An Assessment of the User Benefits of Intercity Bus Service

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Benefits of intercity bus service are examined, and methods to estimate them are proposed. Benefits occur to both users and nonusers. User benefits include travel cost savings, improved convenience, and reduced travel time as well as benefits to freight users. Nonuser benefits include option value, merit value, and perception of community accessibility. Benefits to users are estimated by comparing the disutility of travel by intercity bus to travel by automobile or some other intercity bus route. A model is developed to calculate a benefits index of a given bus service as a function of the characteristics of automobile and bus travel, user characteristics, and modal preference parameters. Sensitivity analyses were conducted and indicate that the level of benefits is highly sensitive to the isolation of a route and to the cost of automobile travel. Other factors such as value of time, out-of-vehicle time weight, out-of-vehicle time, and percentage of captive users have a more moderate effect.

In the aftermath of federal deregulation of the intercity bus industry, considerable attention has focused on the actual or potential loss of intercity bus service in small communities and rural areas across the nation. Much of the discussion has centered on the impact of deregulation in general *(1, 2)*, on small communities *(3)*, and on approaches for addressing the loss of bus service such as subsidies or alternative rural transportation systems, or both *(4)*. In the recent literature, the question of whether intercity bus service should be subsidized has been generally addressed by examining the cost structure faced by the carrier for any particular route and showing that costs exceed revenues *(5)* or by assessing the "need" for service *(4)*. Although theory indicates that a subsidy is warranted only if social benefits exceed social costs, no one has attempted to evaluate rigorously the "benefits" of intercity bus service. To accurately assess the appropriateness of a subsidy for intercity bus service, however, the benefits of intercity bus service must be estimated.

In this paper a procedure for estimating the benefits of intercity bus service is documented. The paper includes a conceptual framework, a model for estimating passenger benefits of intercity bus service, and an application of the model to case studies of two intercity bus routes in Wisconsin, which are currently receiving federal Section 18 subsidies. The paper ends with a discussion of the policy implications of the research and conclusions. For the purposes of this paper, intercity bus service is defined as regularly scheduled line-haul service available to the fare-paying public traveling between two or more cities. Further details on the project are available in a report to the Wisconsin Department of Transportation *(6)*.

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CONCEPTUAL FRAMEWORK

The literature on cost-benefit analysis provides a general outline for assessing the benefits of transportation projects [e.g., Wohl and Martin *(7)*, Mohring and Hartwitz *(8)*, and Manheim *(9)*]. The benefits of transportation projects are commonly identified in terms of user and nonuser benefits.

User Benefits

User benefits of a transportation service are customarily measured by the user's willingness to pay for the service as reflected by the area under the demand curve. To derive the "net" user benefits of a transportation service or project, however, the difference in willingness to pay between this service or project and the next best alternative must be derived.

At present, the consumer-surplus and user-cost measures are the most commonly used ways to evaluate user benefits in transportation projects *(9)*. In this paper the consumer-surplus view has been adopted because, conceptually, it adheres most closely to economic theory and because it is more appropriate when the demand curve is inelastic as it is in the case of demand for intercity bus by most users.

User benefits accrue to passengers and freight shippers and receivers. Essentially, users of intercity bus services benefit by the amount that the intercity bus is cheaper, more convenient, faster, and so on than the next best available mode. User benefits are characterized in terms of differences in user costs (disutility savings) between the bus and alternative modes. Conceptually, passenger benefit of an intercity bus trip between two places is simply the difference between the disutilities of the next best alternative (automobile or another bus route) and the intercity bus.

The question of freight benefits can be handled in a similar manner. Benefits accrue from freight service because intercity bus service has some advantages over alternative freight carriers. In general, intercity bus is used for freight purposes because of a time advantage or because of more liberal commodity or weight limits. In Wisconsin small package service appears to be dominated by other carriers (chiefly United Parcel Service) and intercity bus appears to be used only for certain commodities that cannot be accommodated by the other carriers. Intercity bus is used primarily for delivery of fresh flowers, blood, large automobile parts, and certain documents.

Freight benefits can be calculated using a procedure analogous to that used for passenger benefits.

Nonuser Benefits

In addition to direct benefits to users of bus services, it is often argued that nonusers benefit from public bus service *(10)*. Nonuser benefits include option value, merit value, and perception of community accessibility. Option value refers to goods or services that are used as a backup for another good or service or that will be valuable in the future. For example, the intercity bus has option value to those who would use it if their car broke down. Option value benefits can be measured using the disutility savings framework introduced previously. The main difference is that the probability that nonusers will have to resort to the intercity bus must be factored in *(6)*. Urban public transit and intercity bus service also are considered to have merit value in that many individuals (users and nonusers) would be willing to pay something to assure that these services are available to the public. A third nonuser benefit relates to positive externalities associated with intercity bus service. it has been suggested that communities "perceive" an accessibility benefit because intercity bus service may be the only public link for small communities to other communities *(11)*. However, the magnitude of this benefit, real or perceived, is difficult to gauge. On the one hand, it entails assessing the impact of intercity bus service on business productivity (and on the number of businesses that moved into or did not leave the community) and on job accessibility as well as other real impacts *(12)*. On the other hand, the perceived benefit of community accessibility in general must be assessed. The conclusions of two studies suggest that these external effects of intercity bus service on small communities are negligible *(3, 11)*.

MODELS FOR ESTIMATION OF USER BENEFITS

To compare the user benefits of intercity bus service, a model was developed to allow the characteristics of alternative modes of transportation to be compared on a similar basis. The model is based on the concept of travel disutility. The disutility of a trip is a combination of its time, cost, and inconvenience. For this project disutilities were calculated as follows:

$$DU_{ijm} = IV_{ijm} + C_1{*}OV_{ijm} + CT_{ijm}/C_2 + C_{3m}$$

where

D_{ijm} = disutility of a trip between town i and town j using mode m (measured in minutes);
IV_{ijm} = in-vehicle time using mode m between town i and town j;
OV_{ijm} = out-of-vehicle time between town i and town j using mode m;
CT_{ijm} = cost of travel between towns i and j using mode m;
C_1 = out-of-vehicle time multiplier used to represent the inconvenience of waiting and so forth; 1 min of OV time = C_1 min of IV time;
C_2 = value of time in dollars/minute; and
C_{3m} = mode bias factor that represents negative aspects associated with travel using mode m, such as discomfort or inconvenience of schedule, in units of minutes.

This equation is similar to that which is used in logit mode choice models in urban travel demand analysis.

In-vehicle time is the length of the trip divided by speed. Out-of-vehicle time is a fixed amount (different by mode) that represents the time it takes to wait for and board a vehicle. The cost of the trip is either the bus fare for a bus trip or the product of the trip length and a given cost per mile for an automobile trip. The benefits of a mode can then be represented by the difference between its disutility and the disutility of the next best choice. For instance, given the choice of bus or automobile for traveling to another city, the benefits of the bus would be the net savings it provides over automobile in terms of disutility.

For this analysis intercity bus transportation was compared only with automobile and other intercity bus services. Other possible alternatives (i.e., air and rail) were not considered in the framework because the focus was primarily on small, rural Wisconsin towns that usually do not have access to air or rail transportation for intercity trips within the state.

Extensive sensitivity analyses were conducted to determine the effects of various parameters on overall results. The parameters that varied were out-of-vehicle time multiplier, value of time, mode bias factor, length of trip, access distance, relative speed (bus versus automobile), relative cost (bus versus automobile), and degree of captive ridership.

GENERAL SCENARIO

To examine the relative benefits of intercity bus travel and automobile travel, a general scenario was established. The scenario assumes a direct intercity bus route was in existence between town i and town j (Figure 1) and has been discontinued. Individuals wishing to travel from town i to town j now have two choices: to travel directly by automobile to their destination (direct automobile trip) or to travel to the nearest bus station in another town (x) and then take an alternative intercity bus to town j. When travelers reach the terminal in town j they complete the trip to their destination by local travel. This second type of trip is referred to as an auto-bus-auto (ABA) trip.

The disutility of bus trips needs to be modified to include the access and egress portions of the trips, calculated as follows:

Direct bus service between i and j

$$\text{DUB} = A_{oi} + B_{ij} + E_{jd}$$

Bus service between i and x and j, x, and j

$$ABA = A_{ox} + B_{xj} + E_{jd}$$

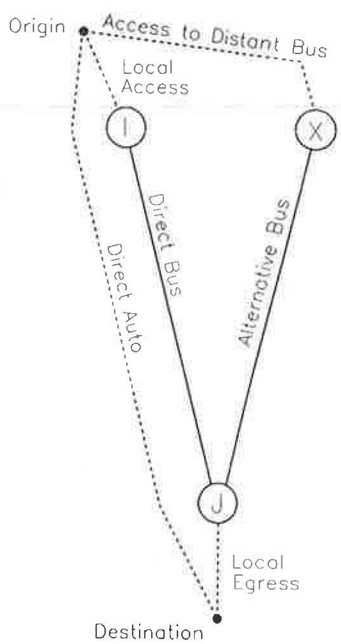

FIGURE 1 General case study.

where

- DUB = disutility of a direct bus trip between an origin in city i and a destination in city j,
- ABA = disutility of an ABA trip using an intermediate terminal in town x,
- A_{oi} = access disutility between origin and a terminal in town i,
- A_{ox} = access disutility between origin and a terminal in town x,
- B_{ij} = bus service disutility between terminals, and
- E_{ij} = egress disutility between terminal in destination city and final destination.

The calculation of automobile disutility is similar in that it also includes local access components in the origin and destination cities. The all-automobile trip has three components of in-vehicle time (for local driving at the origin city, for city to city travel, and for local driving in the destination city) and single out-of-vehicle time, cost, and mode bias coefficients. The disutility of an automobile trip is as follows:

$$ADU = (IV_{oi} + IV_{ij} + IV_{jd}) + (C_1 * OV_{oi}) + (CT_{od}/C_2) + C_3$$

The disutility of an automobile trip is further modified to account for captive users. If a person is a captive user (i.e., unable to use an automobile), it is assumed that the disutility of the automobile portion of the trip would double to account for the disutility of the person who drives to the destination or to the terminal. That is, it is assumed that the traveler would have to compensate a driver by an amount equal to the disutility the driver incurs to make the trip. The disutility of the driver is double because only one-way trips from town i to town j (and not the return trip) are considered.

The disutility of an automobile trip is then its disutility as given previously plus the disutility multiplied by the percentage of captive users to represent these second trips. Thus, because the cost of travel is still paid only once for a vehicle, this is subtracted from the total. The disutility of an automobile trip is then

$$DUA = ADU_{ij} + PC * ADU_{ij} - PC * CT_{od}/C_2$$

where

- PC = portion of users who cannot use an automobile for the trip,
- AU_{ij} = disutility of the automobile trip between town i and town j, and
- CT_{od} = amount of pocket cost of the trip by automobile between the origin and the destination.

It should be noted that DUB and ABA are modified for captive users in a similar way for the access and egress portions of the trip. That is, the disutility of the access and egress portions of the trip is increased to take captive trips into account.

Disutilities are calculated for an all-automobile trip and an ABA trip and compared with the disutility of the original bus trip to determine the disutility savings of the intercity bus service. The savings in disutility (DUS) for an intercity bus trip is then

$$DUS = \text{Min} \begin{cases} DUA - DUB \\ ABA - DUB \end{cases}$$

The disutility savings have to be greater than zero for there to be any direct benefit of intercity travel.

Finally, the disutility savings is calculated for all stations along a bus route, multiplied by a population weight, and divided by the value of time to create the benefit index for a particular transit route:

$$BI = \Sigma\ (DUS_k * PW_k) * C_2$$

where

- BI = benefits index;
- DUS_k = disutility savings of intercity bus at town k in minutes;
- C_2 = value of time in cents per minute; and
- PW_k = population weight for station k; this is an indicator of the activity of station k; ideally it is the number of boardings, but could also be given as follows

$$PW_k = (T * P_k)/\Sigma\ P_k$$

with

- T = annual trips on the route and
- P_k = population of town k.

This equation yields a number that represents the dollar equivalent of the disutility savings for all users along an intercity bus route. It is referred to as a benefit index rather than simply as the benefits of a service because it does not include nonuser or freight benefits. These should be separately recognized when benefits of a service are being analyzed.

APPLICATION

Two intercity transit routes in Wisconsin were examined to demonstrate the use of the model as a means of calculating the relative benefits of different intercity bus routes. The cases used were bus service between Green Bay and Milwaukee via Plymouth, Wisconsin (Green Bay–Milwaukee) and service between Ashland and Abbotsford, Wisconsin. These services are shown in Figures 2–4. Each route is served by one bus a day in each direction. The Milwaukee–Green Bay route has alternative service available relatively close by (Figure 3) and is located in a populous area of the state. The Ashland-Abbotsford service is isolated from other services and located in a sparsely populated part of the state.

A spreadsheet program was developed to calculate the benefits index for these two routes under a variety of conditions. The purpose of this analysis was to test the model and to determine its sensitivity to the various assumptions used. Furthermore, it was used to demonstrate how the model could be used to assess the merits of a particular service for public assistance. A base case was developed and then varied in a sensitivity analysis. The parameters for the base case are given in Table 1. Initially it was assumed that 50 percent of the users had no automobile available for the trip and that annual ridership was 1,000 users in each direction.

TABLE 1 PARAMETERS FOR BASE CONDITIONS

Parameter	Value
Automobile	
Cost/mi	25.00 cents/mi
Rural mph	50.00 mph
City mph	25.00 mph
OV time	5.00 min
Bus	
Cost/mi	14.04 cents/mi
Rural mph	45.00 mph
OV time	5.00 min
Captive ridership	50.00%
Disutility coefficient	
C_1	3.00 min/min
C_2	8.33 cents/min
C_3	
Bus	20.00 min
Automobile	0.00 min
Distance	
Access	1.00 mi
Egress	5.00 mi
Route	60.00 mi
Nearest bus	20.00 mi

Using these values, the benefits index for the Green Bay–Milwaukee route is $3,727 or $1.86 per trip and $7,453 or $3.73 per trip for the Ashland-Abbotsford route. There is a difference between the two routes primarily because the Ashland-Abbotsford route is more isolated from other service (an average of 35.6 mi) than is the Green Bay–Milwaukee route

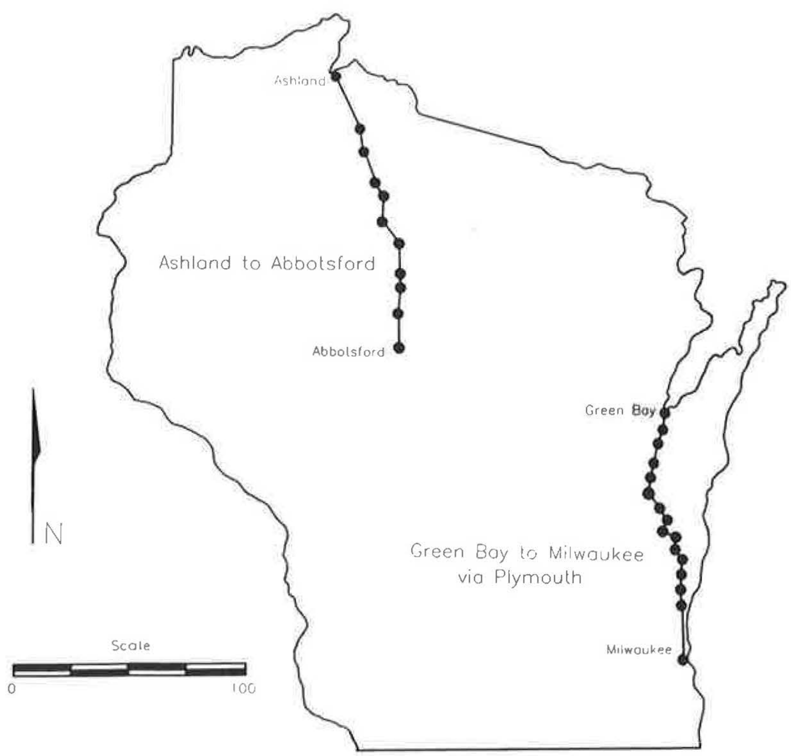

FIGURE 2 General location of test routes.

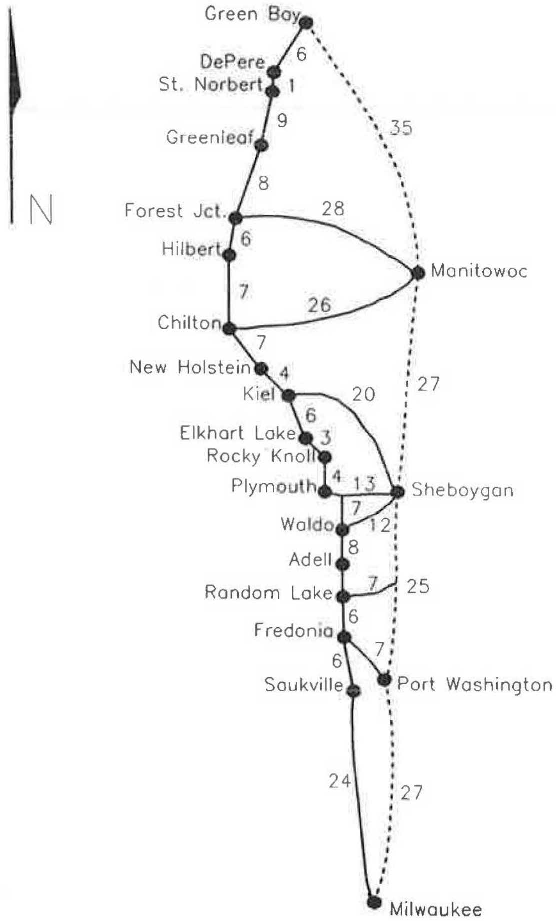

FIGURE 3 Green Bay–Milwaukee route via Plymouth (numbers are distances in miles).

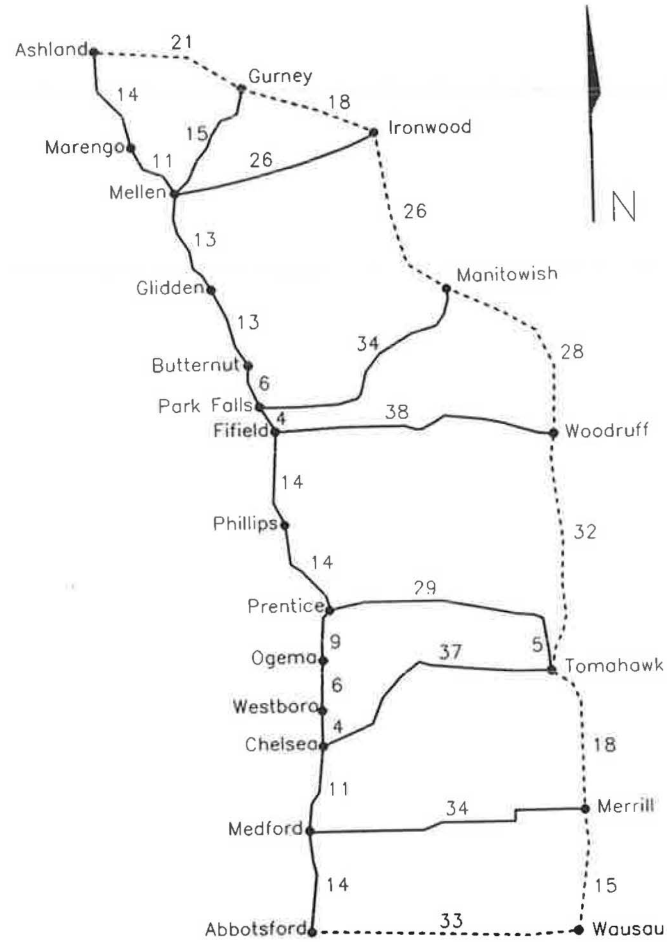

FIGURE 4 Ashland-Abbotsford route (numbers are distances in miles).

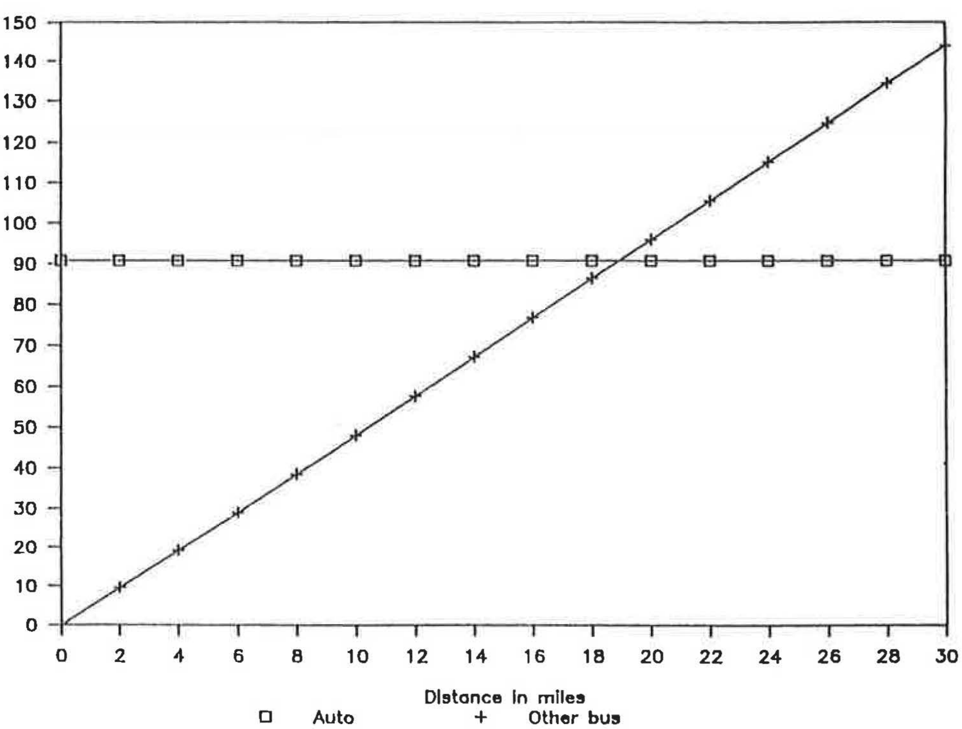

FIGURE 5 Vary distance to nearest alternate bus.

(an average of 15.4 mi). This leads to a larger gap between disutilities of the modes and hence a larger benefits index. This effect can be seen in Figure 5, which shows the effect of the distance to the nearest bus on the disutility calculation for a given station. A 100-mi station-to-station trip is assumed with alternative bus service at a varying distance away. Here the alternative bus is the next best choice for distances of up to about 22 mi. Beyond that point a direct automobile trip is preferred. If the alternative station is remote, the size of the benefits index is large because it depends on automobile travel rather than bus service.

These results imply that the importance of a service depends not only on the magnitude of the ridership but also on the relative isolation of the route. Those routes that are the only service for a large but lightly populated area would tend to have a larger benefits index on a per passenger basis than routes in an area of more dense coverage. Accordingly, policies that relate to public support of intercity bus service should be route specific and consider the effects of alternative services.

The behavior of the model can be further illustrated by looking at the disutilities for particular stops along the routes. Figures 6 and 7 show the disutility savings of southbound bus service for each of the routes. In these diagrams the *DU* savings for automobile and the alternative bus service are shown as bar charts for each station and the preferred choice is shown as a line. For the Green Bay–Milwaukee route alternative, bus service is preferred to the automobile for the first three stops on the route (De Pere, Saint Norbert, and Greenleaf). Beyond that point automobile would be the best choice as an alternative to the original intercity bus service. The Ashland-Abbotsford route shows a similar pattern; however, the automobile is better than the alternative bus in all cases except at the beginning of the route at Ashland. For stations near the south end of the routes (beyond Waldo or Prentice), the automobile has a disutility advantage over the original service for southbound trips (i.e., the benefits of intercity bus are zero for those stops). These stops have a positive benefit for northbound travel. In general, it appears that direct automobile travel has an advantage over intercity bus for relatively short trip lengths.

SENSITIVITY ANALYSES

To get a better feel for the model performance, extensive sensitivity analyses were conducted on key parameters of the model. These were modal choice parameters (value of time and out-of-vehicle time multiplier), user characteristics (percent captive), and modal characteristics (automobile cost and bus out-of-vehicle time per trip). The results of these analyses follow.

Choice Parameters

Results of varying the disutility equation coefficients are shown in Figures 8 and 9. High values of time (Figure 9) indicate a user who is willing to pay more for high speed, and a high out-of-vehicle time multiplier indicates a traveler with a concern for convenience. An increase in the value of time causes a reduction in the benefits index with the index reaching a value of zero at a value of time of $17.00 per hour on the Green Bay–Milwaukee route and $32.00 per hour on the Ashland-Abbotsford route. The rate of change of the index is moderate with a range of +13 or +38 percent to −7 or −20 percent as the parameter is moved up or down 50 percent from its base value.

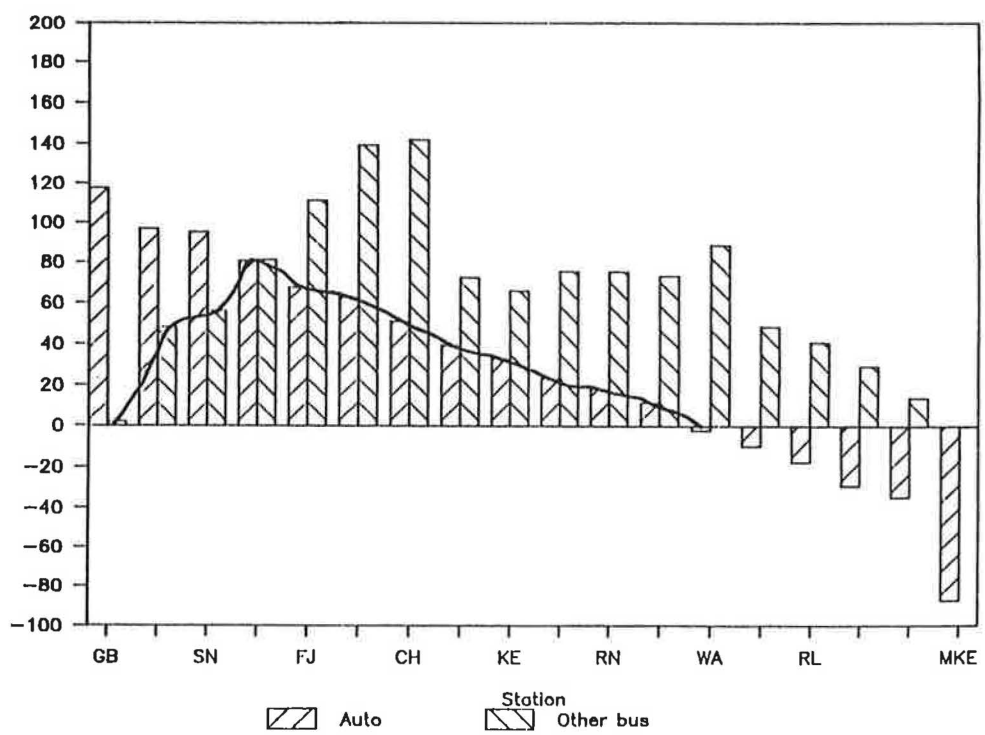

FIGURE 6 Station analysis: Green Bay–Milwaukee via Plymouth (solid line represents least disutility alternative at each station).

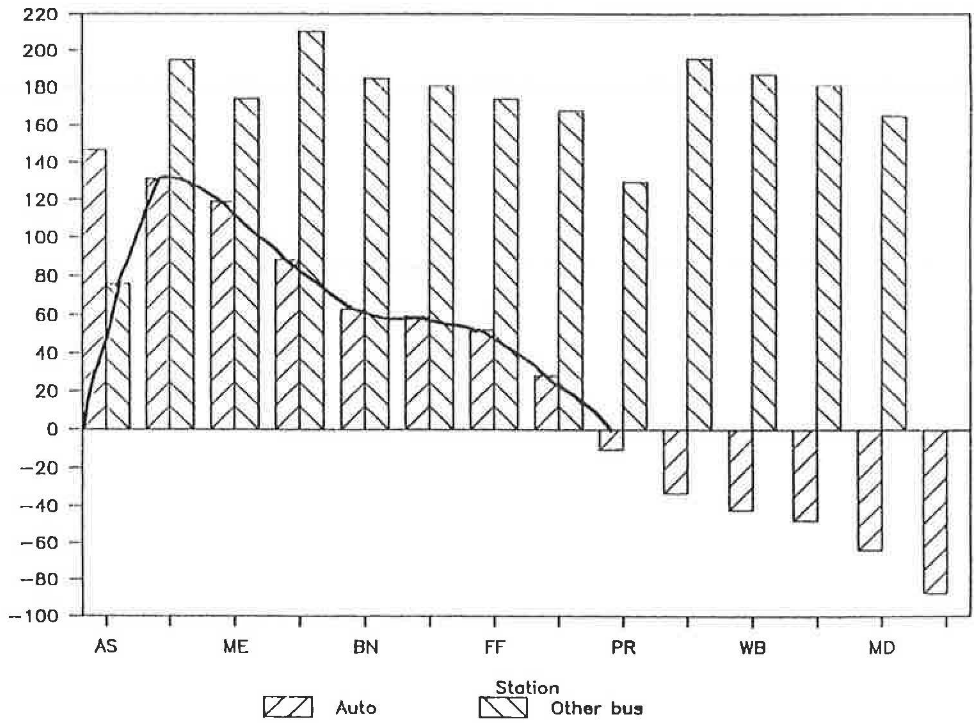

FIGURE 7 Station analysis: Ashland-Abbotsford.

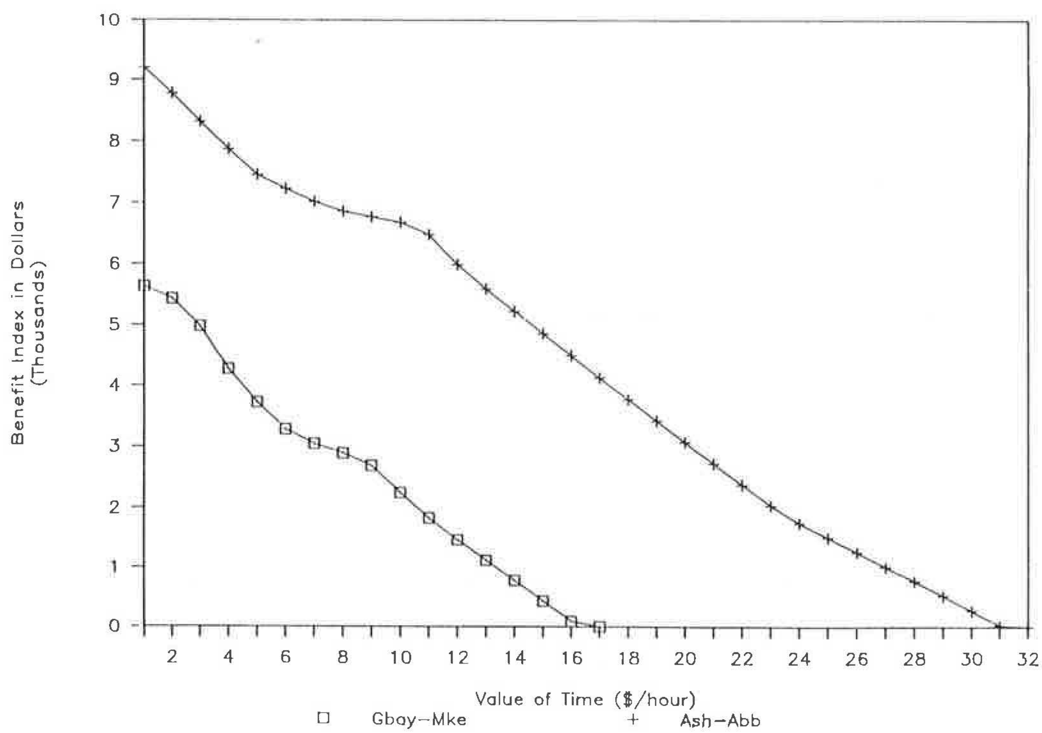

FIGURE 8 Vary value of time.

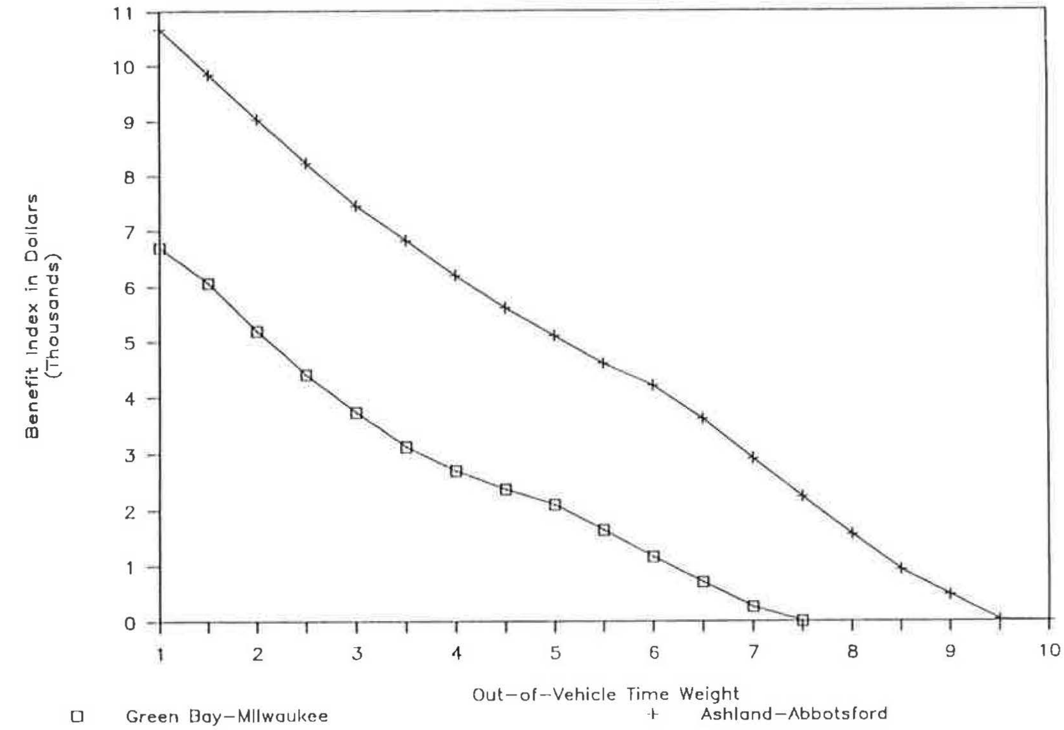

FIGURE 9 Vary out-of-vehicle time weight.

The out-of-vehicle time weight also shows an inverse relationship with the benefits index declining as out-of-vehicle time gains in importance (Figure 9). The benefits index reaches zero with values of C_1 at 7.5 and 10.0 for the two routes. The model is somewhat more sensitive to this parameter with a change of +21 or +62 percent to −25 or −36 percent with a change of the parameter up or down by 50 percent.

User Characteristics

The analysis used a base value of 50 percent captive users for intercity bus services. The concept of captive riders is complex because there are different circumstances in which an automobile is available or not available for a trip. For example, there may be an automobile for a college student to use to go to college but its use would prevent others in the family from using the car while the student was away. Data from the 1985 Wisconsin Intercity Bus Passenger Survey indicate that 49 percent of the users surveyed could not make a trip if bus service were not available that day and 16 percent would be unable to make similar trips if the bus service were permanently eliminated. Results of varying the percentage of captive users are shown in Figure 10. The benefits index increases directly as the percentage of captive riders increases. The changes have a moderate to relatively small effect with a range of +21 or +26 percent to −19 or −25 percent with a change of 50 percent above or below the base value.

Modal Characteristics

Two modal parameters, bus out-of-vehicle time and automobile cost, were varied. These results are shown in Figures 11 and 12. For the base situation, automobile trips had an out-of-vehicle time of 5 min and bus trips had an out-of-vehicle time of 15 min for the intercity segment. Bus intercity out-of-vehicle time was varied as shown in Figure 11. Here the benefits index declines as out-of-vehicle time increases. The rate of change is moderate with changes of +21 or +40 percent to −17 or −27 percent with a ±50 percent change from the base value.

The cost of automobile travel has a major effect on the calculations as shown in Figure 12. When automobile costs are set equal to bus costs (14 cents/mile) the benefits index goes to zero for both routes. The index increases rapidly as automobile costs increase. The index changes by +112 or +153 percent to −100 percent as the cost of automobile travel is varied by 50 percent above and below the base value. These major changes occur because the chief advantage of intercity bus over the automobile is its reduced cost. When this advantage disappears with equal costs, all benefits also are gone.

Interpretation

The sensitivity analysis shows how the benefits of intercity bus service are related to route location, user characteristics, modal characteristics, and choice parameters. The analysis indicates that benefits of service are highly sensitive to the location of the bus route relative to other routes and to the cost of automobile travel. Other factors such as value of time, out-of-vehicle time weight, out-of-vehicle time, and percentage captive users have a more moderate effect.

It should be noted that the relative benefits of the two bus routes remained nearly the same throughout the analysis. That is, the Ashland-Abbotsford route had an index roughly twice that of the Green Bay–Milwaukee route under a wide variety of values for the various parameters. This indicates that the basic

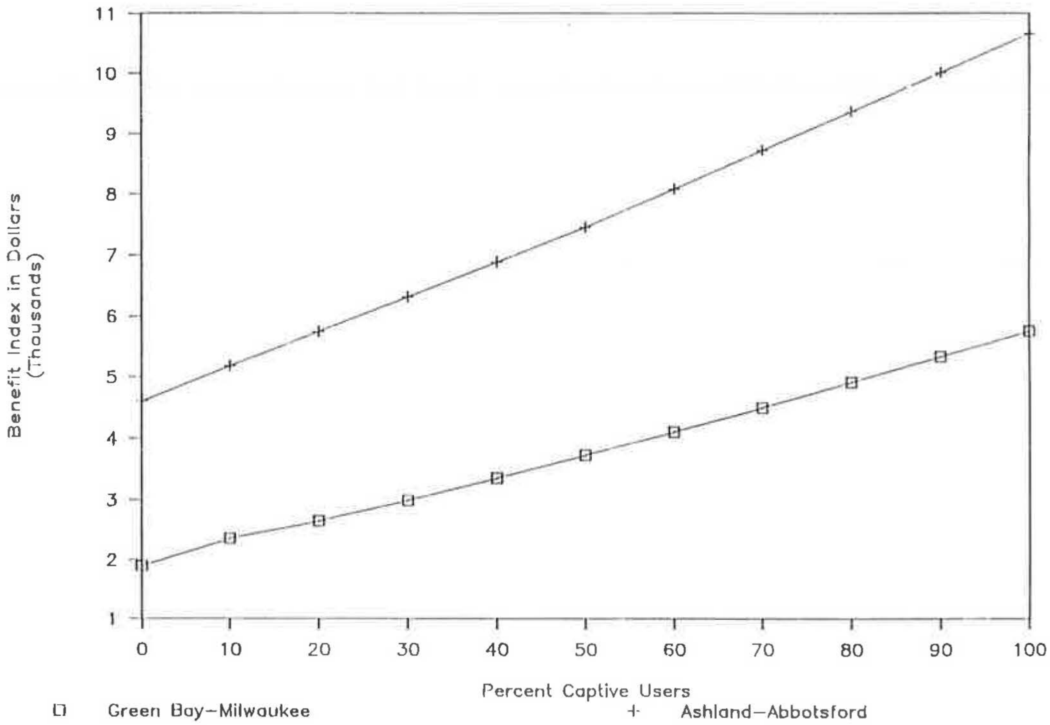

FIGURE 10 Vary percentage captive.

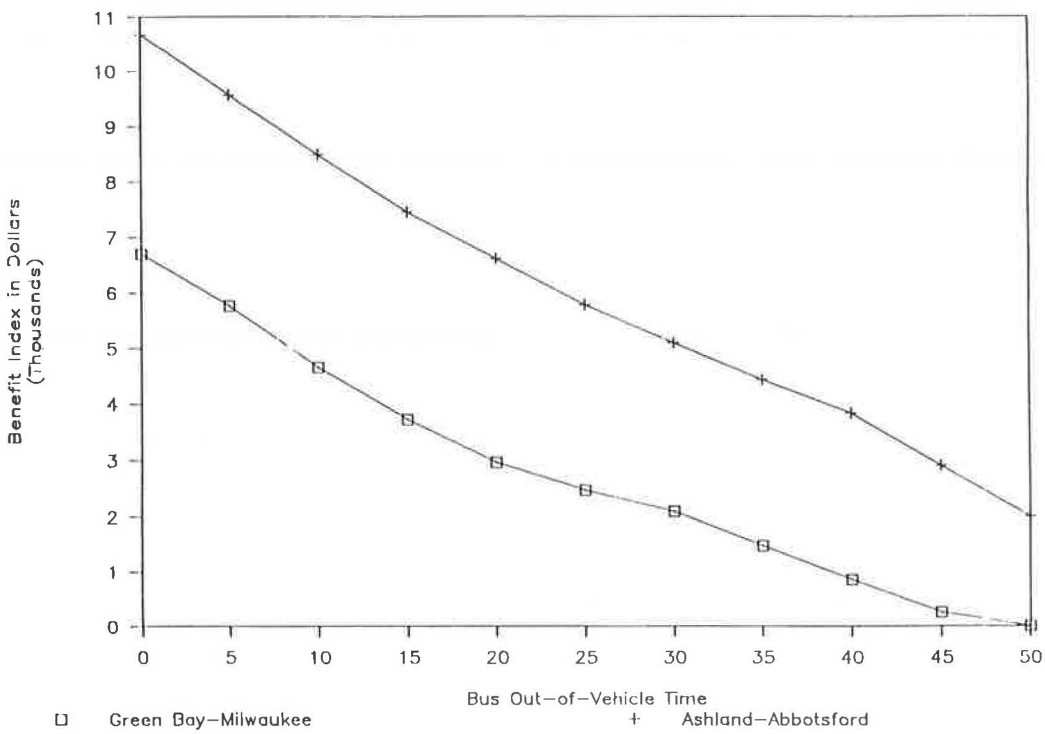

FIGURE 11 Vary bus out-of-vehicle time.

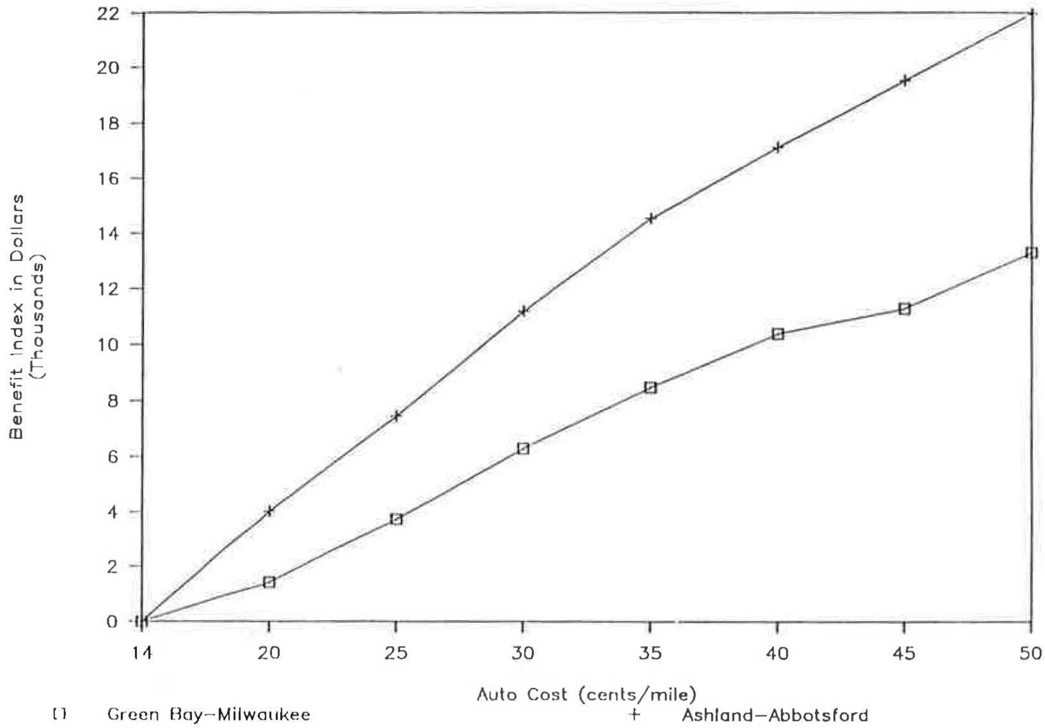

FIGURE 12 Vary automobile cost.

difference in routes results from route location and length rather than assumptions in the model. This result is good for present purposes in that it indicates that the model can be used to determine the relative importance of routes quite independently of assumptions necessary for model operation. Different parameter values affect different routes in the same way and thus do not appear to affect the relative importance of each route as measured by the benefits index. Thus the model may prove to be a useful tool for the selection of routes for public support.

CONCLUSIONS

This paper has provided a look at the benefits of intercity bus service. These benefits were estimated by a benefits index that calculates user benefits as a function of the characteristics of bus and automobile services, the characteristics of users, and choice parameters. Benefits of intercity bus service include savings in user cost, time, and inconvenience; the opportunity to ship commodities of a size or nature not permitted by other carriers; the availability of an option to automobile users; merit value; and the perception of community accessibility.

From the model developed to assess the benefits to users it was found that the level of benefits is highly sensitive to the location of the route relative to other routes. Those intercity bus routes that are isolated from other routes have a higher overall benefit than those that are located near other routes. Automobile cost also has a major effect. Benefits of bus service increase at about twice the rate of increases in automobile costs. Other factors such as value of time, out-of-vehicle time multiplier, bus out-of-vehicle time, and percentage of captive users have more moderate effects on the level of benefits. The level of benefits changes about half as fast as the rate of change in these parameters.

The research has several implications for policy on intercity bus service. If intercity bus service is to receive public support, it appears that support should be provided differentially for different routes and services. An important consideration should be the location of the route relative to other routes and the degree to which the users of the service have no other choices available to them. Important considerations in evaluating whether there should be a state program on intercity bus service include the following:

1. What is the impact on passengers, shippers, and others if bus service is discontinued?
2. To what extent will costs be shifted to the public sector for individuals unable to adjust to the loss of service?
3. What alternatives exist for the provision of mobility if service is lost?

It is recommended that state agencies trying to answer these questions analyze all services in the state according to the procedure outlined in this paper. By using such an approach a rational policy toward intercity bus service can be developed.

ACKNOWLEDGMENTS

This paper is based on a study conducted for the Wisconsin Department of Transportation through a contract with the Transportation Policy Studies Institute of the University of Wisconsin. Acknowledgment is due to Justin Williams, John Morck, and Jeffery Zarr for their contributions to the project. We also would like to thank members of the Wisconsin Department of Transportation staff, especially Dennis Hughes of the Bureau of Policy Planning, for their input. The views expressed here are those of the authors alone and do not necessarily reflect the views of the sponsoring agency.

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Publication of this paper sponsored by Committee on Intercity Bus Transportation.