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Publication of this paper sponsored by Committee on Bus Transit Systems.

Abridgment

Service-Sensitive Indicators for Short-Term Bus-Route Planning

ALAN J. HOROWITZ

Transit performance indicators are useful means of monitoring existing systems and planning for future systems. The development of one type of transit performance indicator, a service-sensitive indicator, is discussed. The purpose of the service-sensitive indicator is to succinctly summarize the effectiveness and fairness of short-term route changes. Included in the indicator are considerations of the important performance variables perceived by riders: in-vehicle time, transfer time, walking time, waiting time, requirements to wait, and requirements to transfer. The service-sensitive indicator is applied to a case study—the improvement of transit service to the Milwaukee County Institutions Grounds, where major public medical care facilities are located. Because questions of equity are of greatest importance, the indicator is separately calculated for each of the potential rider groups. It is shown that the indicator measures the impacts of route alignment and route extensions on relevant population groups and does so without the need for extensive travel survey data.

Recently, there has been an increasing emphasis on the need to provide high-quality yet efficient public transportation services to all segments of the population and throughout urban areas. This emphasis has led to provision of services to population segments such as the elderly, the disabled, women, minorities, and low-income individuals. In addition, efforts have been made to offer convenient service to locations that provide different types of facilities and services, such as jobs, health care, education, recreation, and shopping. Consequently, transit operators have been faced with both the task of monitoring how well their systems serve diverse segments and geographic areas and the responsibility for developing new routes and schedules to remedy perceived deficiencies.

Systemwide indicators of transit performance have been developed to provide operators with information on how effectively and efficiently they are serving their communities. Examples of systemwide indicators are revenue passengers per service area population, revenue passengers per vehicle hour, and percentage of population served (1). Indicators such as these permit the operator to determine whether the transit system is improving over time and whether its quality of service is comparable to that of transit systems in similar communities. However, systemwide indicators are not prescriptive. Many potential short-term route or schedule changes are not revealed by using these overall aggregate measures.

If indicators are to be truly useful for planning system improvements, they must be "service sensitive". That is, a route or schedule change that qualitatively improves service should be reflected as a significant quantitative change in the appropriate indicators. Service-sensitive indicators should determine whether proposed system modifications are suitable, are efficient from current riders' perspectives, and are adequately serving groups of potential riders. Furthermore, service-sensitive indicators should be simple to calculate by using data normally available to transit operators, and they should not require extensive statistical analysis or model calibration.

The purpose of this paper is to demonstrate that service-sensitive indicators can be useful for short-term transit route planning and scheduling. A quality-of-service indicator is developed and applied to a route-planning problem in which equity issues are of paramount importance. Specifically, the problem concerns providing better transit service to the Milwaukee County Institutions Grounds (MCIG), where all the important county medical facilities are located. The example is particularly interesting because transit access to the location from low-income areas of Milwaukee is poor.

SERVICE-SENSITIVE INDICATOR

If a service-sensitive indicator is desired, then it should be based on a concise definition of service quality as perceived by riders. Surveys of current and potential bus riders have led to a better understanding of the notion of service quality (2,3). Riders want to reach desired destinations; they want to do so quickly and reliably. They want to avoid walking, waiting, transferring, or standing while riding. They want protection from weather, but they attach little importance to physical luxury while traveling.

For questions of equity, systemwide indicators may be made more service sensitive by simply breaking them down by population segments or by geographic areas. Rather than the percentage of the total population served, it is helpful to know the percentage of elderly, handicapped, economically disadvantaged, etc., within the service area. The decision as to which segments should be identified will depend on the reason behind the modification of the system.

The service-sensitive indicator developed in this paper is specifically designed to determine whether people have adequate access by transit to a major trip generator. The indicator is constructed by counting numbers of potential riders who can conveniently reach the destination of interest by transit. Of course, not all potential riders use transit to reach this destination. We are concerned with how many people have the opportunity to use the transit service, independent of whether they actually choose to travel by transit, by another mode, or not at all.

The difficulty in creating this indicator lies in producing a suitable measure of "convenience". In this paper, convenience is defined by using a psychological scale of the time spent in bus transit travel (3). The psychological scale provides ratings of major elements of transit travel: riding time, waiting time, transfer time, walking time in fair and poor weather, requirement to transfer, requirement to wait, riding time while standing, and multiple transfers.

The psychological scale was created by a technique known as magnitude estimation (4,5). A series of questions asking for a comparison between two trip descriptions was administered to 84 Chicago residents. The first trip description had a previously assigned numerical value and was used in every question for a particular respondent. This trip description was individually selected to be an everyday trip for each respondent. Respondents were asked to rate the second trip description in each question as a fraction or multiple of the first, making sure that the worst of the two trip descriptions was rated higher. By this means, 115 trips by bus transit, automobile, and walking were rated. Trip descriptions were created to isolate the effect of a single aspect of a trip--its purpose, mode, environmental conditions, requirement to transfer, waiting time, etc. Then, through statistical analysis [described fully elsewhere (3)], the contribution of each aspect to a trip-description rating could be computed.

The resulting ratings were on an arbitrary numerical scale. In order to render the ratings more concrete, they were mapped onto a scale representing minutes of travel to work by automobile. For example, if both a 20-min bus-transit trip with a 10-min wait and a 55-min automobile trip had ratings of x, then the bus-transit trip is evaluated to be equivalent to 55 min of automobile travel. The actual value of the ratings, x, becomes unimportant. Thus, there are two types of minutes used in the following analysis: actual and equivalent. It is important to note that a bus-transit trip that has a rating equivalent to 55 min of automobile travel represents substantially less bus-transit travel time. In this example, the actual bus-transit trip takes 30 min. Measuring the convenience of bus-transit trips in equivalent minutes of automobile travel has three advantages:

1. It is directly based on how riders and potential riders evaluate bus-transit trips.
2. It provides a means of comparing bus-transit trips in a consistent set of units.
3. It provides an immediate comparison with the most important competitive mode, the automobile.

The relation between equivalent automobile time and actual bus-transit time is summarized below:

Trip Element	Bus Travel Time (min)	Equivalent Automobile Travel Time (min)
In-vehicle time	10	13.2
	20	24.5
	30	35.2
	40	45.5
Wait time	5	11.0
	10	21.1
Wait requirement	0	9.9
Transfer time	5	10.0
	10	20.0
Transfer requirement	0	28.0
Fair-weather walking time	5	6.6
	10	13.3

The distinctions made here between wait requirements and waiting time and between transfer requirements and transfer time are not typical for bus-transit planning. The ratings show a strong unwillingness on the part of respondents to either transfer or wait. Once these wait and transfer requirements have been established, additional excess time is rated at about twice automobile travel time. Waiting, transferring, and walking are all represented in the table as occurring under fair-weather conditions. Riders are also assumed to have seat availability.

The ratings from the Chicago residents did not vary according to socioeconomic or personal characteristics of the respondents (3), and the ratings are consistent with value-of-time studies conducted in a variety of cities. Residents of Milwaukee, a city very close to Chicago in location and socioeconomic makeup, would not be expected to produce significantly different ratings.

The quality-of-service indicator is constructed by using a two-step procedure: (a) setting an automobile travel-time standard and (b) counting the number of persons in the appropriate population segment who can travel to the designated destination within that travel-time standard. Separate indicators are calculated for each population segment of interest. It is likely that a single standard will emerge as best for a particular planning problem.

CASE STUDY

MCIG is the location of major, publicly provided health care facilities and extensive private health care facilities within Milwaukee County. Approximately 8000 employees and 8000 nonemployees visit MCIG on any given weekday. MCIG is inconveniently located 6 miles to the west of the Milwaukee central business district (CBD). MCIG is well served by highways, but it is inadequately served by transit. Only three bus routes are near MCIG, and two of these bus routes serve the same east-west corridor. At its closest point, the single north-south route is 0.4 mile from the heart of the MCIG medical facilities.

The inadequate transit service to MCIG makes access for inpatients and outpatients especially difficult. Unlike most medical facilities, which draw their patients from proximate areas, patients coming to MCIG are heavily concentrated in an area just west, northwest, and southwest of the Milwaukee CBD. About 50 percent of MCIG patients reside in the "target area" shown in Figure 1. MCIG patients tend to be low income, and they are heavily dependent on publicly provided health care services.

Figure 1. Current Milwaukee County bus-transit service areas as defined by 30-, 60-, and 90-equivalent-min standards.

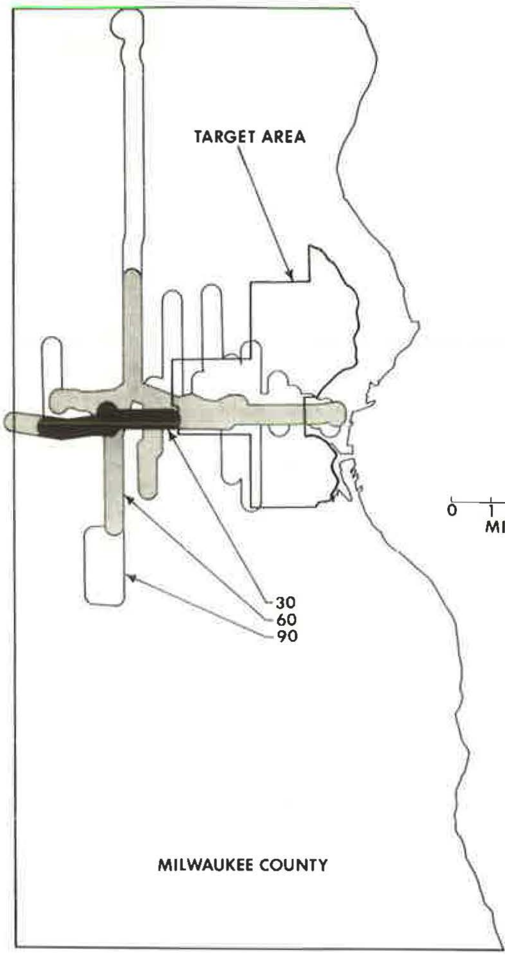

Table 1. Route alternatives for bus service to MCIG.

Alternative	Type	Description	Estimated Cost per Day ($)
A	Do nothing	Existing system	0
B	Alignment	Reroute 67, 71, and 10 into MCIG (current plan)	169
C	Extensions	Reroute 67, 71, and 10 into MCIG; extend 22 (on the north) to MCIG and open a loop within target area; branch 18 (on the south) to MCIG	1042
D	Extension-express	Reroute 67, 71, and 10 into MCIG; branch 18 (on the south) to MCIG; provide new north-south route in the northern target area with an express, freeway segment to MCIG	1127

The objective of the case study was to determine whether short-term route changes would improve transit access for MCIG nonemployees. Service-sensitive indicators, as discussed in the previous section, were computed for various alternative route changes and for segments of nonemployees, employees, and the general population. Indicators were then compared to determine whether any of the alternatives were promising. The alternatives are summarized in Table 1.

In order to simplify calculation of the indicators, it was assumed that bus-transit riders would walk as far as 0.25 mile from their residences to a transit stop. This initial walk was not included in the measure of convenience. A walking speed of 3 ft/s was used to calculate final walking time between the bus route and the front door of the Milwaukee County General Hospital. Waiting time and transfer time were taken as half the headway of the appropriate route. Bus speeds on all streets and headways were for midday and were derived from timetables published by the Milwaukee County Transit System.

Table 2. Percentage of population segment served by bus-transit alternatives under 90-equivalent-min standard.

	Alternative			
Subgroup	A	B	C	D
Mental health patients	25.3	29.7	37.8	38.3
Hospital inpatients	26.0	29.7	41.0	41.7
Hospital outpatients	21.0	28.3	39.4	40.6
Medical students	42.7	53.9	57.5	55.8
Employees	23.0	29.6	34.2	32.5
General population	17.9	21.6	26.7	26.2

A 90-equivalent-min standard has been selected, primarily to yield an understanding of how well the target area is served. Figure 1 shows the existing service area as defined by 30-, 60-, and 90-equivalent-min standards. The target area is not served at all under the 30-min standard and is only minimally served under the 60-min standard. Western and central portions of the target area are served under the 90-min standard, although the total service area is still relatively small. The 90-min standard is used for the remaining indicator calculations.

The impacts of alternatives B, C, and D are summarized by the indicator values given in Table 2. The current plan of the Milwaukee County Transit System (alternative B) substantially increases the area within the 90-min standard at a small daily cost. For the various categories of patients and for employees, the increases in percentage served are between 3.2 and 7.3 percent; for medical students, the increase is 11.2 percent. Alternatives C and D, which call for new route segments, offer greater positive impact than alternative B but are much more costly. Alternatives C and D have almost identical impacts at identical costs. Table 2 indicates that these alternatives have the greatest impacts on patients; in relation to service to medical students and employees, they do not greatly improve on alternative B.

Although it is not the purpose of this paper to recommend particular alternatives, some conclusions as to the effectiveness of the plans can be drawn. The Milwaukee County Transit System plan (alternative B) appears meritorious because of its low cost. However, this plan only partly alleviates the problem of inadequate service to MCIG. The alternatives that include extensive route modifications (alternatives C and D) represent positive improvements but are also considerably more expensive than alternative B. Fortunately, bus-transit operators need not commit themselves to more than one route extension at a time. Alternative C would lend itself to piecemeal implementation, and an evaluation of generated revenues could be made after each new route extension had been introduced.

CONCLUSIONS

The advantages of service-sensitive indicators over other planning methods are emphasized by the MCIG case study. For example, travel demand models would have been useful in evaluating the alternatives, but it is unlikely that credible models could have been developed for population segments as unique as mental health patients.

The indicators were service sensitive without obviously exaggerating the magnitudes of impacts. The differences in routes between plans were small, but the indicators demonstrated which subgroups benefited most and revealed the relative magnitude of the benefits.

The measure of convenience, although adequate for the MCIG case study, is not complete. For route-planning problems where high load factors exist, the measure of convenience should be extended to include seat assurance (3). In communities where weather conditions are sufficiently poor to discourage walking, waiting, and transferring, the measure of convenience would require larger penalties associated with these trip elements (3). Once the definition of convenience has been established, required computations are straightforward and inexpensive.

Any additional service to one particular major trip generator will increase ridership to other locations as well. The indicator presented here is not directly applicable to estimating numbers of potential riders. However, methods have been developed for predicting ridership on the basis of population within walking distance of new bus routes (6), a measure similar to the indicator presented here. Further research into the relation between indicator values and ridership would be a beneficial step in improving current transit planning techniques.

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Publication of this paper sponsored by Committee on Bus Transit Systems.

Houston's I-45 Contraflow Transit Project

ROBERT N. TAUBE AND CHARLES A. FUHS

A general report on the unique characteristics and results of Houston's North Freeway contraflow operation is presented, including the overwhelming response to the project by both bus and vanpool patrons. The North Freeway (I-45) Contraflow Transit Project began operation in August 1979 as Houston's first major effort to provide freeway preferential treatment for transit movement. The facility provides a daily travel-time saving of approximately 30 min during the line-haul portion of the commuting trip. Use of the lane is restricted to authorized vehicles, which include registered and approved buses and eight-passenger vanpools. The North Freeway project is the longest contraflow project in the country [15.4 km (9.6 miles)], the first to operate in both the morning and evening peak periods, and the first to restrict lane use to authorized vehicles that display an appropriate permit. In the first 44 weeks of operation, bus ridership increased by 227 percent and vanpool ridership increased by 114 percent. The project was initiated as an 18-month demonstration project sponsored in part by the Service and Methods Demonstration program of the Urban Mass Transportation Administration. The success of the project has led to a decision to continue operations beyond the demonstration period.

In 1974, shortly after the city of Houston purchased the local bus system from a private operator, discussions with the Texas State Department of Highways and Public Transportation (TSDHPT) were held regarding provisions of preferential treatment for transit. The North Freeway (I-45) was first recognized as appropriate for the application of a technique identified as "contraflow" in January 1975 (1). By March 1975, the Houston City Council authorized the Office of Public Transportation (OPT) to submit an application to the Urban Mass Transportation Administration (UMTA) requesting funds for initiation of preferential treatment on Houston freeways, specifically including contraflow on the North Freeway. In June 1975, UMTA approved a Service and Methods Demonstration (SMD) program Section 6 grant (under the Urban Mass Transportation Act of 1964, as amended) to implement corridor preferential treatments in Houston.

TSDHPT confirmed the feasibility of contraflow in March 1976 and by June 1977 had submitted final plans to the city along with approval from TSDHPT administration and the Federal Highway Administration (FHWA). In order to fully cover the costs of construction as they were defined, in November 1977 the city of Houston applied for and received an additional UMTA Section 5 grant (under the Act as cited above) (2). One week later, TSDHPT let bids for construction of contraflow. TSDHPT was also retained to supervise construction of the project. Construction began in February 1978 and was completed about 16 months later.

As part of the operations agreement reached with TSDHPT to supervise construction of the contraflow project, the city of Houston committed itself to operate the project and "prior to the commencement of such operation...the City's and State's authorized representatives shall promulgate and file an operating plan for the Project." No contraflow-lane (CFL) operation was to begin until this plan was approved and an ordinance duly enacted. The Metropolitan Transit Authority (MTA) assumed responsibility for this effort from the city upon the formation of MTA in 1979. The operating plan finalized and made legal the following: (a) operating hours and schedule, (b) requirements for authorized vehicles, (c)