Evaluation of a Bus Transit System in a Selected Urban Area

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The objective of this study was the investigation and evaluation of a bus transit system as a reasonably acceptable and economical alternative to the construction of additional highways in medium- to large-sized urban areas. In a selected urban area, the location and magnitude of the forecast year peak hour vehicular overloads on the existing and committed highway systems were determined. Two alternative transportation systems were designed to reduce or eliminate the forecast year overloads—one automobile-oriented and the other bus transit-oriented. Through the use of a modal split model developed as part of the study the ability of each system to relieve the vehicular overloads on the highway system was evaluated. The costs of each system were estimated. It was concluded that bus transit was capable of alleviating peak hour overloads on urban freeways. Based on the findings of the study, bus transit systems were considered a viable alternative to increased urban freeway construction.

•THE COMBINATION of widespread single family home-ownership and industrial technological changes is bringing about the development of vast, low-density areas on the periphery of every urban area in the United States. Conventional public transit cannot compete effectively with the automobile in these generally affluent, low-density areas; and thus most travel to and from origins and destinations in these areas is by automobile. Retention of many attractions, particularly employment, in the high-density central areas causes peak hour traffic congestion, partly from private automobiles originating in the low-density suburban areas. The traffic stream toward the central business district (CBD) is composed of personal automobiles destined to, beyond, and short of the CBD and trucks, taxis, and vehicles originating outside the urban area.

Demands for more streets, highways, and parking facilities, the only alternatives to transit, are exceeding the fiscal and spatial resources of some urban areas. Any solution to future transportation problems, short of introducing revolutionary changes or burdensome restrictions on the growth and development of urban areas, must either provide more transit service or more highway facilities or, more realistically, a combination of both, using the best characteristics of each alternative to provide an optimum balance between user needs and cost of building and operating the facilities.

During the last two decades, bus transit systems have experienced lower patronage, higher fares, reduced service, and still lower patronage. Recently, however, there has been a significant countertrend in patronage, indicative of the bus transit system's promising future role in the transportation pattern of cities in the United States. Transit ridership has increased in areas featuring express bus service to congested business and commercial centers and on special, premium fare, door-to-door services. Similar increases have been noted in communities with aggressive and effective mass transit marketing and public relations programs.

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The success of a bus transit system in any community depends on the degree to which it can satisfy the transportation needs of the community and its residents. The development of an effective system, therefore, must be founded on the social, economic, and political goals of the community and must be backed by the willingness of the community to provide the determination, leadership, and resources to meet these goals.

OBJECTIVES OF STUDY

The study, conducted by Peat, Marwick, Mitchell and Company under contract to the U.S. Bureau of Public Roads, represents an attempt to remove some of the uncertainty about the economic viability of bus transit to meet the rising demand of travel in medium- to large-sized urban areas. The objective of the study was the investigation and evaluation of a bus transit system as a reasonably acceptable and economically competitive alternative to the solution of current urban travel problems. To achieve this goal, two transportation systems, one automobile-oriented and one bus transit-oriented, of designed equal utility were evaluated to determine which was the lower cost system.

In order to further ensure that the highway and bus system components were of comparable utility, a relatively uncongested flow was established for both automobiles and buses on the highway network during the peak hour, and most bus passengers had seats for the major portions of their trips. It was felt that these two conditions, both technologically obtainable (at an estimatable cost), would ensure nearly equal comfort and convenience for all travelers.

CHOICE OF TEST SITE

The metropolitan area of Baltimore, Maryland, was selected as the test site to compare the alternative systems. Baltimore was chosen because it was considered typical of many cities with regard to its social, physical, and economic development and because data were available.

The findings of this study, however, are not to be construed as a plan of action for Baltimore because the study differed from a typical analytical transportation planning study in a number of fundamental ways. Initially, there was no "feedback" of information on how the proposed transportation plan would affect land use and subsequent trip generation and distribution, which might, in turn, affect use of the transportation system. Furthermore, no consideration was given to a fixed-rail transit system because the principal goal was specifically the evaluation of a bus transit system, not the evaluation and selection from a number of different competing systems. A fixed-rail system, one possible alternative, has been recommended recently for implementation in Baltimore. No inference, therefore, should be drawn concerning the relative advantage or disadvantage of a competing rail transportation system, specifically for Baltimore.

DESCRIPTION OF STUDY

The method for evaluating bus transit systems is similar in concept to the simulation processes used in urban area studies. The steps typically include land use forecast, trip generation, trip distribution, modal split, network assignment, and evaluation. The study accepted the first three items (land use forecast, trip generation, and trip distribution) as given. All information utilized, including the forecast of trip interchange patterns, was based on data from the Baltimore Metropolitan Area Transportation Study (BMATS) conducted in 1962.

The study was divided into five phases, as shown in Figure 1. A description of the activities in each phase follows.

Phase 1—Determination of Travel Overloads

The determination of travel overloads required identification of the location and magnitude of deficiencies in a future, "committed" highway system, as well as the

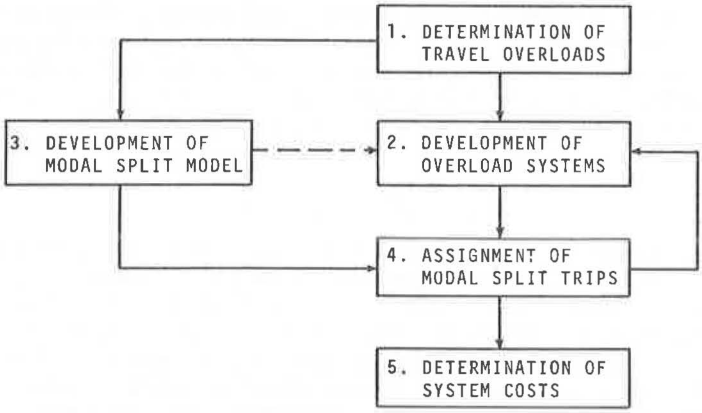

Figure 1. Study approach for the evaluation of a bus transit system in a selected urban area.

identification of any part of the system that might be "under-utilized". The accomplishment of these tasks required some knowledge of how individuals will act and what travel mode choices they will make in the future.

An initial step in determining travel overloads was the development of a special overload trip table. This table was produced by subtracting the number of 1962 transit trips from the projected 1980 total number of person trips. The implications of this assumption were that the existing transit system would attract its present ridership in the future and that the remaining travelers would use automobiles. This assumption was not necessarily true, nor was there any assurance that the present transit system would attract as many travelers or the same patterns of travelers once the committed highway system was operative. This rough approximation seemed less than desirable, but the emphasis was on identifying corridors or areas of overload rather than on exacting values of roadway volumes. It was felt that this procedure would produce a satisfactory picture of travel overloads for the purpose of developing new bus and automobile systems without preparing extensive preliminary modal split information.

For this study, it was desirable to develop a complete understanding of travel behavior and its associated characteristics, and to analyze and properly evaluate differences in alternative investments. Two areas of fundamental concern in the scope of research—congestion and cost—were related to travel occurring over different time spans. Because congestion and associated problems of capacity and delay are generally present during the peak periods of the day, their characteristics usually can best be identified by observing traffic during the "journey-to-work" periods of any weekday. Conversely, costs and revenues should be derived using periods of time that exhibit cyclical travel patterns. Consequently, 24-hour periods were established as the time spans used to study problems of costs. As a result, 2 different hours were selected from a weekday to represent the entire day for data collection and analysis purposes.

The objective of Phase 1 was the identification of trips involved in areas of future roadway congestion during a typical hour of peak and off-peak travel conditions. The attractiveness and success of the proposed new bus services were evaluated for an entire day (peak and off-peak hours) by expanding the travel patterns during these hours to encompass the whole day, based on the percentage of the day they represented.

The peak and off-peak overloads were determined by assigning the overload trip tables to the networks and analyzing the major travel corridors for overload conditions. Several major radial corridors were observed to be significantly overloaded. These corridors approached the CBD from the north, northwest, northeast, east, south, southwest, and west. In addition, a less serious overload was observed on a single crosstown corridor across the north part of Baltimore.

Phase 2—Development of Overload Systems

In Phase 1, the pattern and size of overload areas became apparent. This information was used to formulate designs of two competing alternative transportation systems to solve the overload problem. One system, the automobile-oriented system, consisted of the unimproved transit system existing in the base study year (1962) and a greatly improved highway system designed to alleviate the expected future year peak hour overloads. The other system, the bus transit-oriented system, consisted of an improved transit system and the existing and committed highway system. The design of the improved highway system and the improved transit system is described in the following paragraphs.

Improved Highway System—The determined overloads indicated that an improved highway system was necessary to provide capacity for the peak hour vehicular demands. The most costly highway improvements to alleviate peak hour overloads were required in the inner city or where the high density of trip ends and the funneling of other trips through a small geographic area caused overloads.

Improved Transit System—Today's standard buses reflect vast improvements over earlier equipment. Their wider seats, wider doors, easier access, improved visibility, and air conditioning enhance passenger comfort and convenience. Modern heavy-duty engines and improved acceleration characteristics permit buses to maintain their position in mixed-flow traffic on streets and highways.

The design of the improved transit system was largely concerned with the extra-vehicular considerations of routes, schedules, and the minimization of walking, waiting, and transferring times. In seeking to maximize service and patronage, initial design of routes and frequencies used all service techniques that held promise of realistic success in the Baltimore environment and that could be accomplished within the limits of present technology, labor procedures, and life-styles. These service techniques are described in the following.

Revision of existing service—The integration of transit operations in the area was considered a prerequisite to maximizing service and patronage. The design of an improved transit system was undertaken assuming integration of bus operations in Baltimore and suburban areas. The suburban bus company feeder lines, an outgrowth of suburban expansion, were mainly integrated with principal radial bus routes. Through this integration, additional fares and transfers, the antithesis of maximum service and patronage, were removed wherever feasible.

Supplemental express service—The development of supplemental express service was also considered an essential element to maximizing service and patronage. Supplemental express service was designed to reduce the collection phase in time and space and to expedite movement to the destination over the shortest time path, using the following techniques:

1. Exclusive bus lanes or ways, which are special lanes either on or immediately adjacent to a freeway or on other special rights-of-way that are permanently set aside for the use of buses. These lanes, by providing an exclusive right-of-way for public transportation vehicles 100 percent of the time, allow buses to achieve service comparable to that of a rapid rail facility.
2. Reserved bus lanes, which are freeway lanes set aside for the exclusive use of buses only during peak travel hours, but can be opened for general vehicle use during off-peak hours.
3. Reversible lanes, i.e., all or part of the reversible section of a freeway providing for the peak hour imbalanced vehicular flow that may be reserved for buses.
4. Metering or preferential entry, which involves controlling or "metering" the flow of vehicles onto a freeway to preclude or diminish the over-utilization of the freeway that results in reduced travel speeds. Coupled with this is preferential entry, in which a bus bypasses the queue of vehicles awaiting entry onto the freeway.

Most supplemental express routes were radially oriented and CBD-destined. In addition, several outbound and circumferential express routes were provided to significant employment areas. Even though no outbound highway overload was observed, the outbound routes represented provision of service to a significantly high number of persons in industrially oriented Baltimore with the same equipment operating inbound to the CBD, which would otherwise return to the suburban areas empty. Within the CBD, some express service lanes were routed on reserved street lanes during peak hours to facilitate loading and unloading and to improve speed.

Revision of fare structure—The fare structure was revised to reflect the simplicity of the integrated bus operations. The existing (1962) transit fare structure contained, in effect, 88 different districts. The revised structure contained only 20 fare districts but essentially maintained the basic fares of the previous structure. Transfer charges and the second fares required when transferring between companies were eliminated. A 25-cent base fare for intradistrict travel was established. Generally speaking, at each district boundary crossing, the fare was increased by 10 cents, but circumferential travel, when performed over circuitous radial routes, was not penalized, and the maximum fare was set at 75 cents.

Increase in service frequency—Patronage potential and overload considerations indicate that transit volume, largely on radial lines, must increase by 80 percent in 1980, compared with the 1962 volume, if bus transit is to absorb the highway overload. Accordingly, an 80 percent expansion in frequency of service in radial corridors was planned. The portion of this expansion in excess of the service frequency of the supplemental express service was applied to the existing service in each radial corridor. The expansion in frequency was usually near the outer end of the existing radial routes, as extended by integration of suburban feeders. Of course, this expansion of service frequency was also applied at the maximum load points near the CBD.

The level of service on crosstown (circumferential) lines was improved by increasing service frequency. The increase was approximately 50 percent on the crosstown lines. The revised levels of service at major transfer points were reviewed for optimum "wait time" for interline transfers. In most instances, the estimated wait time (half the headway on the line to which transfer is made) was less than 5 minutes in the peak hour.

Following the preliminary design of the supplemental express service and the revisions of existing service for peak hour operations, the off-peak service was reviewed for improvement in accordance with the development concept. Off-peak service was established on most of the supplemental express lines and was increased on the revised existing system. The planned frequencies were about a third of peak hour frequencies, but not less than hourly.

Downtown distribution plan—In developing rights-of-way for transit vehicles, downtown bus terminals and reserved lanes on surface streets were considered as the basic alternatives. Door-to-door access, travel time, and local customs were the key service considerations in designing the downtown distribution plan.

Phase 3—Development of Modal Split Model

A modal split model was developed for Baltimore, expressing people's choice of travel mode. This model basically consisted of a number of diversion curves for each combination of transit-versus-automobile cost strata and dwelling-unit income strata for the trip purposes of work, school, non-work and non-school. Considerable success utilizing this technique has been achieved in analyzing data from cities such as Philadelphia, Boston, Washington, Toronto, Edmonton, and Winnipeg.

The standardized procedure for calibration and validation of the model considered the basic determining factors to be (a) relative travel time via public transit and private automobile expressed as a ratio, (b) relative travel cost via public transit and private automobile expressed as a ratio, (c) economic status of the trip-maker expressed as median income per worker, and (d) trip purpose and time of day. The basic relationships expressed modal split as a percent of transit ridership against the travel time ratio.

The other variables (relative travel cost and income) were considered as stratification variables in the development of the diversion curves. The relative travel cost variable was defined as the ratio of out-of-pocket travel cost by public transit divided by the out-of-pocket travel cost by private automobile.

Phase 4—Assignment and Analysis of Modal Split Trips

In Phase 4, assignments were made to the transit and highway networks using the forecast trips of the automobile-oriented and bus transit-oriented transportation systems. The networks were balanced by tailoring the facilities designed in Phase 2 for the overload systems to just meet the demand. Highway networks were adjusted by adding or deleting lanes or links, or both. The transit network was adjusted by shortening or lengthening routes and selecting service frequency to conform to the transit load. The route structure of the balanced, improved transit network is essentially the same as that designed in Phase 2.

Analysis of Automobile and Bus Transit Highway Facilities—The bus transit-oriented system attracted approximately 16,000 more persons to the transit system in the morning peak hour than the automobile-oriented system. The difference was concentrated mainly in and near the CBD and alleviated the overload on the existing and committed highway networks in this area. The bus system was not capable of alleviating the overloads that occurred on portions of the Baltimore Beltway or on some outlying highway facilities because of the poorer competitive position of bus transit in areas having low density and highly dispersed travel patterns. Likewise, the improved system was unable to alleviate highway overloads caused by trucks or other vehicles that originated in or were destined to areas outside the metropolitan area. This was the case on the Baltimore Inner Harbor Tunnel, a facility heavily loaded with external and truck traffic. The most pronounced difference between the two alternatives was in the vehicle volumes approaching the CBD.

Major new highway facilities and improvements to existing facilities were proved necessary for the relief of peak hour overload in and near the CBD in the automobile-oriented system. Use of special bus facilities, such as ramps and grade separations, proved beneficial in speeding buses around or over traffic or in a more direct line to their ultimate destinations. These facilities carried loads of between 2,500 and 5,000 persons per hour—the equivalent of 50 to 100 busloads in the peak hour.

Express buses were designed to be routed on freeways into the CBD. The busloads on the densest sections of these radial freeways were also in the range of 50 to 100 in the peak hour. Because of the relatively free flow conditions that were designed for the highway networks, the buses were able to operate in mixed traffic. Exclusive or reserved lanes were not necessary or warranted because the busloads were fairly light, and the time savings over the remaining traffic was small because of the slight speed differential and the short distance traveled on the freeway.

Analysis of Bus Systems—For the autombile-oriented system, 614 fifty-passenger buses were required; the bus transit-oriented system required 900 such buses. By way of comparison, the base year (1962) bus fleet consisted of the equivalent of 812 fifty-passenger buses. The highest peak hour busloads were observed on corridors of travel approaching the CBD. The highest load on any of these corridors was 8,750, with the other corridors ranging from 5,000 to 5,600.

The patronage on most of the supplemental express service routes was fairly good. The most heavily patronized express routes were the radially oriented, CBD-destined routes. Some of the outbound express routes from the CBD to high-density employment sites were also well patronized. Others were not successful for reasons not apparent, such as the circumferential express route. Where a new express route competed for the same business as the existing local route, the express was more heavily patronized, capturing most of the business of the local route.

Local routes operating without competition from express routes in the bus transit-oriented system showed somewhat higher patronage than the same local route in the automobile-oriented system. This was probably due to the relatively improved linking of transit service in the bus transit-oriented system and to the simplified fare structure.

Phase 5—Determination of System Costs

The annual cost method was chosen as the procedure for economic comparison of the two alternative systems. The results were obtained by comparing the annual costs of each alternative. In this manner, each separable increment of proposed investment was considered independently. Based on the theory of capital rationing, which recognizes that resources are and will remain scarce in relation to demand, the preferred solution among alternatives of equal utility was the one incurring minimum cost.

Travel demand, which was projected from the 1962 base year inventory to 1980, formed the analysis period for the study. The systems to be evaluated during this period were defined as the existing and committed highway networks, the existing transit facilities, and additional highway and transit facilities, improvements, appurtenances, buses, and services necessary to meet study objectives.

The uniform annual costs for the 1962-1980 period were computed for each year using an annual discount rate of 6 percent and were expressed in 1966 dollars. For comparison purposes, an annual discount rate of 12 percent was also examined, but it did not produce significantly different results. These costs are given in Table 1.

Public Sector System Costs—Public sector user costs were composed of the following: (a) capital investment, including the costs of construction and rights-of-way for highway facilities, traffic engineering improvements, parking facilities, and fixed transit facilities, as well as those for transit vehicles; (b) plus operating and maintenance costs for highway facilities, traffic operations, and transit vehicles; (c) plus revenue and taxes for both public and private operations; (d) less the remaining service life, which was equivalent to the remaining value of investment as of 1980 for the capital items. Straight-line depreciation, 20-year life, and 20 percent net salvage value for facilities, and a 15-year life and 5 percent salvage value for buses were assumed. It can be seen from Table 1 that only a small economic benefit in the public sector costs was realized from the bus transit-oriented system. The difference between each alternative was so small in relation to the total community costs that no inference was drawn as to which system should be recommended solely on a public sector cost basis.

Private Sector User Costs—In the development of private sector user costs for improved transit systems, the transit fares, automobile ownership costs, and automobile operating costs (including parking fees, tolls, and accident costs) were considered. The uniform annual cost estimate for private automobile operating costs, expressed in 1966 dollars, was $480.3 million for the bus transit-oriented system and $493.1 million for the automobile-oriented system. Comparing these figures with those in Table 1, it can be seen that the magnitude of automobile operating costs dwarfed all other quantifiable monetary transportation costs. It is also apparent that there was an almost negligible difference of less than 3 percent in the automobile operating costs of the two systems. A majority of automobile travel took place in off-peak hours and in areas not affected by congestion and was practically unaffected by the improved bus transit system, which was designed to attract the peak hour overloads in the central business district. The absence of a significant difference indicated the continued overwhelming reliance on the private automobile for most travel, especially in off-peak hours and in low- and medium-density areas. Even though automobile operating costs were the dominant component of all urban transportation costs, they are ironically the least perceived of all costs.

TABLE 1

UNIFORM ANNUAL PUBLIC SECTOR COSTS OF ALTERNATIVE TRANSPORTATION SYSTEMS, 1962-1980

(In Millions of 1966 Dollars at 6 Percent Annual Interest)

Item	Bus Transit-Oriented System		Automobile-Oriented System	
Capital Cost				
Highway facilities	90.5	92.1	105.1	108.8
Parking facilities	1.6		3.7	
Transit facilities	1.4	3.5	0.0	1.3
Transit vehicles	2.1		1.3	
Subtotal	95.6		110.1	
Operating and Maintenance Costs				
Highway facilities	32.8	35.7	33.0	37.9
Parking facilities	2.9		4.9	
Transit facilities	0.2	25.9	0.0	20.0
Transit vehicles	25.7		20.0	
Subtotal	61.4		58.3	
Remaining service life[a]				
Highway facilities	35.9	36.5	41.7	43.3
Parking facilities	0.6		1.6	
Transit facilities	0.6	1.1	0.0	0.3
Transit vehicles	0.5		0.3	
Subtotal	37.6		43.6	
Total	119.4		124.8	

[a]To be deducted from capital, operating, and maintenance costs.

An estimate of the annual transit profit or subsidy required for the bus transit system indicates that the automobile-oriented transit system was able to sustain a slight profit ($2.2 million), whereas the bus transit-oriented system operated at a deficit of $400,000. The automobile-oriented transit system, which did not have the goal of attracting the peak hour overload, operated at relatively higher load factors in the peak hours, had a smaller transit fleet maintenance cost than the bus transit-oriented system, and operated with relatively greater efficiency during the off-peak hours.

The potential for decreased automobile ownership because of increased transit ridership was approximated by the decrease in home-to-work automobile trips for the bus-oriented system compared with the decrease for the same trips in the automobile-oriented system. The extent to which this potential reduction could be realized is problematical. The question essentially concerns the effect of relative transit accessibility on automobile ownership. A regression analysis of automobile ownership in 20 major cities indicated that approximately 735,000 automobiles were estimated to be owned by the Baltimore study area residents under the automobile-oriented system and approximately 670,000 under the bus transit-oriented system, thus resulting in a net savings of the costs of owning about 65,000 automobiles for the bus transit-oriented system. It can be seen that there is approximately an 8 percent savings in automobile ownership costs for the study area residents in 1980.

Community Impact Costs—In addition to considering costs associated with the two alternate transportation systems and those associated with the users, there are impacts on the region and its inhabitants that must be taken into account. These impacts concern social values, environmental values, the general economy, and the use of land. In general, these community impact costs were largely intangible and could not be directly or objectively reduced to quantifiable monetary terms. However, the framework of generally agreed upon community goals should be established, and alternative transportation systems should be evaluated objectively in light of fulfilling these goals.

CONCLUSIONS

Based on the findings of this study, bus transit systems should be seriously considered as an alternative to the construction of additional highways in medium to large urban areas. The following conclusions were drawn from the case study and are recommended for consideration by those who may plan and implement bus transit systems in the near future:

1. Bus transit is capable of alleviating peak hour overloads on urban freeways. Radial freeways in the densest part of the city can be relieved of peak hour demand to the degree where no additional community resources are required in the near future to provide additional capacity. Bus transit is not able to compete effectively in less dense areas or where transit desires are widely dispersed, nor is bus transit able to relieve to a significant degree the overload from highway facilities that are heavily loaded with traffic not susceptible to bus transit such as through, external, or truck traffic.
2. In the urban area studied, relatively free flow was designed for the highway network during the peak hour. Exclusive rights-of-way, however, are distinctly advantageous for bus travel to maintain its competitive position. Either "busways" or preferential entry to metered or reserved freeway lanes during peak hours is recommended to speed bus transit around congested peak-period traffic.
3. In view of the relatively light busloads observed on the most densely traveled sections of typical urban freeways, it appears worthwhile to recommend that other special vehicles, such as high-person-occupancy automobiles, be allowed to use exclusive busways or reserved freeway lanes during the peak period in order to take advantage of the available vehicle capacity.
4. The existing and committed highway systems developed in most cities, primarily under the impetus of the Federal-Aid Highway Act of 1956, are the basic ingredients for the successful operation of a viable bus transit system. These high-speed paths represent the backbone of a competitive bus transit system route structure. Direct and rapid access from suburban areas to the CBD is extremely important. Where no such paths exist or where the bus is severely disadvantaged by operating at typical

peak period forced-flow conditions, the competitive position of bus transit suffers. Completion of certain essential links in some cities' freeway systems is recommended in order to provide direct and speedy bus routes. Once the basic freeway system is constructed, however, bus transit on the basic system can eliminate the need for additional links or lanes, in many areas, by being able to accommodate peak hour overloads.

5. Analysis of the economic findings in this study revealed that the costs of the bus transit-oriented and the automobile-oriented systems are nearly equal on a direct quantifiable monetary cost evaluation. Within the range of costs studied and methodology of evaluation used, no inference can be made as to which system is to be recommended based solely on direct quantifiable monetary considerations.

6. Analysis of the noneconomic findings, however, indicated that the advantage seems to be to the bus transit-oriented over the automobile-oriented system. The former system, as compared to the latter, is considered by the authors to provide more accessibility to more people, promote more heterogeneous social contacts, be less disruptive of the community values, and be more aesthetically pleasing.