Cost-Effectiveness for Circulation-Distribution Systems

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The Environmental Impact Statement for the Omni and Brickell legs of the Miami Metromover required a cost-effectiveness analysis. As the analysis was undertaken, it became evident that the cost-effectiveness procedures usually used to analyze major regional transit improvements were not appropriate for circulation-distribution systems. One of the primary functions of circulation-distribution systems is to change trip-making patterns usually resulting in longer trips and sometimes in increased travel times. No provision in current cost-effectiveness procedures measures this travel impact. The methodology also fails to consider farebox revenue and local subsidies as offsets to either local or federal "costs." These issues, encountered during the cost-effectiveness analysis phase of the study, are described and suggestions made for modifying the procedures, so that the results of circulation-distribution system analyses are meaningful. A comparison of the values computed using different procedures for the analysis of the Omni and Brickell legs is also presented.

The transit system in Miami consists of three major components: Metrorail, Metrobus, and Metromover. Metrorail is the regional rapid rail component extending from Dadeland in the south through downtown Miami to Hialeah in the northwest. Metrobus provides regional and local bus service throughout the remainder of the region. Metromover, an Automated Guideway Transit (AGT) system, is the downtown component of the system designed to provide for the distribution of transit travelers within the downtown and improve circulation among the Omni area to the north, the Downtown, and the Brickell area to the south across the Miami River.

The first phase of the Metromover component, a 1.9-mi double-loop system, opened for service in 1986. Design work has begun on the Omni and Brickell legs that were the object of this study. Although the specific debate about the Miami Metromover is moot, the issues raised during this analysis are relevant to future studies of major transit investment alternatives.

INTRODUCTION

The primary purpose of a circulation-distribution (C/D) system is to improve accessibility to and mobility within a densely developed area. Improvements in accessibility and mobility, in turn, are expected to increase the amount and density of economic activity in the developed area where other infrastructure needs can be provided effectively and efficiently. Because it is difficult to quantify the impacts of transportation system improvements on promoting development and structuring future growth, the effectiveness of such improvements is usually measured in terms of accessibility and mobility changes as they affect travel characteristics and transportation system use. Changes in the number of trips made, travel time, and the distance traveled within the downtown area are valuable measures of the effectiveness of C/D systems.

As part of the studies conducted for the Environmental Impact Statement for the Omni and Brickell legs of the Miami Metromover system (*1*), it was necessary to conduct a cost-effectiveness analysis. Costs for building the legs were estimated to be $240 million ($96 million per mile) in 1986 dollars based on preliminary engineering studies. Operating and maintenance costs were estimated to be $2.5 million more for the build alternative compared with the no-build alternative in 1986 dollars considering both the increases in Metromover costs and decreases in bus operating costs. Operating revenues were estimated to be $0.7 million more for the build alternative. The task was to determine whether the expenditure necessary to build the Omni and Brickell legs was cost-effective.

It became evident that the procedures currently used to measure the cost-effectiveness of transit improvements do not adequately measure the effectiveness of C/D systems. In particular, the cost-effectiveness indices used by the Urban Mass Transportation Administration (UMTA) to analyze transit investment options nationwide (*2*) assume that introduction of a new transit system has no effect on the generation or distribution of trips, nor do they consider the diversion of walk trips to transit within the downtown area if the travelers arrive in the downtown by regional transit. Changes in travel patterns and the distribution of regional transit trips throughout the downtown are two of the primary functions of C/D systems.

The purpose of this paper is to describe the findings of the cost-effectiveness analysis conducted for the Omni and Brickell legs of Metromover by Metro-Dade County and suggest new procedures for evaluating future C/D systems. Of particular interest is the rationale and method for measuring the value of increased trip lengths induced by the legs.

BACKGROUND

Cost-effectiveness has evolved over the last 15 years or so as a method for evaluating alternative investment strategies that

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lack a common basis for comparison. Alternative transportation investment strategies frequently have vastly different initial costs, annual operating and maintenance costs, and life expectancies, and usually do not achieve the same performance level. Cost-effectiveness provides a mechanism for evaluating the performance level of alternatives for achieving some stated objective, or group of objectives, with respect to costs.

The concept of cost-effectiveness, as applied to transportation projects, was fostered by UMTA and has been applied to the decision-making process for all major transit system investments since the mid 1970s. UMTA was searching for an alternative to single-valued indices such as benefit/cost ratios and internal rates-of-return to evaluate project performance. Single-valued techniques require the conversion of all project costs, benefits, and disbenefits to their dollar values. Numerous assumptions are required regarding the dollar value of travel time saved, the dollar value of accidents foregone, and so on. These assumptions, and the often complex calculations involved in applying them, tend to mask the performance and impact differences among alternatives.

Cost-effectiveness provides the opportunity to examine a project from many different perspectives. The effectiveness of a transportation system improvement can be measured in terms of the number of trips it serves, the different travel markets accommodated, or its economic impacts. Using cost in the numerator of the cost-effectiveness measure scales the performance by the project's cost.

Cost-effectiveness has its roots in economics. Like many economic analysis techniques (e.g., equivalent uniform annual cost, rate-of-return, benefit/cost ratio), initial costs for construction, vehicle procurement, and rights-of-way (i.e., the capital costs) are annualized and added to annual operating and maintenance costs, or the actual costs by year are converted to their present worth. In some applications, benefits that accrue to transit system users are converted to dollar values and subtracted from the costs. The costs are then divided by a measure of effectiveness.

One difficulty in applying this concept to the Omni and Brickell legs of the Metromover system was the absence of a frame of reference to guide in determining if the cost-effectiveness values computed indicated good, average, or poor performance. This project had been restricted by the federal legislation mandating the study of the build and the no-build alternatives. There was, therefore, no separate Transportation System Management (TSM) or other build options to use for comparison. (The no-build alternative and the TSM alternative were considered to be the same for the purpose of this study.) Without some frame of reference, the cost-effectiveness indices would be of little value in the decision-making process.

UMTA has adopted a cost-effectiveness index used throughout the country to determine whether a project is eligible for funding. The measure of effectiveness is the change in regional (linked) transit trips. (A trip from primary origin to primary destination is a single-linked trip, regardless of the number of separate conveyances used.) The index can be calculated to represent the total project cost-effectiveness (the total index), the cost-effectiveness with respect to the local share of the project cost (the local index), or the cost-effectiveness with respect to the federal share (the federal index) of the project cost. Using the UMTA index would allow comparisons of the results of the "cost per additional transit rider" for the Omni and Brickell legs against other projects and against UMTA criteria.

The single-valued cost-effectiveness index described above has the same flaws as a benefit/cost ratio, an internal rate of return, or a uniform annual cost. There are assumptions regarding the benefits of the project to transit users (computed as travel time savings), and the difference in operating and maintenance costs are added to annual costs regardless of who pays. The application of the guidelines for computing the index (*2*) does not differentiate between the functions and impacts of C/D systems and regional transit systems improvements. Despite these difficulties, it was decided to apply the concept to the analysis of the Omni and Brickell legs of Metromover. Revisions in the methods of calculating costs, benefits, and the measures of effectiveness adopted for this analysis are presented.

DEFINITION OF THE COST-EFFECTIVENESS INDEX

The incremental annual cost per incremental annual rider, that is, the total index used by UMTA, is further described as follows:

$$\text{Index} = \frac{\Delta\$\text{CAP} + \Delta\$\text{O\&M} + \Delta\$\text{TT}}{\Delta\text{RIDERS}}$$

where

Δ = change between the alternative being considered and the base case,
$CAP = total capital cost annualized over the life of the project,
$O&M = total annual operating and maintenance cost,
$TT = annual value of travel time by existing transit users, and
RIDERS = annual transit ridership measured in "linked" trips, that is, not counting transfers among transit modes.

The index is often referred to as the cost per additional transit rider.

The federal index is computed by substituting the federal capital cost contribution in place of $CAP. Note that the federal cost-effectiveness index includes all the annual O&M costs, regardless of who pays. Because they are paid largely by revenues and local subsidies, it would appear that they should not be included in the federal index. The local index is computed also by substituting the local capital cost contribution in place of $CAP.

COST CALCULATIONS

The capital cost used in the numerator of the UMTA index is the total base-year capital cost, annualized assuming a 10 percent net discount rate, representing the time value of money. The life of the project is assumed to be 100 years for rights-of-way, 30 years for guideway facilities, 25 years for rail vehicles, and 12 years for buses. Operating and maintenance costs are computed for a transit operating plan developed for the project horizon year (usually 15 to 20 years into the future) and stated in base-year dollars. This technique essentially implies that the horizon year represents the operating characteristics throughout the project's life.

Farebox revenues are not considered in the UMTA index despite the fact that they are used to offset, and perhaps cover, increases in operating and maintenance costs. C/D systems are generally considered to be more efficient in terms of their ability to cover operating and maintenance costs from farebox revenues than more traditional regional transit systems because they require fewer operating personnel. This characteristic is lost in the UMTA index, which does not include the revenue generated by the system as an offset to operating costs.

BENEFIT CALCULATIONS

The UMTA index includes a measure of user benefits subtracted from the costs. Benefits are computed for the travel time savings that accrue to base system transit users with improved services. The procedure assumes that transit users are making the same trip, that is, the same origin and destination, with or without the C/D system. The value of time is specified to be $4 per hour for work trips and $2 per hour for nonwork trips in 1984 dollars.

The benefit calculations for base system transit users with a C/D system do not account for the redistribution of trips that occurs with improved service. People take longer trips that may increase their travel time. Despite the increased travel time, this must represent a benefit to users or they would not choose a longer trip. Failure of the UMTA index to consider this benefit is a significant deficiency in the use of the index to evaluate C/D systems.

One way to measure the value of longer trips to the user is to assume that the additional time spent traveling times the dollar value of time is a measure of the benefit. This procedure appears to be consistent with assigning a value to the travel time saved when a person makes the same trip as before, and it is compatible with information available from the travel demand and simulation models. Total travel time savings would consist of the time people would save if they were making the same trip with the C/D system as with the base system. The additional travel time they incur to make a longer trip with the C/D system represents the benefit of the longer trip. The travel time saving would be added to the additional travel time incurred to make a longer trip and then multiplied by the appropriate value of time ($4 per hour for work trips, $2 per hour for nonwork trips) for that trip purpose to estimate the value of the travel benefits.

MEASURES OF EFFECTIVENESS

The primary transportation function of a C/D system is to increase mobility within the downtown area, thus increasing accessibility and encouraging increases in the level of economic activity and the density of development. The measure of effectiveness, therefore, should be the number of new transit trips made within the downtown, regardless of the mode of arrival. The UMTA index uses the change in regional transit trips (linked trips) as the measure of effectiveness. Although this is an important consideration in evaluating a C/D system, it does not capture the contribution of the C/D system to downtown mobility.

CALCULATIONS OF THE INDEX

Estimates of ridership, travel time, and capital and operating costs documented in the draft EIS for the Omni and Brickell legs of the Metromover system (*1*) have been used in calculating the cost-effectiveness indices. All costs are in 1986 dollars.

- The annualized capital cost difference (Δ$CAP) between the build and no-build alternatives was estimated at $20 million (Table 1).
- The difference in annual operating and maintenance costs (Δ$O&M) between the build and no-build alternatives is $2.5 million ($149.0 − $146.5 million) (Table 2).
- The difference in net operating and maintenance cost (Δ$O&M minus the difference in operating revenue) is $1.8 million.

TABLE 1 ANNUALIZED CAPITAL COST (SAVINGS) SUMMARY (1986 COSTS TIMES THE CAPITAL RECOVERY FACTOR FOR THE APPROPRIATE LIFETIME OF THE COMPONENTS AT A 10 PERCENT DISCOUNT RATE)

	NO-BUILD	BUILD
METROMOVER	0	20.3
METRORAIL	0	0
METROBUS	0.3[a]	0

[a]16 more buses are required to operate the No-Build Alternative. Buses bought by MDTA in 1986 cost $145,000 each.

TABLE 2 OPERATING AND MAINTENANCE COST (SAVINGS) SUMMARY (ALL COSTS IN 1986 DOLLARS × $1 MILLION)

	NO-BUILD	BUILD
METROMOVER	4.03	8.26
METRORAIL	52.72	52.72
METROBUS[a]	89.73	88.00
TOTAL	146.48	148.96

[a]SOURCE: "Methodology for Calculating Operating and Maintenance Costs and Revenues for the MDTA Regional Transit System in the Year 2000," Feb. 27, 1987. Gannett Fleming.

The Metromover's transportation function is both to distribute trips arriving and leaving the CBD, and to circulate trips within the CBD.

- It is estimated that 23,602 daily Metrorail users will save an average of 2.79 min per trip, and Metrobus users will lose an average of 0.61 min per trip. This translates to 43,389 min saved per day, or 217,000 hr per year (Table 3).
- Assuming that two-thirds of the trips are work trips and one-third are nonwork trips, and the value of time in 1986 dollars is $4.41 per hour and $2.21 per hour for work and nonwork trips, respectively, the travel time savings (Δ$TT) is estimated to be $0.80 million for these users.

Other transit users who will benefit from the proposed build alternative improvements are internal travelers. This includes only person trips within the downtown made by Metrorail, Metromover, Metrobus, and walking.

- There will be 369,995 daily internal workplace-based trips and 154,075 daily non-workplace-based trips made within the expanded CBD with the no-build alternative in the year 2000 (Table 4).
- If the Omni and Brickell legs were built, the average travel time savings would be 0.46 min for the workplace-based trips and 0.41 min for non-workplace-based trips. Using $4.41 per hour for workplace-based trips and $2.21 per hour for non-workplace-based trips, the value of time saved is $4.45 million per year.
- The average trip length for Metromover trips for the no-build alternative is 0.61 mi and that for the build alternative is 1.16 mi. For the 15,700 Metromover users on the no-build alternative, the additional 0.55 mi at 11 mph average speed represents a travel time of 47,100 min per day or 235,500 hr per year. (It is recognized that this is an approximation of the additional travel time incurred; however, it was the best approximation available at the time the analysis was conducted. Reconstruction of the travel demand and network simulation model output would have been necessary to provide better estimates.)
- Assuming that two-thirds of the trips are work trips and one-third are nonwork trips, and the value of time is $4.41 and $2.21 for work and nonwork trips, respectively, the difference in travel time savings (Δ$TT) is estimated to be $0.87 million per year for this market segment.

TABLE 3 EXTERNAL/INTERNAL DAILY TRANSIT TRIPS AND AVERAGE TRAVEL TIME SAVINGS (LOSSES) IN MINUTES PER TRIP

	NUMBER OF TRIPS	SAVINGS (LOSSES)
METRORAIL USER	23,602	2.79
METROBUS USER	36,820	(0.61)

TABLE 4 INTERNAL DAILY TRANSIT TRIPS[a] AND AVERAGE TRAVEL TIME SAVINGS (LOSSES) IN MINUTES PER TRIP

	NUMBER OF TRIPS	SAVINGS (LOSSES)
WORKPLACE BASED	369,995	0.46
NONWORKPLACE BASED	154,075	0.41

[a] Walk trips are included.

The difference in the number of transit trips (riders) within the downtown is 8,681 per day (Table 5). Using a multiplier of 300 average days per year, the annual difference in transit riders is 2.6 million. If, however, the difference in the number of linked trips is used, the number of new transit users is 5,197 per day or 1.6 million per year. Applying these costs, benefits, and measures of effectiveness yields the results presented in Table 6.

CONCLUSIONS

Table 6 shows the results of adopting different assumptions to the calculation of cost-effectiveness for the Omni and Brickell legs of the Miami Metromover system. It is obvious that the assumption regarding the appropriate method for measuring

TABLE 5 DAILY TRANSIT TRIP SUMMARY (YEAR 2000)

		NO-BUILD	BUILD	DIFFERENCE
EXTERNAL/ INTERNAL MARKET	PARKING LOTS	593	1,167	574
	METRORAIL	10,001	15,349	5,348
	METROBUS	36,820	36,419	-401
INTERNAL MARKET	WORKPLACE	6,105	7,939	1,834
	NONWORKPLACE	2,408	3,734	1,326
TOTAL		55,927	64,608	8,681

TABLE 6 IMPACT OF DIFFERENT ASSUMPTIONS ON THE COST-EFFECTIVENESS RESULTS FOR THE OMNI AND BRICKELL LEGS OF METROMOVER (DOLLARS PER ADDITIONAL TRANSIT RIDER)

	TOTAL INDEX	FEDERAL INDEX	LOCAL INDEX
UMTA GUIDELINES	$10.78	$7.66	$1.40
USING THE INCREASE IN DOWNTOWN TRANSIT TRIPS	$ 8.63	$4.71	$0.86
ADJUSTING FOR LONGER TRIPS	$ 6.30	$4.37	$0.53
ADJUSTING FOR FAREBOX REVENUES	$ 6.03	$4.10	$0.26

effectiveness has the most significant impact on the values of the indices. The impacts of adjustments for the benefits of longer trips and for the consideration of changes in farebox revenues are smaller, but not insignificant.

The method of estimating the value of increased trip lengths is a new concept that deserves further consideration. The procedure adopted here equated the value of increased trip lengths to the value of the increase in travel time spent to make the longer trip. That is, had the person decided to make the same trip after the C/D system was introduced, the trip would have taken less time. The value of that decrease in travel time would have been measured by multiplying the value of time by the time saved. Because the person chose a longer trip, he or she has chosen to incur additional travel time. It seems reasonable that the value of the longer trip is at least equal to the value of the additional travel time he or she chose to incur. Although there may be other methods of estimating the value of longer trips, this method is compatible with the information available from current travel demand and network simulation models and consistent with concepts of applying values to travel time savings.

The results of this analysis indicate that any technique for evaluating alternative investment strategies, be it cost-effectiveness, benefit/cost ratios, internal rates of return, or equivalent annual cost, must be applied with a great deal of judgment and care. These techniques can help decision makers make judicious decisions if they are consistently applied to all options being considered. In the case of the Omni and Brickell legs of Metromover, only one build alternative was being evaluated. It was difficult to make judgments regarding the absolute value of the cost-effectiveness index in the absence of other alternatives. The primary value came from comparing the index with those computed for transit improvements in other cities and with UMTA criteria. These comparisons indicated that the Omni and Brickell legs were reasonable investments based on transportation performance.

Cost-effectiveness indices are not, however, the only relevant considerations. Land use and economic development impacts; infrastructure costs; and the vitality of social, recreational, and cultural activities should also be considered in selecting downtown circulation/distribution system investment strategies for major metropolitan areas. There is a need to refine procedures and techniques for evaluating cost-effectiveness and to develop a more comprehensive structure to provide decision makers with better, more useful information on the consequences of alternative transportation system investment strategies.

REFERENCES

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