BREAK-EVEN BENEFIT-COST ANALYSIS
OF ALTERNATIVE EXPRESS
TRANSIT SYSTEMS

By David S. Sawicki*

INTRODUCTION
One can view types of public transit services as lying on a continuum. At one end
of the continuum there is the local bus and at the opposite end there are high speed
express rail systems. In between, the service progresses from local bus to express bus,
to express bus running over a controlled access auto freeway or on its own dedicated
lanes, to express bus over a private busway, to dual mode, and finally to rail transit.
The object of this research is to study a portion of this continuum as it varies with
the level of demand.

Like many other metropolitan areas of its size, Milwaukee has begun to entertain
the idea of constructing some kind of mass transit facility. The comprehensive
regional plan prepared for Southeastern Wisconsin in 1966 proposed as a central
element a bus rapid transit system. Thus the opportunity presented itself to study
the costs and benefits inherent in such a proposal, and possibly to draw conclusions
for other similar cities.

The purpose of the research was to determine, first, the economic rationale in
terms of benefits and costs of building a rapid transit busway; second, to determine
the break-even demand points where the benefit-cost ratio of alternative systems
became better than the busway. Three alternative systems were to be compared:
1. The existing system, called the Freeway Flyer, an express bus running between
the central business district and outlying shopping centres where co-
operating merchants have allowed Flyer vehicles to park. The Flyer runs
during peak hours and uses only existing arterials and freeways.
2. A Controlled Access scheme on the more congested freeways, which would
control the access of automobiles on the freeways but would always allow
Flyers the right-of-way. (This is not a scheme currently under consideration
in the region.)

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alone.

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3. The proposed Busway system, which would include its own right-of-way. For a number of reasons to be discussed later, we used a conservative estimate of the design and cost of such a busway, which differed somewhat from the latest proposal by consultants.¹

These three alternatives were to be compared in the cost-benefit framework both with one another and with a pure auto system of commuting.

The research does not explicitly forecast modal choice. That is, the results of the investigation do not hinge on whether or not our forecasts of individuals’ choice of mode or travel behaviour are accurate. Rather, comparisons are made of the three systems at varying levels of demand and modal split. The research is concerned with determining which of the three systems produces the highest benefit–cost ratio at different levels of demand.² The benefit–cost ratio is developed from the point of view of society rather than of individual preferences.

ASSUMPTIONS BEHIND THE ANALYSIS

A number of critical assumptions were necessary to make the analysis possible. Probably the most important was that the comparison of the three systems was limited to one major corridor and not extended to the entire region. We felt that an analysis of the operation of all three systems on a region-wide basis was beyond our scope. The east–west freeway corridor in Milwaukee County was chosen for the analysis. This corridor, the most heavily travelled in the region, is the site of the present Freeway Flyer service and the proposed site for a busway. Data were readily available for this area and it is generally representative of a high-volume transport corridor. The fact that we have dealt with just this corridor and not with the entire network can have important effects on the results of the analysis. Spillover on to arterial streets is a result that is entirely taken care of within the delineation of the corridor. However, the alternative use of major freeway segments outside the corridor but within the network is a topic that remains unexplored.

Second, we chose to break the elements of each transport system into three components—collection, line-haul, and distribution³—and to analyse only the line-haul portion. The main reason for this decision was time—we could not study the costs and benefits of all three components of all three systems in the time available. The line-haul portion was chosen, again, because we felt that the results from analysing it would be most conservative—if the proposed transit system did not look good in line-haul, it probably would not measure up well. Furthermore, all three alternatives can use similar collection and distribution systems; hence it is reasonable to

²An alternative to comparing B/C ratios is to compare differences between discounted benefits and costs. This is not a standard procedure because it favours larger rather than smaller projects. Though in our case the method has some merit, the criterion of maximising the size of the difference is inappropriate. The energy crisis alone argues against such an approach. In our research the criterion of maximising B/C ratio was seldom (four out of twenty-five cases) at odds with the criterion of maximising the difference between benefits and costs. See Tables 1-5.
³The breakdown is not original to this study. For example, see J. R. Meyer, J. F. Kain, and M. Wohl: The Urban Transportation Problem (Cambridge, Mass.: Harvard University Press, 1965).
treat the analysis of each component separately. It was considered likely that any of the three bus transit systems would display higher cost–benefit ratios if only the line-haul portion were considered.4

Third, the analysis was provided only for peak-hour volumes in the corridor—that is, for the four most heavily travelled hours of the day. This again is thought to be a conservative approach, since any benefits that might accrue outside those hours are not considered, and many of the costs included in the analysis are total costs of items, which are incurred whether the system is used for four hours or for twenty-four. On the other hand, it was felt that most of the benefits of any transit system in a city configured like Milwaukee fall in the peak hours.

Another assumption was that the three proposed systems were best compared with a hypothetical pure auto system. There were two possibilities: we could measure the costs and benefits of the proposals on an absolute basis, or we could assume that the transport requirements in this corridor had been previously justified and then simply compare the costs and benefits of alternative schemes. The latter method was chosen, and the three proposals were compared with a pure auto system, which is best described as moving people through the corridor by means of automobiles only. At certain levels of demand this can mean that only the existing freeway is used, but at other levels spillover is experienced on to arterials, and costs are therefore higher. The increasing costs are expressed as a geometrically increasing function of excess demand.5

Fifth, a number of the normal assumptions made in benefit–cost analysis are used in this research.6 Probably the most sensitive ones in this study are that:

1. An appropriate distribution of goods and services is assumed; that is, the analysis is not sensitive to the distribution of goods and services to different classes or groups of people—it is indifferent.

2. The analysis is done from society’s point of view and is not sensitive to the sources of the funding of the project. That is, whether user charges or local, state or federal taxes pay for the project, the analysis gives the same results.

The last of the major assumptions is that those variables that were amenable to quantification provided an adequate estimate of the true costs and benefits. A number of important spillovers were left unquantified and not considered in the analysis.

4In other words, neglecting the collection and distribution portions of the trip does not distort comparisons among the three bus alternatives, but does short change the automobile related alternatives. It doesn’t change the size of the three B/C ratios relatively, but does move all three up higher absolutely.

5Actual data were used for the interstate route: average speed and density of traffic flow. These data were converted into speed-density data by using conversion estimates from the U.S. Department of Transportation. The speed of traffic flow is not used directly in the computation within the B/C equation, but is used in the determination of personal travel time. Actual data were similarly used to develop the relationship under conditions of controlled access. In both instances, it was assumed that spillover to arterials occurred at the peak congestion point. This assumption was based on the regressive tendency in traffic flow of lowering speeds above peak demand. Once overflow traffic was “spilled” on to arterials, the autos concerned encountered longer trip times (again, as a function of total volume) and parallel changes in accident, depreciation, operating and other costs. However, these costs were not made a function of speed.

The principal unquantified variables were: (1) the real cost and social costs of rights-of-way needed for the hypothetical second freeway and the proposed busway, (2) the differential costs to human life of the pollutants of each system and (3) the economic rewards for construction itself. Many have argued that the actual cost of any right-of-way grossly underestimates the real cost of the right-of-way.\textsuperscript{7} In addition to uncompensated and undercompensated costs to residents in the path, there are the quantifiable but real costs of psychological distress. In addition, there seems to be little question that there have been serious but unquantified costs in the destruction of our natural environment. It is well known that such costs are very difficult to measure. If they could be measured and included in the analysis, they would reduce the value of the pure auto system (which requires a new freeway at high levels of demand) and the proposed busway. Second, it is believed that, though it is very difficult at this time to get a real measure of the effects on human life and health of various pollutants, the systems involving more bus transport rather than auto should be favoured from the viewpoint of abatement of pollution. Therefore, the analysis without pollution will overvalue the pure auto system and undervalue the bus systems. Third, construction itself provides individuals with jobs and provides multiplier effects to the economy. This is in itself a value, and any proposal that involves construction will probably be undervalued in our analysis because the economic value of construction itself is not included. To be certain one would have to consider alternative uses for the construction moneys.\textsuperscript{8}

\textbf{THE BENEFIT–COST MODEL}\textsuperscript{9}

As stated previously, the benefit–cost model assumes a “pure auto” alternative as the \textit{status quo}. Thus, using a discounted cost, or net present value formula\textsuperscript{10} for twenty years:

\[
\text{(Benefit–cost ratio)}_i = \frac{(O.C.P.A.)_i - (O.C.P.S.)_i}{(C.C.P.S.)_i}
\]

where:

- \((O.C.P.A.)_i\) = Operating costs (plus additional needed capital costs) of an equivalent \textit{pure auto} system at demand level \(i\) (in total passengers).
- \((O.C.P.S.)_i\) = Operating costs of one of the three \textit{proposed systems} at demand level \(i\).
- \((C.C.P.S.)_i\) = Capital costs of one of the three \textit{proposed systems} at demand level \(i\).


\textsuperscript{8}The multiplier effects from road construction are probably no different from the multiplier effects from other alternative investments. However, it is likely that the effects from construction will be felt more locally than investments in, for example, rolling stock which is provided somewhere else. This effect remains uncounted because the model deals neither with multiplier effects nor with effects different from a point of view of (non-regional) society.

\textsuperscript{9}See Appendix A for a more detailed description of the model and the computer program used.

The operating costs of a pure auto (O.C.P.A.) system may include:

1. Cost of passenger time
2. Operating and capital costs of an auto (per mile over freeway)
3. Cost of accidents (property, fatalities, injuries)
4. Cost of traffic overflows on to arterials:
   a. additional passenger time costs
   b. added costs of accidents
   c. added auto operating costs
5. Cost if an additional hypothetical freeway is needed:
   a. savings in passenger time
   b. savings in accident costs
   c. savings in auto operating costs
   d. the capital and maintenance costs of the new freeway itself.

The operating costs of one of the three proposed systems (O.C.P.S.) may include (depending on the proposal):

1. Cost of passenger time
2. Operating costs of buses (per mile over freeway)
3. Cost of accidents of buses (property, fatalities, injuries)
4. Maintenance cost of controlled access equipment
5. Maintenance cost of the busway
6. A portion of any of the costs shown under the pure auto system which cover the auto portion of a mixed auto–bus system.

The capital costs of one of the three proposed systems (C.C.P.S.) may include (depending on the proposal):

1. The capital cost of buses and related equipment
2. The capital cost of controlled access equipment
3. The capital cost of the busway
4. The capital cost of automobiles for the auto portion of a mixed auto–bus system.

As can be seen from the list of costs, in reality more than three alternatives were tested. In fact, each of the three alternatives was tested by itself and with a mixture of automobiles. Thus, at various levels of demand, the three systems were tested on the following assumptions:

1. 2-5% of all passengers using bus, 97-5% using auto (approximately the present modal split)
2. 10% of all passengers using bus, 90% using auto
3. 25% of all passengers using bus, 75% using auto
4. 50% of all passengers using bus, 50% using auto
5. 75% of all passengers using bus, 25% using auto.

Thus, fifteen proposals were compared with a pure auto system. The possibility of developing a feedback loop which projected mode choice, given passenger time and cost, was considered; but it was felt that the main purpose of the research was to project costs and benefits at assumed levels of demand and mode choice. It was argued that mode choice could be influenced through public policy. However, it
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should not be assumed that total demand would be the same under any of the three proposals or under a pure auto system. Each proposal may develop its own demand function. The model allows one to compare costs when demand is the same. One scheme may cause individuals to travel more or less than another scheme. The B/C model was tested at a number of levels of modal split, and the demand in the east–west corridor was varied from no passengers to the present eight to ten thousand an hour (peak) and then to over ninety thousand an hour.

A computer program was developed which was capable of generating B/C ratios, given numerous changes in parameters. The initial runs gave ratios for the fifteen alternatives at approximately nineteen levels of demand. In these runs values were assumed for all variables. These values were gathered from a number of sources: the research literature, consultants' reports, and original computations. These initial values are shown in Appendix B. In subsequent runs, most variables were tested for their sensitivity. Those found to be sensitive were then analysed in depth.

INITIAL RESULTS

In each of the fifteen runs, the point of most interest was probably where the B/C ratio broke over a value of 1-0. This is the point where the present value of the cost savings of the proposed system over a pure auto system was the same as the present value of the capital cost of the proposed system. Beyond this point in demand, it was more rational to invest in the proposed system. If the operating costs of the pure auto and the proposed systems were the same, the numerator would contain only those capital costs associated with the pure auto system, exclusive of sunk costs which were not counted. If these capital costs were larger than the capital costs of the proposed system, this would also make the B/C ratio larger than 1-0.

Case 1: 2-5% passengers using bus, 97-5% using auto (present modal split)

At this, the present modal split, the Busway proposal never becomes economically justifiable. The range of B/C ratios is from nearly zero at low demand levels to nearly one at an impossible 80,000 passengers. (See Figure 1). The sense of this finding is obvious, since at the present modal split only 1000 passengers per hour use the bus at a total demand of 40,000 per hour (2.5% × 40,000). Thus, a Busway

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11Projects cannot be legitimately compared by cost–benefit analysis alone if their ratios of operating to capital costs are not comparable. The problem of differing capital costs for different proposals is generally investigated by viewing the ratio of operating, maintenance and routine replacement costs incurred annually to the fixed investment. This statistic is called the "O/K ratio". Generally, one expects that projects developed to solve a certain problem share similar O/K ratios, but disparate projects may have startlingly different O/K ratios (i.e., 0-11 for a harbour improvement project, but 0-009 for an irrigation project). In our research, the O/K ratio varies with demand, increasing as demand rises for all systems considered. It also increases as the primary travelling mode shifts from one of the proposed systems to auto. The depreciation costs of auto are computed on a mileage basis and are an integral part of the capital costs of the schemes. Our various O/K ratios within the analysis are comparable except at very low levels of demand, where the busway is clearly an inferior investment. At higher levels of demand, the differences in O/K ratios appear minimal.

12Figure 1 and all succeeding tables show demand varying to only 40,000 passengers. Beyond 40,000 in each table there were no changes of real interest. For presentation purposes, then, we chose to show only demand under 40,000 passengers per hour.
Figure 1
2.5% of all passengers using bus and 97.5% using auto

Table 1
2.5% of all passengers using bus and 97.5% using auto

<table>
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<th>Demand</th>
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*In millions of dollars.

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is proposed for construction which would handle only 20 buses (1000 passengers ÷ 50 passengers per bus) per hour at that high demand level. Since present demand is around 10,000 passengers per hour, and is unlikely even to double, the Busway seems like a bad investment unless people begin to decide to use other transport than auto in the corridor.

Both the Freeway Flyer (present system) and Controlled Access prove to be far better investments at this modal split. The Controlled Access system is not justified until demand exceeds 2,000 persons. But after that point it is a good investment, although exceeded everywhere by the Freeway Flyer without controls. The metering cost never seems justified by the increased saving in passenger time. If we knew that the modal split was going to remain at the current ratio (97-5% auto, 2-5% bus), we could unequivocally suggest as the best choice the Freeway Flyer using the existing interstate and arterial system.

Case 2: 10% passengers using bus, 90% using auto
If individual behaviour within the corridor changed considerably, we might be able to anticipate a substantial change in bus ridership, to 10% using bus as opposed to the current 2-5%. The 1990 Transit Plan for Milwaukee projects this particular modal split. Its results are very different from those for the 2-5%–97-5% split. First, although the Busway is an inferior investment at all demand levels, it does become economically justifiable at 22,000 passengers, as at that point the B/C goes above 1-0. The B/C ratio climbs to above 3-3 at total demand of 80,000 passengers per hour. The Freeway Flyer is clearly the best alternative at this modal split until demand reaches about 8000 persons per hour. At that point the saving in passenger time makes the Controlled Access scheme the best alternative throughout the rest of the demand range.

Ranging well above 2-0 throughout the range, both the Flyer as it exists and the Flyer with controlled access are good economic investments. Such strong B/C ratios argue strongly for legislating the modal split at a higher ratio for buses and implementing an escalated Flyer system or a Flyer with controlled access. The reason why this has not happened is complex. First, our analysis is of line-haul only. The auto has proved to be more convenient, safer and pleasanter, especially during collection and distribution. And second, although buses are a more “rational” choice for society, travel decisions are made on an individual basis. Legislation that would allow only a certain number of autos to travel through the corridor smacks of a limiting of free choice in transport.

Figure 2 and the remaining figures show a strange “hump”. This is because the model reflects increased costs as the freeway begins to become congested. Relatively, the Flyer and Controlled Access proposals have their highest B/C ratios in time of maximum congestion on the freeway. When spillover begins, the B/C ratios decline.

Case 3: 25% passengers using bus, 75% using auto
Without strong negative sanctions it appears unlikely that the modal split could ever go so high in favour of buses that they would be used by 25% of passengers, with 75% using auto. But there is disagreement on the point. For this reason, and for the purpose of viewing the full spectrum of demand and modal split possibilities in the corridor, we present this case, and also cases four and five. It seems unlikely,
Figure 2
10% of all passengers using bus and 90% using auto

Table 2
10% of all passengers using bus and 90% using auto

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*In millions of dollars.

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**Table 3**

25% of all passengers using bus and 75% using auto

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<th>Demand</th>
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<td>1.19</td>
<td>2.25</td>
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</table>

*In millions of dollars.
though, that such modal splits could develop without basic changes in the way people view their rights of free choice of mode and least time and distance.

It is interesting that at this modal split even the Busway proposal shows B/C ratios of over 1.0. Only when total demand is under 8000 passengers per hour is the busway an uneconomic investment. This gives credence to the consultant reports, which suggest that the busway is a sound alternative under the assumption of large crossovers to bus usage.

Yet at every demand level the Busway is again surpassed as an investment both by the Flyer as it exists and by the Flyer with controlled access. Sensibly, the Flyer alone stands as the best alternative until congestion begins. With congestion and a good number of persons now riding the bus, the controlled access plus Flyer becomes the best alternative at total demand of over 10,000. The great money saving is in passenger time. The controlled access plus Flyer remains the best at total demand of 10,000 persons per hour or more. See Figure 3.

**Case 4: 50% passengers using bus, 50% using auto**
As mode choice moves in favour of bus, the Busway becomes economically feasible at lower levels of demand. At a 50%–50% modal split, the Busway is justifiable at total demand of under 8000 persons. From that point its B/C ratio rises to almost 10.0 at total demand of 80,000 passengers per hour.

Again, though, at all levels of demand the Busway as an investment is definitely inferior to the other two alternatives. The Freeway Flyer as it now exists is the preferred investment until congestion is reached at total demand of about 14,000 passengers per hour. At that point the Controlled Access alternative takes over as best and stays best throughout the demand range. Both the Flyer and the Flyer with controlled access have B/C ratios above 3.0 throughout the demand range. But when congestion occurs, Controlled Access allows many more persons to save travel time with the bus, and thus Controlled Access is the best solution. See Figure 4.

**Case 5: 75% passengers using bus, 25% using auto**
As shown in the previous case, the greater the percentage of bus passengers, the earlier in the demand range the Busway becomes justifiable. At the 75%–25% bus–auto modal split, the Busway becomes a viable investment at total demand of 7000 passengers per hour. This would give 5250 passengers per hour on 105 buses travelling on the Busway. Of course, as demand rises, so does the Busway’s B/C ratio, peaking at nearly 12.0 at total demand of 80,000 passengers per hour. But current demand is, again, only 10,000 passengers per hour.

Despite the heavy emphasis on bus use, the Flyer and the Controlled Access Flyer both continue to present better investment opportunities than a pure Busway. With this level of bus use, the existing Flyer system remains the best until demand reaches almost 20,000 passengers per hour, 15,000 of whom are using the bus. This happens because, with so many passengers using the bus, congestion comes very slowly to the existing freeway and controlled access is not needed or justifiable. If mode choice could be changed thus drastically, the difference between a 14.0 B/C for the Flyer and a 17.0 B/C for the Controlled Access Flyer would appear to be slim indeed. At this kind of modal split, we could say safely, and with little reluctance, that the existing system of Freeway Flyers is the best alternative. See Figure 5.
BREAK-EVEN B/C ANALYSIS OF EXPRESS TRANSIT SYSTEMS

David S. Sawicki

FIGURE 4
50% of all passengers using bus and 50% using auto

![Graph showing break-even analysis for different transit systems.]

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*In millions of dollars.
Figure 5
75% of all passengers using bus and 25% using auto

Table 5
75% of all passengers using bus and 25% using auto

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*In millions of dollars.
SENSITIVITY ANALYSIS

The benefit–cost model developed had as its basis many variables the values of which were subject to change and revaluation. Thus it became important to determine which of these variables caused the basic conclusions of our experiment to change as a result of changes in their values. Among those tested (shown with their original values) were:

- Demand level (already discussed)
- Occupancy ratio of autos (1.3 passengers/auto)
- Occupancy ratio of buses (50-0 passengers/bus)
- Route length (9 miles)
- Passenger time value ($2.82/hr.)
- Discount rate (6%)
- Bus empty on return trip (yes)
- Operating and accident cost differentials by route:
  - freeway to arterials ($0.005/mile)
- Capital cost of the Busway ($36,000,000)
- Capital cost of Controlled Access equipment ($121,264).

Initial tests were run to determine which variables were the sensitive ones. It was found that the value placed on passengers' time was the one that stood apart from all others in sensitivity. Although changing others had some effect on the results of the model, none affected the results as much as changing the value of passenger time. Therefore, it was decided to vary the value of passenger time from zero to $10 per passenger hour and observe the results.

Figure 6 shows how varying the values of passenger time affected the B/C ratios of the three proposals, given a likely mode split, 90% auto, 10% bus. Most important, the relative merits of the proposals remain the same: the existing Freeway Flyer system is best, the Controlled Access scheme a close second, and the Busway, third, a distinctly inferior investment. The Busway, in fact, is the only alternative which is not viable at all demand levels, at all values of passenger time, at this modal split.

As the cost of passenger time is varied upward from zero, all three proposed schemes become more attractive and show higher B/C ratios. This means, of course, that they become more efficient alternatives than using only automobiles. An interesting way to view Figure 6 is to obtain the value of passenger time that justifies building the busway at certain demand levels. For example: at the 90%-10% split and demand at 10,000 passengers per hour, the Busway is justifiable (B/C = 1.0) at about $7.50 per hour passenger time. This type of analysis may be used in suggesting to public policy makers the value system they infer when they entertain certain proposals like building a Busway.

IMPLICATIONS OF THE RESEARCH FOR PUBLIC POLICY

The research appears to provide guidance under three separate headings for public policy-makers. The first heading concerns the results of testing the economic viability of the three transit systems in Milwaukee; the second concerns the applicability and usefulness of the methodology employed. The third relates the other two: that is,
Figure 6
90% of all passengers using bus and 10% using auto with the cost of passenger time varied.
are there any conclusions drawn from the Milwaukee case that are applicable generally to other cities? What are the factors that make these results particular to Milwaukee?

In the first instance, the principal finding is, of course, that the Busway is not the best alternative in any case, no matter how high the demand or how the values of the sensitive variables are altered. In most cases the Controlled Access proposal is superior, but this does depend on certain sensitivities as well as on the level of total demand. At the split that has the least use of buses, the current 97.5% auto, 2.5% bus, the existing Freeway Flyer system seems best. The time saving from controls does not warrant the cost. At the other end of the modal split spectrum, 25% auto, 75% bus, there is so little congestion that the existing Freeway Flyer system is adequate, and best until demand gets very high. An interesting point is that if the existing freeway carried buses only, congestion could not occur until nearly 125,000 persons per hour were travelling on it at the same time; but 6400 persons congest it if they all use automobiles. The difference is staggering.

This brings up the question of what is possible, and furthermore likely, in both modal split and total demand. We explored the extremes of both split and demand for research purposes. But for public policy purposes it would be somewhat unrealistic to assume that total demand in the corridor could climb much beyond double its present size. Our interests should, then, focus on the results of demand between 10,000 and 20,000 passengers per hour. In terms of modal split, the latest consultants' report suggests that there may be an 88% increase in bus use in twenty years. This means, if applied to the east–west corridor, a total of less than 500 persons per hour—less than ten buses per hour. This total cannot support a busway—common sense in addition to our research supports that conclusion. The present laissez-faire system of commuting policy should be examined more closely if any kind of meaningful change is to come about.

It is appropriate to review what the Controlled Access system is and how it is simulated within the B/C model. Controlled Access in this study means metered and controlled entrance ramps added to the existing entrance ramps on Interstate 94 in the East–West corridor. An integral part of the proposal is that the meters will prohibit autos from entering I-94 if the flow of vehicles gets above the optimum flow for speed and volume (around 4700 auto length equivalents per hour). But buses are always afforded the right-of-way. They are provided with express on-ramps and are allowed to ignore the meters which keep autos off the freeway.

The research points to such a Controlled Access system as more than likely to be the best within the reasonable ranges of demand and modal split. It should be remembered, however, that the model which generated these findings rests on a number of explicitly stated assumptions, the most important of which is that only line-haul is considered. Though probably not causing any bias in favour of any one of the three bus-oriented proposals rather than another, the analysis does look more favourably on all three than it does on an auto-oriented system. In any event, under the Controlled Access system, a shifting of the burden of costs should be noted.

13Barton-Aschman, op. cit. (see footnote 1).
Thus the research points to the Controlled Access system as more than likely to be the best alternative by far within the reasonable ranges of demand and modal split. However, the model does show a shifting of the burden of cost under that proposal. The process is simulated within the model in this way: at a 90%-10% auto–bus split, cars and buses proceed on the existing freeway without problems while total demand is below 7200 passengers. Above 7200, congestion begins and, without Controlled Access, vehicles begin to spill over on to arterial roads. After spillover has started, Controlled Access often becomes the economically best system. Instituting Controlled Access allows an additional 1000 vehicles to flow freely on the freeway. But with total demand above 9000 persons, automobiles begin to get backed up at entrance ramps, while the Flyers proceed at optimum speed with autos on the freeway (here is where the cost burden is switched from bus riders to some auto riders). It should be noted, in addition, that the benefits arising from the use of buses instead of autos also accrue to some auto users. Beyond the initial back-up point, some automobiles begin to use arterials again. At this point the research would suggest that the Flyers be introduced at several of the more congested entrance ramps. (So far only a point-to-point analysis has been done.) Again the Flyer should have the right-of-way. This proposal has a number of significant policy implications. First, and most important, the cost burden begins to be shifted from bus riders (who “pay more” in less convenience, privacy, and until now more time en route) to auto riders. If one goal is to place the cost burden where it truly belongs—on the auto commuter—this system accomplishes that goal. Second, this system, again unlike the Flyer without controlled access, begins to modify individual behaviour patterns. The stark reality of an added half-hour wait, with the Flyer coming by as commuters sit in their cars at interchanges, will do a lot to push the modal split in favour of Flyer use. Additionally, the Controlled Access Flyer scheme appears to provide a good transition to a full-fledged transit system. It is a solution probably applicable to many more situations than the east–west Interstate, both in Milwaukee and in other like cities.

The research has emphasized for us the possible benefits to be derived from using the existing system of routes and vehicles, but with different policies. It suggests that planners might think more about policy construction instead of physical construction. The suggestions put forward here may be politically unappealing but economically sound. This may be true for numerous cities with the size and configuration of Milwaukee. The next step in testing these ideas, it seems, would be to include collection and distribution as well as line-haul in an analysis comparable to the one we have carried out here. Perhaps the findings will not be sustained. In any event that analysis seems crucial before any decisions can be made.

As mentioned, the second heading under which guidance is provided by the research relates to the viability of the methodology for policy analysis. All along we were not content to simply describe or predict behaviour. Elaborate models have been developed to explore the question of mode choice and our contribution, if we have made any, is neither descriptive nor predictive, but analytical. We have begun with the assumption that mode choice is a proper area for public scrutiny and public policy—not something that is the product of a free market and destined to remain so. Thus we wished to provide decision-makers with an analysis of what costs and benefits could be expected if they took certain actions. We have
assumed that through public policy the following critical things could be manipulated: total vehicles in the corridor, mode choice of passengers in the corridor, and the direction of the burden of cost for that travel.

Traditional techniques would predict the level of demand and the modal breakdown for some target date. We have shown an infinite number of possible situations by varying demand and modal split. We feel that this method provides new direction to transport policy planning. It goes beyond simply asking where to build, and asks whether to build. The whole philosophy conveyed by the research is one of the openness of transport policy planning to manipulation by public decision-makers. It presents a transport situation not as a predicted fait accompli, but as open to public decision and manipulation.

Third, how far can the Milwaukee results be applied generally? Is a busway an inferior investment for every city? The answer is: definitely not. At some point, even in Milwaukee, at high levels of demand, the busway is the best investment. The factors which make Milwaukee a special case follow:

1. Collection and distribution have been excluded from the analysis; but in Milwaukee parking is relatively inexpensive and generally adequate for present demand. This makes the implementation of any mass transit proposal much more difficult.

2. Milwaukee City has a population of 717,000 and the region approximately 1.4 million. The city is 95 square miles and the region 1,456. It is typical of many mid-western American cities in size. It is spread out. It lacks density; therefore, most forms of mass transit are inappropriate for this reason alone. Collection is difficult; and, in the future, passenger distribution to an even more diverse geographical spread of employers will be more difficult as well. Any transit system that has a fixed path will be less feasible than more flexible types. With higher densities, operating costs per passenger mile of transit facilities would be lower—the busway, for example, would compare more favourably.

3. The Milwaukee region has a high rate of automobile ownership (89.3 per cent of persons eligible to operate an auto own one). This means the size of the auto-immobile population is quite small. Demands for mass transit are correspondingly reduced.

4. In Milwaukee there is an automobile chauvinist ethic. Though this statement cannot be documented, it is nevertheless true. The primary mode of travel is the car; it has been so for some time, and most people refuse to consider other modes.

5. The transport network in Milwaukee features a grid plan with major arterials at half-mile intervals. Outside the city there is a one-mile grid. Thus a corridor of significant width offers almost unlimited choice of street routes. This makes the creation of a limited access scheme, as described in this paper, more feasible. Many alternatives are available to the auto driver prevented from entering the freeway. Additionally, a relatively rich supply of four-lane divided highways makes their use for bus an attractive possibility.

6. Lastly, Milwaukee has its own set of costs relevant to the various proposals (see Appendix B). In other cities, costs may be very different. If the costs are sensitive ones, they may alter the results of the analysis.
The value of the approach presented here is not its conclusiveness about the “best” mode, but its exposition of the factors to be considered in making such a decision, the sensitivity of the model to the factor values, and the conditions that favour one alternative rather than another.

APPENDIX A

Equation of Freeway\* Flyer II Computer program

Following is a verbal description of the equation:

**Numerator—Benefits**

(difference of equivalent autos from buses with relation to accidents, passenger time, and operating costs)\* \+(change in passenger time due to controlled access)\* \+(change in operating costs, accident costs, and passenger time due to spillover with a pure auto system)\* \+(change in bus operating costs due to busway)\* \+(cost of new freeway)\** \+(cost of maintenance of freeway)\**

**Denominator—Costs**

(capital cost of actual autos) \+(capital cost of buses) \+(capital costs of controlled access)\* \+(maintenance of present freeway) \+(capital cost of busway)\* \+(maintenance of busway)\*

The benefit–cost ratio is then obtained by discounting the above amounts and dividing the benefits by the costs.

A list of variables, both given and computed, is available from the author direct.

APPENDIX B

Values used in benefit–cost model

**General**

Discount rate \( \ldots \) \( \ldots \) \( \ldots \) 6%  
Time span \( \ldots \) \( \ldots \) \( \ldots \) 20 yrs.  
Time intervals \( \ldots \) \( \ldots \) \( \ldots \) 4 hrs/day  
\hspace{1cm} 255 days/yr.  
Passenger time \( \ldots \) \( \ldots \) $2.82 per hr.  
Maximum capacity \( \ldots \) \( \ldots \) 5250 vehicles/hr.  
(\ without controlled access)  
Maximum capacity \( \ldots \) \( \ldots \) 5600 vehicles/hr.  
(\ with controlled access)

\*If applicable.  
\**Assuming that overflow costs are greater than the cost of building a new freeway.
### Auto
- Occupant ratio ... ... 1.32 people/auto
- Route length ... ... 9.0 mi.
- Accident costs ... ... 3.6 cents/mi.
- Freeway operating cost ... ... 3.9 cents/mi.
- Change in operating cost (freeway to arterial) ... ... 1.5 cents/mi.
- Change in time (freeway to arterial) ... ... 35 min.
- Depreciation of auto ... ... 2 cents/mi.

### Bus
- Occupant ratio ... ... 50 people/bus
- 1 bus = 1.6 auto lengths
- Route length (round trip) ... ... 18 mi.
- Accident costs ... ... 3.1 cents/mi.
- Speed ... ... 50 m.p.h.
- Freeway operating cost ... ... 88 cents/mi.
- Cost per bus ... ... $32,000
- Life span of a bus ... ... 12 yrs.

### Busway
- Length ... ... 9.5 mi.
- Maintenance ... ... $40,000/yr.
- Life span ... ... 20 yrs.
- Capital cost ... ... $36,000,000

### Controlled Access Equipment
- Capital cost ... ... $60,000
- Life span ... ... 8 yrs.