentage of passengers.

Based upon the findings about the acceptable levels of waiting times, the required boundary values for the six service categories, A through F, were established. As was done in case of travel time, acceptable levels of MOE to defined minimum percentages of passengers were applied as the criteria to establish the boundaries of the six service levels. The LOS categories were thus established for the waiting time PM.

Load factor

Passenger comfort is greatly concerned with the load factor, which can be measured directly from the level of loading or actual physical space occupying. Considering a greater tolerance limit of the people of the developing countries, it would not be appropriate to compare available space on-board with any western standard. Moreover, according to survey conducted, the adopted standard to determine legal capacities of buses in Dhaka was even lower than the standards adopted for Bangkok (by Quium and Tanaboriboon, 1994) which is a Third World city. However, load factor compared to legal capacity was taken as the MOE for this PM and legal capacity of buses for Dhaka was estimated according to on-board survey conducted and from the survey findings of previous studies. Legal capacity of buses related to a standard based on number of seats plus 6 passengers per square meter for the standees was arbitrarily defined as the C level. The lower limit for the E level was defined based on "crush-load" limit of 12 passengers per square meter for the standees. Other levels were established in relation to these defined levels. Ultimately LOS categories were determined considering standards adopted for Bangkok and results of bus-occupancy survey done in Dhaka.

Regularity of service

Regularity of service of a particular transport largely determines its reliability. It affects both passenger waiting time and level of occupancy. Irregularity of services not only decreases reliability but also deteriorate quality of service. Service regularity may be assessed based on the indirect measurement of excess waiting time due to irregular services. The following empirical relationship developed by Henderson, et al (1991) to calculate a passenger waiting index based on the original formula put forward by Bowman and Turnquist in 1981 was used for indirect measurement of regularity of service.

$$W = 1/(1 + cv^2(h)) \quad \ldots (2)$$

where W = proportion of the average waiting greater than the minimum average waiting

cv(h) = coefficient of variation of headway.

Reciprocal of W indicates how longer is the estimated waiting time than the waiting time when services were perfectly regular. For example, if W is 0.8, it would imply that the estimated waiting time was 1/0.8 or 1.25 times longer than the waiting of a perfectly regular service. W can be expressed on a scale of 0 to 1, where the value '1' indicates a perfectly regular service. In this research, equation 2 was used to estimate passenger- waiting index as a measure to assess the regularity of the PBS and the BCS.

Reciprocal of W was taken as the MOE index for the Regularity of Service PM. The six service levels and their boundary values were determined based on rationality, keeping in mind the possible range of W and acceptable maximum limit of 1/W as observed by previous

researchers (e.g. Quium and Tanaboriboon, 1994), Thus the LOS category distribution for the Regularity of Service PM was constructed.

Comfort

In-vehicle comfort or simply comfort is a major factor in attracting travelers to use improved bus services. This PM was defined to be consisting of four constituent elements, namely cleanliness, crowdiness, temperature, and crew behaviour. Each of these elements were placed before the passengers for evaluation on a 5-point scale (0 to 5) where 0 indicated the least acceptance or the worst performance and 5 indicated extreme acceptance or excellent performance. Individual acceptability/ performance index for each element was then calculated for all respondents with help of the following equation.

$$I_a = \sum (s_i f_i) / N \quad \ldots (3)$$

where I_a = Index of acceptability for service attribute a,
f_i = frequency of respondents giving rating i to service attribute a,
s_i = scale value of the rating i,
N = Summation of frequencies of respondents giving lowest to highest rating
$= \sum f_i$

MOE index for the comfort PM was taken to be the geometric mean of the index values for the four constituent elements of comfort. Geometric mean was used, because the index values are conventionally interpreted as pertinent percentages (e.g., an index value of 0.8724 is interpreted as virtual 88.24% of the sample), and the type of mean used for percentages is 'geometric'. This mean-value would give some indication of overall acceptability of the service attribute comfort as a whole, in terms of acceptability of existing performance to that percentage of users (respondents) as given by the MOE index value. The values of the MOE index thus obtained must lie between 0 to 1. This span was divided into six groups, simply based on rationality, to define and form boundary values of the six service levels.

3.2.3 Procedure for determining relative importance of the PMs

Determination of relative importance or weights of the selected PMs was essential for combining the individual LOS categories against the PMs. The technique of Analytic Hierarchy Process (AHP) (Anon., 1992) was employed for this purpose. AHP was developed by Thomas L. Satty in 1977 mostly to help find out hierarchy of different items in an analytic process. To apply the AHP technique in determining priorities or relative importance of competing items, a model of the hierarchical relationships is first prepared. In an AHP model, there would be one goal; several nodes under the goal; several sub-nodes under all or some of the nodes; etc. The nodes, sub-nodes, etc. are taken in all possible number of pairs during the calculation or compilation of the program, and both local and global priorities can be determined from the AHP model on computer.

In order to determine relative importance of the five selected PMs, a simple AHP model was prepared with five nodes (five PMs) under the goal of "Determination of relative importance of PMs". Pair-wise relative importance of the PMs, as obtained from each passengers' response in the attitude survey, were input to the program, and overall relative importance of the PMs assigned by each passenger (respondent) was separately obtained by running the program. However, those judgements of some respondents were discarded which, on being

fed into the AHP model, produced an inconsistency ratio beyond a defined limit (3.0). Having thus obtained relative importance of the PMs for individual respondents' responses, average overall weightage for each PM was determined by taking average of all the 'valid' individual respondents' assigned weightages. The actual determination of relative importance of the five selected PMs are presented in later chapter.

3.2.4 Aggregation technique of LOS scores against individual PMs

The aggregate overall levels of service of the PBS and the BCS on the particular route was determined from the LOS categories against each of the five PMs by employing the assigned points for each category (0 to 5) and the weighting factors found from the survey results. To calculate the overall LOS, the points for an operating LOS against a PM was multiplied by its weighting factor. Summation of the five weighted points provided the overall LOS score.

4. APPLICATION OF THE LOS MODEL

4.1 Boundary Values of Service Levels for the PMs

Travel time

MOE index for this PM was defined as the ratio of the difference between travel times of PBS or BCS and mini bus service, and the minibus travel time on the same route. In the attitude survey, the passengers were asked about their opinions regarding how faster (or slower) PBS (or BCS) compared to a mini bus would be acceptable to them. A wide range of options about the acceptable level of relative speed for the PBS and the BCS compared to a mini bus in percent form was given to the passengers for selection according to their expectation. The collected responses are illustrated with Fig. 1.

Acceptable levels of MOE to defined minimum percentages of passengers were applied as the criteria to establish the boundaries of the six service levels for this PM. Accordingly, it was arbitrarily defined that the MOE value acceptable to at least 50% passengers was the "C" level of service. Similarly, MOE value acceptable to 75% passengers as level B; to 35% as D; to 20% as E; and to less than 20% as F. After defining these minimum percentages of passengers for each LOS category, A to F, the corresponding values of the MOE were obtained from Fig.1. The derived LOS category distribution for travel time PM is presented in Table 1.

Table 1. LOS category distribution for travel time

LOS category	Defined minimum percentage of passengers	Acceptable speed of PBS relative to minibus (from Fig. 1)	Acceptable speed of BCS relative to minibus (from Fig. 1)
A	90	23.4 % greater	26.6 % greater
B	70	10.9 % greater	14.4 % greater
C	50	1.5 % greater	5.3 % greater
D	35	6.7 % lower	3.5 % lower
E	20	15.9 % lower	12.6 % lower
F	< 20	< 15.9 % lower	< 12.3 % lower

Notably, the same travel speed for both PBS and BCS do not indicate the same LOS category for each bus service. This is due to the fact that these categories were defined based on passengers' attitude, and the two passengers groups differed.

Waiting time

Results of passengers' attitude survey were employed in defining the six service levels of this PM. Passengers' were asked about the maximum waiting times acceptable to them with few rational options. Fig. 2 represents the results of the passengers' opinion toward acceptable duration of waiting time for PBS and BCS. Based upon the findings about the acceptable levels of waiting times the required boundary values for the six service categories, A through F, were established. As was done in case of travel time, acceptable levels of MOE to defined minimum percentages of passengers were applied as the criteria to establish the boundaries of the six service levels. The LOS categories thus established for the waiting time PM are presented in Table 2.

Table 2. LOS category distribution for waiting time

LOS category	Defined minimum percentages of passengers	Acceptable maximum waiting time in minutes (PBS)	Acceptable maximum waiting time in minutes (BCS)
A	90	6.1	6.3
B	70	8.2	8.8
C	50	10.5	11.5
D	35	12.4	13.5
E	20	15.0	16.3
F	< 20	> 15.0	> 16.3

Load factor

Load factor compared to legal capacity was taken as the MOE for this PM and legal capacity of buses for Dhaka was estimated according to on-board survey conducted as well as from the instances of predecessor's work (Quium and Tanaboriboon, 1994). The legal capacity of buses related to a standard based on number of seats plus 6 passengers per square meter for the standees was arbitrarily defined as the C level. The lower limit for the E level was defined based on "crush-load" limit of 12 passengers per square meter space for the standees. Ultimately the LOS categories were determined considering standards adopted for Bangkok by Quium and Tanaboriboon, and results of bus-occupancy surveys actually done for Dhaka. Other levels were established in relation to these defined levels. The distribution of LOS categories is presented in Table 3.

Table 3. LOS distribution for load factor

LOS category	Maximum passenger load per capacity
A	0.70
B	0.80
C	1.00
D	1.20
E	1.30
F	> 1.30

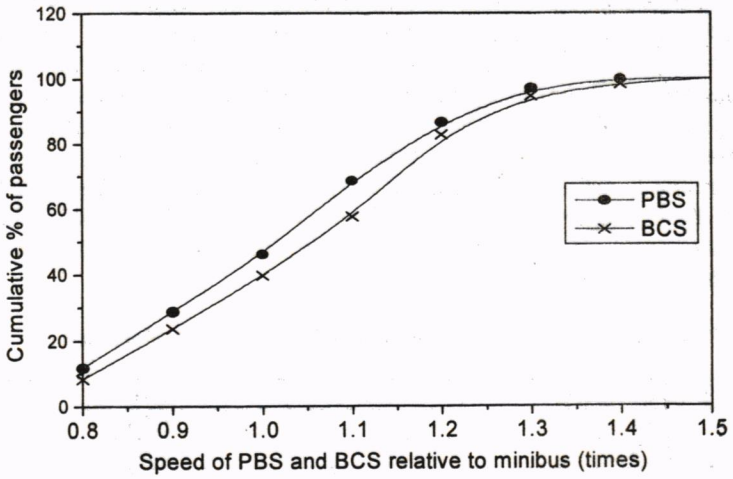

Fig. 1 Travel speed of PBS and BCS expected by the users

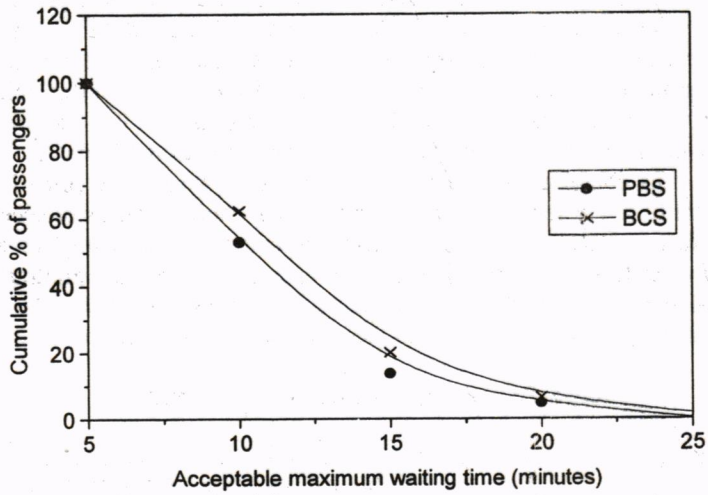

Fig. 2 Maximum waiting times acceptable to passengers

Regularity of service

A passenger- waiting index, W, was calculated from the headway data of PBS and BCS, using equation 2. Reciprocal of W, which indicates, in relative terms, how longer is the estimated waiting time than the waiting time when the services were perfectly regular, was taken as the MOE index for the Regularity of Service PM. Up to 1.5 times of the minimum waiting time (in the perfect condition) was considered arbitrarily as the service level C. Boundary values for the service categories A and E were established considering possible levels close to perfect condition (i.e. when W is nearly 1) and worst performances (based on actual evidences), respectively. Up to 2.0 times of the minimum waiting time in perfect condition was arbitrarily defined as the service category E. A situation worse than this level was defined as the F category. The B and D levels were defined in-between the already defined levels A and C, and C and E, respectively. Resulted distribution of the LOS categories is presented in Table 4.

Table 4. LOS category distribution for regularity of service

LOS Category	1/W
A	1.10
B	1.30
C	1.50
D	1.75
E	2.00
F	> 2.00

Comfort

This PM was defined to be consisting of four constituent elements, namely cleanliness, crowdiness, temperature, and crew behaviour. Each of these elements were placed before the passengers for evaluation on a 5-point scale (0 to 5) where 0 indicated the least acceptance or the worst performance and 5 indicated extreme acceptance or excellent performance. Individual acceptability/ performance index for each element was then calculated for all respondents with the help of equation 3. MOE index for this comfort PM was taken to be the geometric mean of the index values for the four constituent elements of comfort. The value of the MOE index thus obtained must lie between 0 to 1.0; it would give some indication of overall acceptability of the service attribute comfort as a whole, in terms of acceptability of existing performance to that percentage of users (respondents) as given by the MOE index value. A value of at least 0.25 and another value of at least 0.55 were arbitrarily taken to define 'E' level and 'C' level of service, respectively. Other service levels for the comfort PM were arbitrarily defined with respect to these two levels, as given in Table 5, based on rationality.

Table 5. LOS category distribution for comfort

LOS category	Minimum value of the MOE index (i.e. geometric mean of the acceptability indices of the 4 elements of comfort)
A	0.85
B	0.70
C	0.55
D	0.40
E	0.25
F	< 0.25

5. RESULTS AND DISCUSSION

5.1 LOS Scores for Individual PMs

LOS score for travel time

In order to find to which category the travel time of PBS and BCS fell, separate travel time surveys for the PBS, BCS and mini bus service on the same route (Uttara-Motijheel) were conducted, since the MOE index for this PM was defined as the ratio of the difference of travel time of PBS or BCS and the mini bus travel time, and the minibus travel time.

According to analysis of the travel time survey data (not provided in this paper), mean velocity for PBS, BCS, and mini bus service was 21.10, 19.50 and 21.90 mph, respectively. From these data, MOE index values for PBS and BCS were calculated to be 3.65% (slower) and 10.96% (slower), respectively. On comparison of these measured MOE values with the defined service categories in Table A-1 for the travel time PM, it was found that travel time of PBS fell into 'D' category of service and travel time of BCS fell into 'E' category of service. Thus, the travel time PM for PBS got a LOS score of 2 and the travel time PM for BCS got a LOS score of 1. The results are shown below in tabular form.

Table 6. LOS category and LOS score against travel time

Type of bus	LOS category	LOS score*
PBS	D	2
BCS	E	1

***Note:** LOS score against the six service levels are: A=5, B= 4, C=3, D= 2, E=1, and F=0.

Reasons for the low LOS score for travel time PM of both the improved bus services can be realized from the fact that no special priority on the road were provided to these services. They had to run in competition in the mixed mode situation. Moreover, the mini buses used to run desperately amidst the mixed-mode traffic condition which practice would not be attempted by the improved services for the sake of safety of the passengers as well as of the vehicles. However, the BRTA has prepared some draft working papers (Development Design Consultants Ltd. and others, 1996a and 1996b) on PBS, which had proposed special plans of special lanes for bus services, and the travel times of these buses might dramatically improve provided those plans were implemented.

LOS score for waiting time

Mean passenger-waiting time, which was taken as the MOE index, was calculated using equation 1. In order to determine to which category the waiting times of PBS and BCS fell, mean passenger waiting time for each bus service was calculated from the headway data collected from field survey (in January, 1998) and from complementary data taken from the bus operators' Time Keeper Form (TKF).

Based on the collected data, mean, h and coefficient of variation, cv(h) of headway for PBS were found to be 4.90 minutes and 63.88%, respectively. For BCS, these values were 10.08 minutes and 68.35%, respectively. From these mean- and coefficient of variation values of

headway, mean passenger waiting time for PBS was calculated (using equation 1) to be 3.45 minutes. And mean passenger waiting time for BCS was calculated as 7.39 minutes. Comparing these calculated mean values with the defined LOS categories presented in Table 2, it was seen that the waiting time for PBS fell into service category 'A'and the waiting time for BCS fell into service level B. Accordingly, LOS score against waiting time for PBS was 5 and for BCS, it was 4.

Table 7. LOS category and LOS score against waiting time

Type of bus	LOS category	LOS score
PBS	A	5
BCS	B	4

Since the PBS provided very frequent services, the mean passenger waiting time was not long and the PBS on the particular route was found to provide services at A level. Due to somewhat lower frequency of service, estimated mean passenger waiting time for BCS was longer and this bus service was found to providing service at B level. However, as in both the cases estimated waiting times were used, the actual passenger waiting times could be slightly different. But due to high frequency of the services, these were not expected to be much different.

LOS score for load factor

Load factor compared to legal capacity was taken as MOE index for this PM, and legal capacity of bus service was defined as a standard based on number of seats plus 6 passengers per square meter for the standees. It is necessary to mention that average occupancy of PBS and BCS as found from load factor survey data were 28.32 and 45.24, respectively. According to the definition, legal capacity for PBS and BCS were found to be 50.02 and 68.68. Calculated MOE index for the two bus services were 0.57 and 0.66, respectively. On comparison of these index values with the defined LOS categories (Table 3) it was found that load factor for PBS fell into service level 'A' with corresponding LOS score 5, and load factor for BCS fell into service level 'B'with corresponding LOS score 4.

Table 8. LOS category and LOS score against load factor

Type of bus	LOS category	LOS score
PBS	A	5
BCS	A	5

As both the PBS and BCS were operated with all seated accommodation, and moreover, as even all the seats at all times were not occupied by the passengers, both services were found to serve at defined highest category, A.

LOS score for regularity of service

MOE index for this PM was taken as the reciprocal of the passenger-waiting index, W, which was calculated from the headway data through use of the empirical equation 2. The coefficient of variation of headway, cv(h) for both the bus services were calculated from the headway survey data. The cv(h) values for PBS and BCS were found to be 63.88% and 68.09%, respectively. MOE index for PM was defined as reciprocal of W in the equation 2.

Thus, MOE index values for PBS and BCS were calculated to be 1.41 (W=0.70) and 1.47 (W= 0.68).

On comparison of the calculated values of the MOE index with the defined service categories of Table 4, it was found that regularity of service for both PBS and BCS fell into service category 'C', with corresponding LOS score 3.

Table 9. LOS category and LOS score against regularity of service

Type of bus	LOS category	LOS score
PBS	C	3
BCS	C	3

As is evident from the LOS category values, both the bus services were somewhat irregular. But calculated 1/W values for the bus services implied that average waiting time for PBS on this route was 1.41 times longer than the waiting time if the services were perfectly regular, and average waiting time for BCS was 1.47 times longer than the waiting time for perfectly regular services. This meant that service regularity of PBS was little higher compared to BCS. However, the 1/W values also indicate that there was much scope to further reduce waiting time and to improve service level by making the services more regular.

LOS score for comfort

Comfort was defined in this study to be a combined result of cleanliness, crowdiness, temperature and crew behaviour. These components were separately measured in terms of acceptability indices calculated using equation 3, from ratings of each component on a 5-point scale given by respondents of the passengers' attitude survey. The geometric means of the calculated index values for the four elements of comfort for both PBS and BCS were found out to produce overall MOE index values for the PM comfort. Comparing the calculated MOE index values for PBS and BCS with the defined LOS categories in Table 5, operating LOS categories and LOS points against the PM comfort were found, and shown in Table 10.

Table 10. LOS category and LOS score against the comfort

Name of Bus service	Acceptability index values of the constituents				MOE index (Geometric mean of the 4 indices)	LOS Category	LOS Score
	Cleanli-ness	Crowdi-ness	Tempera-ture	Crew behaviour			
PBS	0.8181	1.0000	0.8493	0.8902	0.8868	A	5
BCS	0.7384	1.0000	0.6781	0.8192	0.8003	B	4

Table 10 indicates that the four constituent factors of comfort, namely cleanliness, crowdiness, temperature and crew behaviour were acceptable to 81.81, 100.00, 84.93 and 89.02 percent respectively, of the surveyed premium bus passengers. The corresponding percentage values in the surveyed BCS passengers were 73.84, 100.00, 67.81, and 81.92, respectively. Geometric mean of the four index values for each bus service was taken as the MOE index for comfort. On comparison of this value with the defined LOS categories it was found that in terms of comfort imparted to the passengers, PBS was providing service at A level and BCS was providing service at B level. Corresponding LOS scores for PBS and BCS

were 5 and 4, respectively. Thus it is clear that overall comfort provided by the PBS was obviously better than the comfort provided by the BCS.

The acceptability index values indicated that the crowding in buses for both the services were extremely satisfactory and hence no measure was required to ameliorate the level of crowding. But all the other three aspects called for improvement measures for both the bus services. However, since these three parameters were performing at low levels in BCS compared to PBS, they warranted more attention to take improvement measures.

5.2 Aggregate LOS Scores for Individual PMs for Each Bus Service

In order to aggregate the LOS scores against individual PMs through 'weighted-sum' aggregation method for each of the two bus services, a prerequisite was to find relative importance or weights of the PMs. The technique of Analytic Hierarchy Process (AHP) (Anon., 1992) through the AHP Package Programme was employed to find out relative importance of the PMs. All the five PMs were placed pairwise (a total of possible ten pairs) before the PBS and the BCS passengers for assigning relative importance to the preferred/ over-weighted PMs on a 5-point scale (0 to 5) where 0 indicated equal importance and 5 indicated extreme (relative) importance. The overall weightage given to each of the five PMs by each respondent were then calculated by using a simple AHP model. In this model, the 'GOAL' was taken as 'Determination of relative importance of five PMs' and the five nodes of the model were the five PMs, i.e., travel time, waiting time, load factor, regularity of service, and comfort. Mean weightage for each PM was then found out considering only rational responses of the interviewed five hundred passengers of each bus service. Those attitude-survey responses were considered to be rational, or acceptable, use of which in the AHP model produced an inconsistency ratio not exceeding 3.0 (an arbitrarily defined limit). A total of 308 Premium Bus Passengers and 302 BCS Passengers (out of a sample of size 500 in each case) were found to give such rational responses regarding relative weights of the PMs. The mean weightages for the PMs thus found has been shown in Table 11.

Having obtained the relative importance or weight for each of the five PMs for both the bus services, the assigned points (score) for each operating service-category against individual PM was multiplied by the respective weighting factor to determine the weighted points. The weighted points thus obtained were summed up to give aggregate overall LOS score for a particular bus service. The individual LOS categories together with corresponding weights of the PMs, and the overall LOS scores determined therefrom, are presented in Table 11.

Table 11. LOS categories and weighting factors of the PMs and aggregate LOS score for each of the bus services

Bus type	LOS category and weighting factor (in parenthesis) against the PM					LOS points	Weighted aggregate LOS points
	Travel time	Waiting time	Load factor	Regularity of service	Comfort	Average	
PBS	D (0.209)	A (0.187)	A (0.259)	C (0.139)	A (0.206)	4.0	4.10
BCS	E (0.220)	B (0.178)	B (0.243)	C (0.170)	B (0.189)	3.2	3.17

Notes:
1. A=5; B=4; C= 3; D=2; E=1. 2. Weights of PMs from passengers' attitude survey (not shown)

It is seen from Table 11 that overall LOS score for PBS is greater than that for BCS. Moreover, all the five operating LOS categories against the selected PMs for PBS were either superior or at least equal (in case of regularity of service only) to corresponding LOS categories for BCS.

As judged against defined LOS categories, the operating LOS category against the travel time PM for both the bus services were poor (D for PBS and E for BCS). The reason is, as was mentioned previously, that these improved bus services are not provided with any bus priority privilege on their route, and they are more concerned about safety of the passengers and the vehicle than traveling fast (alike minibus, which runs desperately). If the separate bus routes proposed in the plans prepared by Bangladesh Road Transport Authority (BRTA) (Development Design Consultants Ltd. and others, 1996a and 1996b) are implemented, both the LOS against travel time PM and the aggregate overall LOS might be improved. Regularity of service in the LOS category C for both the bus services. This parameter required to be improved by the operators. All the other three PMs, namely waiting time, load factor and comfort, for PBS fell into A category of service, which implies that these three parameters were in the highest expected performance levels. However, indication directs that these three parameters for BCS called for improvement measures since corresponding each PM was found to lie in B category of service.

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