Level-of-Service Measures for Ferry Systems

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Currently there is no evaluation methodology for monitoring and comparing the adequacy and quality of service on the various routes of ferry systems on the basis of the level-of-service concept. Because the level-of-service concept has been applied so successfully in other modes of transportation, particularly highway and public transit, it was strongly believed that this concept could be applied to ferry service as well, albeit with major modifications. Based on an extensive literature survey, a basic model was developed for application to ferry systems. Eight ferry system performance measures are used as indicators in obtaining the composite level of service; these are accessibility, transit time, frequency, reliability, cost, marketing and planning, passenger comfort, and delay. Collectively these indicators provide the operating characteristics and level of service of the ferry as perceived by its users. Fewer criteria can be used at the discretion of engineers and administrators, for example, accessibility, transit time, frequency, and reliability. The methodology of determining the level of service on a route-by-route basis is described. This research can be implemented immediately by ferry systems, and such implementation will be most useful in monitoring, comparing, and controlling the performance of ferry service as well as in allocating the budget for changes and improvements.

Currently all transit and ferry systems across the nation are suffering from increased operating costs. The need for effective evaluation is most evident for labor-intensive systems, such as ferry systems, that require ever-increasing subsidies; Washington State Ferries (WSF) is a good example.

WSF is the largest ferry system in the nation. It includes about 100 nautical mi and transports more than 17 million persons and 7 million vehicles per year to work, to shop, and to attend school and for recreation and the sheer joy of riding the ferry. There is a direct person-to-person contact between WSF personnel and more than 50,000 paying customers on a daily basis. WSF has the responsibility to provide safe, efficient, and reliable transportation along its routes. Hence the quality of service is extremely important (*1*). Currently WSF does not have an evaluation methodology for monitoring and comparing the adequacy and quality of service on various routes of its system. The basic problem is that of integrating a quantitative evaluation and a qualitative one.

This paper contains the results of research regarding the applicability of the concept of level of service (LOS) measures to ferry systems. Various LOS indicators and service quality variables are considered. Collectively they provide a composite measure of the operating characteristics as perceived by users. This research embodies a preliminary investigation, assessment, and application of the LOS concept to ferry service.

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BACKGROUND

During the past 30 years, the LOS concept has been used with much success as an evaluation tool, particularly in the context of highways, for assessing the quality of service offered. Recently some limited work was done in applying the LOS concept to bus transit. However, there is hardly any literature available on such applications to ferry systems. Complications in applying LOS concepts to ferry systems are obvious because of the plethora of parameters involved. Safety, comfort, accessibility, reliability, efficiency, travel time, fares, and loading and unloading time are some of the parameters included in LOS consideration. In spite of these complications it was strongly believed that the LOS measure would prove to be useful in monitoring and controlling the performance of ferry service. In a secondary sense it was also thought that the concept could be used for budget allocation. The bottom line seemed to be that the LOS measure could be adopted as an integral part of a program to increase ferry system efficiency and productivity.

LOS CONCEPT

The level of service is the overall measure of all service characteristics that affect users. Indeed, having a good level of service is basic in maintaining the current level of patronage and in attracting potential users to the system. Level of service comprises two groups of parameters:

1. Performance elements that affect users, such as operating speed, reliability, fares, and safety (*2*);
2. Transportation hygiene factors, consisting of qualitative elements of service, such as convenience, riding comfort, aesthetics, simplicity of using the system, cleanliness, and behavior of passengers and personnel (*2–4*).

The combined effects of these two categories contribute to the setting up of performance measures for ferry service.

The level of service of a system is based on one or more operational parameters that best describe the operating quality for the system. These parameters are called "measures of effectiveness" and represent those measures that best describe the quality of operation. Each level of service represents a range of conditions for which boundary conditions have been established.

LITERATURE SURVEY

The use of level of service in public transit has a relatively short history. However, because of some similarities this use has a direct bearing on LOS application to ferry systems. In the literature surveyed, "performance measures" (PMs) are a combination of selected LOS indicators or measures of effectiveness.

Of the 30 literature references that had some connection with transit level of service, not a single reference was devoted exclusively to ferries. Some of the references were useful in conceptualizing what PMs to consider for ferry LOS application (*4*). For example, the procedure manual produced by the National Committee on Urban Transportation (*5*) was the earliest attempt to standardize operational characteristics of bus systems on fixed routes. Vuchic's (*6*) attempt to qualify and quantify characteristics of public transportation systems and Botzow's (*7*) application of the conventional A to F LOS categories were important breakthroughs. The Pennsylvania Department of Transportation (PennDOT) procedure guide (*8*) and Southern California Association of Governments (SCAG) Transit Service Policy memorandum (*9*) were aimed at making transit operation as efficient as possible. Research done by Bakker (*10*), Allen (*11*), and Alter (*3*) helped greatly to formalize LOS concepts for public transportation systems. In 1978 the California Department of Transportation (Caltrans) published a report introducing a practical method of applying performance measures (*12*). Public organizations and private researchers have proposed several factors in addition to the ones above (*13–23*).

In the literature review, certain similarities in PMs became obvious and the measures most often used are the following:

1. Route density (transit route miles per square mile),
2. Headway,
3. Speed,
4. Reliability of service,
5. Frequency of service,
6. Capacity,
7. Fare,
8. Comfort,
9. Convenience,
10. Directness of route, and
11. Safety and security.

PERFORMANCE MEASURES

A ferry evaluation methodology is developed that can be undertaken by independent observers familiar with the ferry system. Ferry service characteristics are complex and comparatively difficult to evaluate. They differ from highway characteristics but are in some ways similar to express bus characteristics. The users of the ferry system also differ; there are in-vehicle passengers and walk-on passengers.

One way of categorizing ferry users is by mode of travel to and from the ferry. In a recent survey of weekday riders on WSF, it was found that, in general, 40 percent of the passengers walked aboard (walk-on) and 60 percent drove or were driven on board (in-vehicle). The distribution is different during the weekends, when 26 percent are walk-on and 74 percent are in-vehicle passengers (*1*).

The basic input to the task of selecting potential PMs came from transit literature. Nearly a hundred different PMs were extracted from this review and reduced by elimination on the basis of duplication, relevance to the ferry system, and data obtainability.

At meetings held between personnel from WSF and members of the Washington State Transportation Research Center (TRAC), eight PMs were finally selected. They were to be measured on a scale of A through F, with A representing the best and F the worst. These indicators are discussed in the following sections.

Accessibility

For in-vehicle passengers, accessibility would include the time to buy the ticket for the ferry ride, to get into the correct queue, to wait in the queue, and finally to drive onto the ferry. For walk-on passengers, it would include the time to buy the ticket, to wait, and to walk onto the ferry. The in-vehicle and walk-on passenger times and LOS categories are as follows:

	Time (min)	
LOS Category	*In-Vehicle Passenger*	*Walk-On Passenger*
A	<30	<20
B	30–45	20–30
C	45–60	30–40
D	60–75	40–50
E	75–90	50–60
F	>90	>60

Travel Time

Travel time would include locking the car and going upstairs in the ferry, the ferry journey time, and getting into the vehicle and waiting for the vessel to come to its destination. For walk-on passengers, it would include waiting in the ferry, the ferry journey time, and finally waiting till the ferry arrived at its destination.

Because the general public is familiar with automobiles and transit travel time is often compared with the identical automobile travel time (assuming that the same route was taken), it was believed that ferry travel time should in some way measure the ability of the ferry to compete with the private automobile. Although this comparison is hypothetical, it does serve a useful purpose. Simply stated, the index for this indicator is ferry travel time divided by automobile travel time. Note that in this case ferry access time is not included in the calculation of travel time. The distribution is as follows:

LOS Category	*Index*	*Comparison with Automobile*
A	<1.00	Ferry faster
B	1.00–1.10	Ferry 10 percent slower
C	1.11–1.35	Ferry up to 35 percent slower
D	1.36–1.50	Ferry up to 50 percent slower
E	1.51–2.00	Ferry twice as slow
F	>2.00	Ferry more than twice as slow

Frequency

Frequency of service is really a function of demand. In the final analysis, this PM indicates whether riders are satisfied with the current frequencies. Based on occasional surveys, a feel for the satisfaction or dissatisfaction expressed by the public would be the most pragmatic way of measuring frequency. The adequacy of frequency is as follows:

LOS Category	*Percent of Riders Satisfied*
A	100
B	75
C	50
D	40
E	20
F	0

Reliability

Although adherence to schedule is the popular interpretation of reliability, a more pragmatic way of looking at it is the absence of breakdowns. In the long haul, this interpretation of reliability would involve what percentage of sailings are canceled because of breakdowns per week or per month on a particular route. Another way of looking at this problem would be to determine what percentage of sailings are delayed 60 min or more because of breakdowns. In a way, reliability and delay are related. The LOS distribution based on percentage of breakdowns (percentage of delay of 60 min or more) is as follows:

LOS Category	*Percentage of Breakdowns*
A	0.0
B	0.5
C	1.0
D	1.5
E	2.0
F	>2.0

Cost

The individual cost, or fare, depends upon the willingness of the rider to pay for the level of service offered. In some cases willingness is constrained by the ability to pay and the availability of alternative means of travel. Because one thrust of the LOS methodology is to compare ferry service parameters with those for automobile trips, as in the transit time measure, it is recommended that the "cost" measure involve a quantitative comparison of the fare paid by the ferry rider with the cost of operating a private automobile. This latter cost varies from about 20¢ to 25¢ per mile. Using this criterion, the following LOS measures could be used. An on-board survey followed by a telephone survey of those responding to the on-board survey is the means whereby public opinion on costs and alternative fare proposals can be obtained.

LOS Category	*Passenger Fare (PF) Versus Automobile Operating Cost*
A	PF less or the same
B	PF up to 10 percent more
C	PF up to 25 percent more
D	PF up to 50 percent more
E	PF up to 100 percent more
F	PF more than 100 percent more

Public Information

Public opinion about the availability and quality of public information needs to be surveyed periodically to improve ferry service. On-board opinion surveys can be followed with a telephone survey of those who respond. Certain basic components of public information such as timetables, systemwide maps, maps coordinated with land transit systems, public information telephone numbers, and informational signage in the ferry terminals are most important. LOS categories based on satisfaction with public information are as follows:

LOS Category	*Percent Satisfied*
A	100
B	75
C	50
D	20
E	10
F	0

Passenger Comfort

Good seating, appearance, and cleanliness of the vessel and terminals; appearance and cleanliness of food service; quality of food service; and employee attitudes and behavior are aspects of passenger comfort.

The traditional levels of comfort applicable to transit systems can be included as well: crowding and passenger density, odor, ventilation, noise, vibration, acceleration, and deceleration. These levels of comfort are not considered of prime importance, but should be included in opinion surveys. The distribution is shown below:

LOS Category	*Percent Satisfied*
A	100
B	75
C	50
D	20
E	10
F	0

Delay

Delay represents a reduction in the level of service because of unexpected increases in normal running time. Boarding delays, travel delays, starting delays, and unloading delays are random occurrences reflecting the level of service calculated on a route-by-route basis. All these segments of delay can be aggregated, if necessary, to represent total delay.

Total delay affects computations of overall speed and, of course, travel time. Total delay could be broken down into segments, for convenience, because each segment can be individually corrected. Some planners might argue that ferry service should not be expected to adhere to strict on-time performance because so many factors affect its smooth operation. Weather, for example, is one important factor. Loading accidents could be another. However, total delay, which consists of boarding delays, travel delays, and starting delays, could be measured as shown below:

LOS Category	Delay (min)
A	0
B	10
C	20
D	30
E	40
F	>40

WEIGHTING-FACTOR METHODOLOGY AND RESULTS

The constant sum, paired-comparison method was employed for computing the results (*24*). It serves two purposes: (a) it helps to reduce, if necessary, the list of candidate PMs to a more manageable size; and (b) it formalizes an approach to evaluation of ferry LOS categories with the use of possibly a single index composed of the final PMs determined. The approach was used to rank PMs in order of perceived importance by a mixed group of 300 consisting of engineers, planners, and actual users of the ferry system.

Briefly, the constant sum, paired-comparison method is a systematic approach for determining the relative importance of each of a large number of factors using group consensus. Thus, not only a ranking of factors by importance is obtained, but also the relative importance or weight of each factor with respect to the other items.

The application of the constant sum, paired-comparison methodology to the eight indicators selected yielded the following results:

Rank	Indicator	Mean	SD	Percent
1	E: Cost	.152	.026	15
2	D: Reliability	.146	.020	15
3	B: Travel time	.137	.012	14
4	C: Frequency	.138	.019	14
5	H: Delay	.131	.021	13
6	A: Accessibility	.116	.033	12
7	G: Comfort	.108	.024	10
8	F: Public information	.072	.008	7

These eight indicators were weighted on a percentage basis as indicated in the last column. It is possible to do an extensive survey on a systemwide basis and revise these weights from time to time. It may also be appropriate to develop ranking on a route-by-route basis, if so desired.

The eight indicators (A through H) were measured on a 5-point scale from LOS A = 5 (the best) to LOS F = 0 (the worst). Also, Indicators A, B, D, and H are directly measurable from current data. Indicators C, E, F, and G can be assessed through an on-board or telephone survey.

To use these indicators properly in an evaluation, an aggregation of factors is required.

Finally, each indicator was ranked and weighted according to its importance. Ferry service administrators could develop their own ranking and weighting for the indicators, based on the numerous research survey techniques explored elsewhere. To determine the overall LOS for a particular ferry route, multiply the number of points for the LOS for each indicator by the weighting credits; the total number of points accumulated equals the aggregate level of service.

An example of this procedure follows. Suppose that a ferry route has the following characteristics:

Indicator A: Access time plus loading time = 55 min for in-vehicle passenger and 35 min for walk-on passenger.

Indicator B: The ratio of ferry travel time to automobile travel time = 1.05.

Indicator C: The current frequency of sailings satisfies 42 percent of the riders.

Indicator D: Breakdowns (departing late by more than 60 min) affect 1.2 percent of sailings.

Indicator E: Passenger fare is 8 percent more than automobile operating cost.

Indicator F: Almost every rider is pleased with the public information for the system.

Indicator G: About every other rider feels comfortable with the service provided on board.

Indicator H: Average delay in the sailings is 40 min.

The ranking and weighting of the LOS indicators shown earlier are used to determine the overall level of service for the ferry routes. Levels A through F and the corresponding points are determined from the values provided in this paper. The relevant calculations are as follows:

Indicator	LOS Category	Points	Weight	Total
Accessibility	C	3	.12	.36
Travel time	B	4	.14	.56
Frequency	D	2	.14	.28
Reliability	C	3	.15	.45
Cost	B	4	.15	.60
Public information	A	5	.07	.35
Comfort	C	3	.10	.30
Delay	E	1	.13	.13
Grand total				3.03

Because 3.0 corresponds to LOS C, the aggregate level of service for this route is slightly better than C.

It must be pointed out here that it may be appropriate to use fewer criteria, for example, four or five, purely at the discretion of the service operator.

A step-by-step procedure is given below:

Step 1: Choose a set of criteria.

Step 2: Apply the constant sum, paired-comparison method to determine the relative weight of each criterion. The size of the sample can be determined by applying standard statistical methods. For a group response the means and standard deviations of the values can be determined.

Step 3: After examination of the results, the list of candidate criteria may be reduced, if necessary, and a final list of criteria adopted.

Step 4: The mean values of the criteria finally adopted can be used to rate (or weight) the importance of the criteria.

Step 5: A five-point scale for the six levels of service should be adopted. The points may be adjusted if necessary.

Step 6: "Hard" indicators such as accessibility and transit time are directly measurable from current data, whereas "soft" indicators such as passenger comfort can best be assessed through an on-board survey.

Step 7: Indicators may be aggregated as follows:

a. Assign a level of service to each chosen indicator,
b. Assign a point value to each level (A = 5 through F = 0),
c. Assign a weight to each criterion,
d. Multiply points by weight for each criterion,

e. Add the products to obtain a grand total, and
f. Assign a level of service to this grand total.

USES AND BENEFITS

There appear to be at least four primary applications of the results of this methodology. First, the results form a tool to guide decision makers in evaluating the quality of ferry service being delivered. Second, they identify what can be considered an ideal route or benchmark with which other routes can be compared on the basis of either individual attributes or aggregate values. The third primary application is as a planning tool to develop future perspectives of ferry service. The fourth application is for use in budgeting funds for route improvements. There are probably other uses as well.

The need for further refinement and verification of the research methodology used here is clearly indicated. The performance measures must be used over a period of time to verify that they are methodologically appropriate and that the results they produce truly reflect the quality of ferry service being evaluated. The ranges of values proposed for the various measures must be further verified and refined (if needed) by obtaining operational data for a wider array of ferry service configurations. It may also be necessary to decrease the number of indicators if data gathering poses a problem.

CONCLUSION

The increasing necessity to evaluate public transportation services has created a need for a methodology. Two key independent combinations of factors can be directly controlled by policy makers: transportation hygiene factors and LOS indicators. Of these two, only LOS indicators can really motivate potential riders. Nevertheless, poor transportation hygiene factors discourage potential users.

It is vital to perform this evaluation regardless of the level of public funding for ferries. It is only through a thorough evaluation that decisions based upon objective facts may be made. The evaluation model contained herein may contain subjective values: it is a starting point for further analysis and refinement. It should be remembered, however, that any evaluation methodology developed will contain some subjective concepts. This evaluation procedure using the LOS concept provides a useful framework for ferry service administrators, professionals, and decision makers to evaluate ferry service on a route-by-route basis.

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