EVALUATION OF RAIL RAPID TRANSIT AND EXPRESS BUS SERVICE IN THE URBAN COMMUTER MARKET

J. Hayden Boyd,* Motor Vehicle Manufacturers Association of the United States, Inc., Detroit, Michigan;
Norman J. Asher, Institute for Defense Analyses, Arlington, Virginia; and
Elliot S. Wetzler,* Econ, Inc., Princeton, New Jersey

ABRIDGMENT

The basic alternative transportation modes in the urban commuter market, which are bus and rail transit, are covered in this paper. Comparing these alternatives on the basis of full cost, which includes supplier cost (costs for vehicle, way, and structure) and user-time cost (costs for access, waiting, in-vehicle, transfer, and egress time), is dealt with. A modern rail rapid transit line has about the same passenger-carrying capacity as a bus system has if the bus system uses an exclusive busway for line-haul and surface streets for downtown distribution. The levels of user-time cost for a modern rail rapid transit line are equivalent to those for a bus system, but the supplier costs are much higher for rail rapid transit. Lower full cost can be achieved for low-density, short-haul residential collection if 8-passenger bus-wagon jitneys are used instead of 50-passenger buses.

•MAJOR new public transportation facilities are being built in or planned for large U.S. cities principally to serve the high-density urban commuter market. This paper reports the results of a study of the 2 main alternatives for serving the urban commuter market: (a) modern, highly automated rail rapid transit and (b) integrated express bus service. This paper is a summary of a more detailed report available elsewhere (1).

We compared various versions of the main alternatives on the basis of full cost (supplier costs plus user-time costs). Supplier costs include capital and operating costs for vehicles, way, and structures. Supplier costs would be equal to fares when fares cover all operating and capital costs and a normal return on investment. In recent years, fares generally have not covered supplier costs. User-time costs include costs for access and egress walking, waiting, in-vehicle, and transfer time. External costs, such as those associated with aesthetics, noise, and air pollution, were not included in the comparisons although calculations of emissions of several pollutants were performed. The commuter trip was broken down into residential collection, line-haul, and central business district (CBD) distribution phases.

Level of patronage was treated as a parameter, and the relative ability of alternative systems to attract customers was not analyzed explicitly. However, empirical research indicates that money fares and travel time (including both out-of-vehicle and in-vehicle time) are the most important determinants of commuters' choice of mode. The method of analysis sought to reduce the elements of different systems that were not suitable for comparison by including user-time costs and by standardizing floor space per passenger for bus and rail passengers. If one alternative system has lower

*Dr. Boyd and Dr. Wetzler were with the Institute for Defense Analyses, Arlington, Virginia, when this research was performed.

Publication of this paper sponsored by Committee on Public Transportation Planning and Development.

full costs than another has in a given market, then it is likely to attract more patronage if equal subsidy is assumed.

The sources of supplier costs and a detailed explanation of the costing methodology are given in the complete study (1). In general, supplier costs were based on actual capital and operating costs of current transit systems that were adjusted where necessary to reflect differences between existing and modern systems. The trends of these costs in constant dollars over time have been established and were used as a basis for projecting future costs. In the case of operating costs, the time period used for projecting costs was 1960 to 1970. Accordingly, the recent increases in fuel costs were not reflected in our projected operating costs.

Costs for rubber-tired vehicles and rail rapid transit were first developed for conventional operations on an average cost basis. Cost-estimating relationships then were developed from the average cost data. These estimating relationships allocate a greater than average amount of driver and capital costs to peak-hour service and permit one to ascertain the effect of operating speed on cost per vehicle mile (vehicle kilometer).

User-time costs depend on both travel time per trip and time valuation. Recent literature based on statistical analyses of travel behavior and mode choice indicates that travelers value time spent in urban transit vehicles at about 40 percent of their hourly average earnings. Out-of-vehicle time, such as walking and waiting time, is valued at about hourly earnings or 2.5 times in-vehicle time. In the study, we compared alternatives for commuter services by assuming 2 values of time. The values we used correspond to hourly earnings of \$3.00 and \$7.50 to represent the range of values that commuters place on their time. Surprisingly, the time value assumption has little effect on the ranking of alternatives established by our analysis.

Full costs for each of the alternatives and subalternatives were computed for patronage levels ranging from very low to very high. In each case, service frequency was optimized to minimize the sum of supplier and user-time costs. At a given level of patronage, increasing frequency results in lower waiting-time cost but higher supplier cost per passenger.

For the residential collection phase, average route spacings of 3 blocks and 6 blocks were analyzed. The closer spacing reduces costs for access walking time but increases [for a given level of passengers generated per mile^2 (kilometer^2)] costs for waiting time or supplier costs per passenger or both.

For residential collection for a rail transit system, we analyzed 5-passenger automobile jitneys, 8-passenger bus-wagon jitneys, 19-passenger minibuses, and 50-passenger conventional buses. For any time value, larger vehicles become relatively more economical than smaller vehicles on longer routes. Supplier costs [low seat-mile (seat-kilometer) costs] become relatively more important than waiting costs (high service frequencies). Furthermore, for routes of any length, the advantage of smaller vehicles over larger vehicles increases with time value. People who value time highly are willing to pay a higher fare, which means a higher seat-mile (seat-kilometer) cost, for more frequent and faster service. The effect of frequency is more important than the effect of higher speeds to commuters for the conditions analyzed because values for in-vehicle time are lower and the difference in speeds among residential collection modes is relatively slight.

Our analysis indicated that the 8-passenger bus-wagon is nearly always the most desirable low-cost alternative for residential collection even though conventional buses may have lower supplier costs at high densities. Conventional buses have lower full costs only for combinations of low time value, long routes, and high passenger density. We can infer, then, that bus-wagons operating as jitneys are likely to have lower full costs than bus transit for inner-city circulation services (those bus operations within the city that are for other than peak-hour CBD commuting).

Rail rapid transit tunnel, roadbed, and station costs vary considerably. The costs of Chicago's Milwaukee-Dearborn-Congress subway and the new Toronto, Montreal, San Francisco, Washington, Atlanta, and Baltimore systems are examples of the cost of a typical new system. Each cost about \$23 million/route mile (\$14.4 million/route km) (exclusive of rolling stock) in 1972 dollars with a 1 percent/year upward trend net of general inflation.

The Lindenwold Line between Philadelphia and the New Jersey suburbs is an example of an inexpensive system. The cheapest of the automated, high-quality North American transit lines, the Lindenwold Line uses an already existing downtown subway and bridge over the Delaware River and a former suburban railroad right-of-way. Costs for tunnels, roadbed, and stations were about $7 million/route mile ($4.4 million/route km), which is about a third of the costs for the typical new system.

Full costs for rail line-haul and CBD distribution plus full costs for residential collection were compared with full costs for an integrated bus system in which the same vehicle is used for all 3 phases of the trip. Bus line-haul was assumed to use either an exclusive busway or mixed-traffic operation on an arterial street. Both the busway and the rail line were assumed to have a peak-hour capacity of about 30,000 seated passengers/h. The bus operating on a busway is the least costly at high passenger flows; the bus operating on arterial streets is the least costly at lower passenger flows. In all cases, total cost for a rail system is markedly greater than for an integrated bus system. The disadvantage for rail transit increases with line-haul distance but decreases with number of transit passengers in corridor. The difference between typical new system full costs for rail and bus systems ranges from about $1/passenger at high passenger volumes and 6-mile (9.6-km) line-haul to about $5/passenger at low passenger volumes and 14-mile (8.75-km) line-haul. The inexpensive way and structure cost reduces, but does not eliminate, the full cost disadvantage of rail. The much higher supplier cost for rail transit buys service virtually identical to that of an integrated bus system when measured by user-time costs.

ACKNOWLEDGMENT

This study was sponsored by the Office of the Assistant Secretary for Policy, Plans and International Affairs, U.S. Department of Transportation.

REFERENCE

1. J. H. Boyd, N. J. Asher, and E. S. Wetzler. Evaluation of Rail Rapid Transit and Express Bus Service in the Urban Commuter Market. U.S. Government Printing Office, Rept. DOT P 6520.1, 1973.

DISCUSSION

Vukan R. Vuchic, University of Pennsylvania

It has always been known that rail technology is the most logical choice for transit lines that have reasonably high passenger volumes. Under such conditions rail technology has not only an operational advantage but also (depending on local conditions) a cost advantage over other modes. In recent years, several dozen cities throughout the world that have built new rail systems have made that choice after detailed analyses of economic, operational, environmental, and other relevant factors of different modes. Successful rapid transit lines sometimes carry as few as 30,000 to 40,000 persons/day (the Lindenwold Line carries 42,000 persons/day); light rail often carries not more than 10,000 persons/day.

It appears surprising, then, that several recent "theoretical" studies claim that rail technology should be used only when passenger volumes are extremely high (tens of thousands of persons/h). Figures such as these are actually much higher than can ever exist without the presence of a rail line. How did several previous studies (1, 3, 6) reach results directly contrary to the well-known and proved facts about characteristics of different modes? These studies reached results contrary to the cost analyses done by virtually all agencies and consultants in actual transit planning studies, a recent example of which is available elsewhere (4), and contrary to the worldwide trend toward accelerated improvements and construction of light rail transit, rapid transit, and regional rail transit systems. What is the cause of such a drastic discrepancy between actual planning and comparisons (8) and this type of hypothetical study? An examination of the Boyd, Asher, and Wetzler study (1), which is typical for this kind of hypothetical study, is given elsewhere (7). Only some of its major points (objective, methodology, and numerical values used) will be summarized briefly here.

Although the objective of the Boyd, Asher, and Wetzler study (1) is not clearly stated, it obviously attempts to compare bus and rail technologies on the basis of their operating and user costs. The model for this is a single hypothetical corridor. Serious deficiencies exist in this approach. Minimum cost cannot be the sole criterion of comparison unless modes offer identical services; the rail and bus systems compared by Boyd, Asher, and Wetzler differ not only in service quality but also in the origin-destination pairs that each one can serve. "Rail" and "bus" are technologies, not modes. Type of right-of-way determines characteristics of modes more than technologies do. Thus a streetcar is more similar to surface bus than to rapid transit. The performed comparison of such diverse modes as rapid transit, surface bus, and even jitney is equivalent to comparing single-family housing, condominiums, and tenements on the basis of costs only and concluding that the cheapest is the best.

The methodology used also abounds in conceptual and factual errors that are discussed elsewhere in considerable detail (2). It should be mentioned that the evaluation methodology used is much less comprehensive than the one developed by the American Association of State Highway Officials for highways in the 1950s (2), which itself has been superseded by extensive works on evaluation methodology, such as those by Kuhn (5) Hill, Morlok, Wohl, Martin, and others. The authors show no awareness of these works.

The most serious deficiency in the methodology, however, is the assumption that patronage is the same on all modes even though their services drastically differ. This assumption is so contrary to the modal-choice behavior abundantly documented in professional literature that it, alone, would be sufficient to invalidate all results of the study.

Finally, numerical values used in the study are largely incorrect. Thus assumed bus capacity is 28 percent higher than can be physically accommodated within vehicles of legal maximum size; bus speed is overestimated by 25 percent.

The bias against rail is obvious throughout the study. The most drastic example is the absurd claim that air pollution caused by electrically powered vehicles is about the same as that caused by buses. This claim neglects the facts that electric power plants produce pollution outside the city and can be controlled and that bus exhaust is delivered in the CBD area where the concentration of people is highest. Pollution caused by diesel oil refineries, which corresponds to that caused by power plants, is not even mentioned.

The antirail bias is also obvious in the fact that the rail rapid transit mode is based on the most expensive systems without considering the superior features of such systems in the areas of reliability, comfort, and fail-safe operation. The study does not mention light rail systems; the authors admittedly were not aware of the existence of this mode.

It is obvious that, with the deficiencies in the objective, methodology, and numerical values as well as an extreme modal bias, the results of this study and other studies that used the same approach must be far from reality. This study therefore has no value in clarifying urban transportation issues. Actually, it only confuses them.

In previous oral and written debates concerning the study, the authors used 2 defenses. The authors maintained that, even if different numbers were used, the results would not change significantly. However, some of the tests performed on the model by the Transportation Systems Center in Cambridge, Massachussets, resulted in a situation where rail transit came out cheaper for low passenger volumes and buses came out cheaper for high volumes. This result and the claimed insensitivity of the model to cost changes, both of which are contrary to real-world facts, show that the model is inherently unrealistic. The second defense of the authors was that their study was limited to costs only. If this is the case, then most of the extremely general statements in the study report (1), particularly all of those in Chapter 6, are totally groundless. In Chapter 6 of the report (1), the study presents a sweeping criticism of virtually all actions of the Urban Mass Transportation Administration and other government bodies toward improvement of transit including criticism of improvement of bus services. The only constructive suggestion in this section is that the Urban Mass Transportation Administration should organize a demonstration of jitneys in 1 or more small cities that currently have no transit. This criticism clearly shows that the study most likely was undertaken as a quasi-scientific cover for an attack on all progress in urban public transportation and improvements of cities.

One of the basic reasons for founding the U.S. Department of Transportation in 1967 was to introduce treatment of transportation as a function performed by a combination of coordinated modes. This approach, which gives adequate consideration to all efficient modes from walking and private automobile to express bus and rapid transit, should substitute for the unimodalism of the 1950s and 1960s, which favored only the private automobile. We are only beginning to realize the damaging consequences of the unimodal policy.

The U.S. Department of Transportation has fulfilled many expectations in this direction. But the sponsoring of this and similar studies (3) that use obsolete methodology to pursue the futile search for the "best mode" shows that the efforts to substitute professional expertise for fanatical promotion of individual modes have been only partially successful. The efforts must be continued more energetically if we are to answer the urgent needs of cities for better transportation, which will result in high mobility, economic efficiency, and a better urban environment.

REFERENCES

2. Road User Benefit Analysis for Highway Improvement. American Association of State Highway Officials, 1960.
3. K. Bhatt. Comparative Analysis of Urban Transportation Costs. Paper in this Record.
4. Comparison of Bus and Rail Modes: Line-Haul Service Henrietta-Charlotte. Corddry, Carpenter, Dietz and Zack, Engineers, Rochester, N.Y., 1971.
5. T. Kuhn. Public Enterprise Economics and Transport Problems. Univ. of California Press, Berkeley, 1962.
6. J. Meyer, J. Kain, and M. Wohl. The Urban Transportation Problem. Harvard Univ. Press, Cambridge, Mass., 1966.
7. V. R. Vuchic. A Critique of the Study "Evaluation of Rail Rapid Transit and Express Bus Service in the Urban Commuter Market" by the IDA. Urban Mass Transportation Administration, Feb. 1974.
8. V. R. Vuchic and R. M. Stanger. Lindenwold Rail Line and Shirley Busway: A Comparison. Highway Research Record 459, 1973, pp. 13-28.

AUTHORS' CLOSURE

Vuchic's comments deal with the larger study on which the abridgment published in this Record is based (1). Apparently, he has come to different conclusions about the relative efficacies of alternative urban transportation modes, but he presents no facts in his comments that are relevant to a comparison between modes. Instead, he makes sweeping and undocumented appeals to "well-known and proved facts about characteristics of different modes." He accuses us of extreme modal bias and alleges that "the study most likely was undertaken as a quasi-scientific cover for an attack on all progress in urban public transportation and improvements of cities." Vuchic is entitled to his opinions, of course. Unfortunately, his comments make a number of factually incorrect statements about the contents of the full report (1), the data, methodology, and conclusions of which are explained in detail. A few comments on Vuchic's discussion are, however, in order.

In support of a general assertion that "numerical values used in the study are largely incorrect," he claims that "assumed bus capacity is 28 percent higher than can be physically accommodated within vehicles of legal maximum size; bus speed is overestimated by 25 percent." In fact, as a perusal of the final report summary will indicate, we assumed 50 seats/bus, which is standard for North American 40-ft (12.2-m) transit buses. We assumed that buses operate at 15 mph (24 km/h) in residential collection, 20 mph (32 km/h) in express service on arterial streets, 45 mph (72 km/h) on exclusive busways, and 9 mph (14.4 km/h) in the CBD. These speeds are consistent with U.S. transit operating experience.

We have never claimed that, even if different numbers were used, the results of the study would not change significantly. In fact, a large part of the study was devoted to assembling a comprehensive data base on present and projected transit operations. The conclusions of the study are robust, and the relative full costs of various modes do not change with variations in the cost parameters within the ranges suggested by the various commentators on the study. The abridgment published in this Record discusses the results of varying the most significant of the cost parameters—the cost for rail way and structures.

Vuchic makes the distinction between light rail and heavy rail technology. Light rail operations currently exist in Boston (part of MBTA), Philadelphia (part of SEPTA), Shaker Heights, Ohio, and Newark, New Jersey. These operations are included in the computerized data base for the full report, and complete details and cost breakdowns have been published (9). Car-mile (car-kilometer) operating costs of existing light rail systems are in the same range as those of heavy rail systems, which is several times higher than for bus operations.

In our comparison of pollutants per passenger trip by various modes, we clearly stated that electric generating plants may be located away from the metropolitan area and that this could reduce the effects of pollution on the population (1, p. S-14, p. 58). We neglected to consider sulfur oxides and particulate emissions, which are likely to be significant for electricity generation. We did not consider refinery pollution for production of oil for diesel buses or for electricity generation or pollution caused by transportation of coal. These secondary pollution effects are likely to be minor compared to the burning of the fuel itself.

Vuchic's statements about our comparison methodology are somewhat easier to understand if one recognizes that, in his lexicon, user cost is a synonym for money fare. Thus, his concept of user cost has nothing to do with user-time cost as we have defined it in the study. A study by Vuchic and Stanger (8) that compared a rail transit system with a busway system used a different method of accounting for travel time inputs. In place of a calculation of access walking time, the Vuchic and Stanger study presented a subjective evaluation of "availability." A qualitative judgment about "frequency" was used instead of a computation of waiting time. Similar subjective judgments were made about other elements of what we have called "full cost," and these judgments were arrayed in tabular form. We believe that our methodology is advantageous because objective measures based ultimately on travelers' valuations as expressed in their choice of mode are used.

We agree with Vuchic's point that an integrated bus system and a rail rapid transit system offer different types of service and geographic coverage. It is for this reason that we explicitly analyzed the entire commuter trip, including the residential collection necessary to get patrons to the rail rapid transit station. We concluded that bus-wagon jitneys have lower full cost for residential collection in most of the cases analyzed. Despite its overall lower full cost, the integrated bus is at a disadvantage in the residential collection phase of the trip.

Current transit policy supports existing bus and rail systems and supports construction of new, high-quality commuter systems, largely with capital grants from the federal government. Rail transit has been the technology of choice for these new systems. Our evidence suggests that alternatives to rail technology exist that use less of society's and the traveler's scarce resources for commuter trips. Our evidence further suggests that alternatives to conventional bus services exist that use fewer resources for low-density, short-haul public transportation. The discussion that has greeted our research, exemplified by Vuchic's comments here, has yet to identify compelling reasons for preferring one mode over another that are not related to the public and traveler costs that we discussed. There may be specific, local situations falling outside the range of the parameters we considered that might lead to different conclusions about relative modal full costs. References to past policies that have favored rail transit hardly refute our research. Indeed, recent press accounts of public dissatisfaction with cost overruns on the Washington, D.C., Metro and continuing operational and financial difficulties with the San Francisco Bay Area Rapid Transit System coupled with favorable experience with busway services in Northern Virginia and elsewhere tend to support the major conclusions of our study.

REFERENCE

9. J. D. Wells et al. Economic Characteristics of the Urban Public Transportation Industry. U.S. Government Printing Office, Stock No. 5000-0052.