Toward an Evaluation of Subarea Transportation Systems

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In the traditional approach to transportation plan development, subarea plans are prepared after the regional plan has been completed. Often this approach results in subarea alternatives that are in direct conflict with the regional system elements. It is the viewpoint of the authors that subarea planning, which is oriented to short-range decisions, must be carried out as an integral part of regional planning. This will allow subarea and regional goals to be achieved concurrently, thereby permitting decisions to be made on projects that are useful to the local community and the region.

The Bethesda-Chevy Chase area in Maryland is used to illustrate the approach and the measures for the evaluation of alternative multimode transportation systems for well-established and intensely developed subareas within a metropolitan region. Of concern to the subarea are measures that reflect community impact (both positive and negative), land service, level of transport service, and economic considerations. The number of structures displaced and system costs were evaluated as were also (a) the impact of transit stations on developable land and the service they afford to the transit users; (b) the accessibility that the transit system affords the residential interests through reduction of through traffic, access to major employment concentrations, and access of emergency service vehicles; and (c) the accessibility of major employment concentrations to the areas that these concentrations attempt to serve. This paper also discusses the difficulty of using a weighted index as an input to the decision-making process.

•ONE OF THE most challenging problems faced by planners and decision-makers is the development of a comprehensive plan for subareas within a metropolitan region. These subareas can be many types. At one scale are counties that may comprise 20 percent of the regional land area. At another scale are new towns, such as Columbia and Reston; and at even a smaller scale are activity centers such as Fort Lincoln in Washington, D.C.

One common problem faced for each of these areas is how to relate the subarea under study to various elements of regional systems such as sewers, water, transportation, and public services. The approach taken in a particular case depends on the type of subarea, the regional system elements that will have a major impact on the planning, and the specific community objectives to be achieved.

This paper is concerned with the evaluation of alternative transportation systems for one type of subarea—an area located between a center city and its rapidly growing outer suburbs. Often the type of subarea under consideration contains long-established communities that have become engulfed by the expansion of the metropolitan region. They tend to have little vacant land so that the continued growth pressures can

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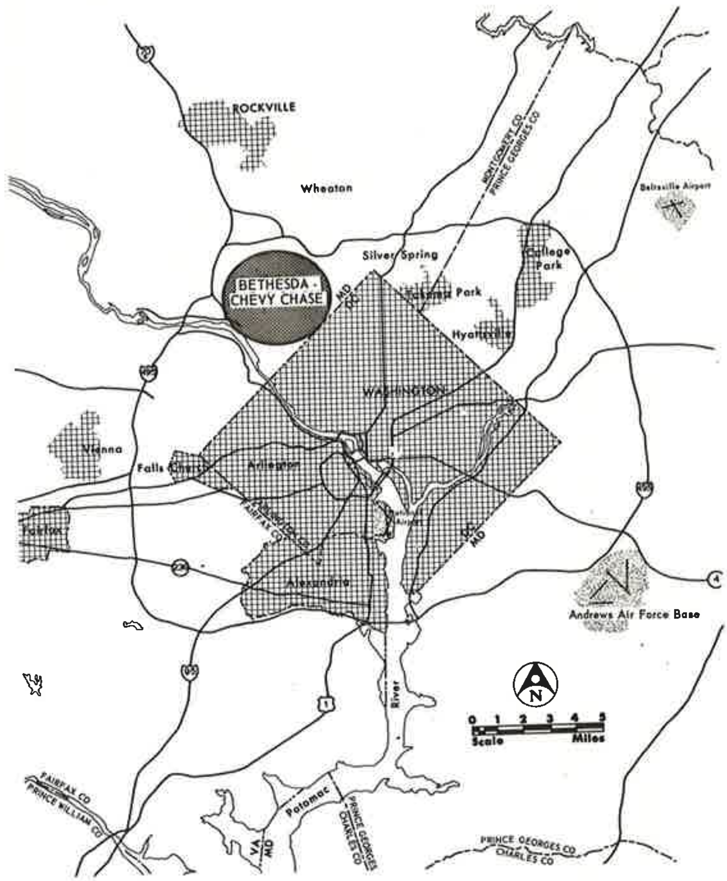


Figure 1. Location of Bethesda-Chevy Chase subarea.

only be satisfied by increasing the intensity of the existing development. In addition, many of the regional system elements, such as hospitals, colleges, water mains, and major highways, have been established for some time.

A typical subarea of this type is the Bethesda-Chevy Chase area in Montgomery County, Maryland, located north of Washington, D.C., between I-495 (Washington Beltway) and the District (Fig. 1). Table 1 summarizes the growth in land activity forecast for this subarea.

TABLE 1

SUMMARY OF LAND ACTIVITY GROWTH FOR THE BETHESDA-CHEVY CHASE SUBAREA

Area	1966	1975	1975/1966 (percent)	1990	1990/1966 (percent)
Population					
Bethesda	9,400	10,500	112	11,600	123
Chevy Chase Lake	4,100	6,000	146	12,000	293
Chevy Chase-Friendship Heights	7,400	9,500	128	11,200	138
Remainder of subarea	70,800	82,000	116	95,200	134
Total	91,700	108,000	118	130,000	142
Employment					
Bethesda	11,600	14,000	121	19,500	168
Chevy Chase Lake	200	1,200	600	1,500	750
Chevy Chase-Friendship Heights	3,900	5,400	138	8,000	205
Remainder of subarea	22,600	29,400	130	31,000	137
Total	36,300	50,000	130	60,000	157

Due to the development constraints imposed by the lack of vacant land, these subareas will grow much slower than the region and may generate little need for additional capacity in the regional system elements. However, as the surrounding region grows, additional demands may be placed on the regional system elements located within the subarea. This is most true of the transportation system where the residential growth in the other suburbs and the increase in center-city jobs create additional travel

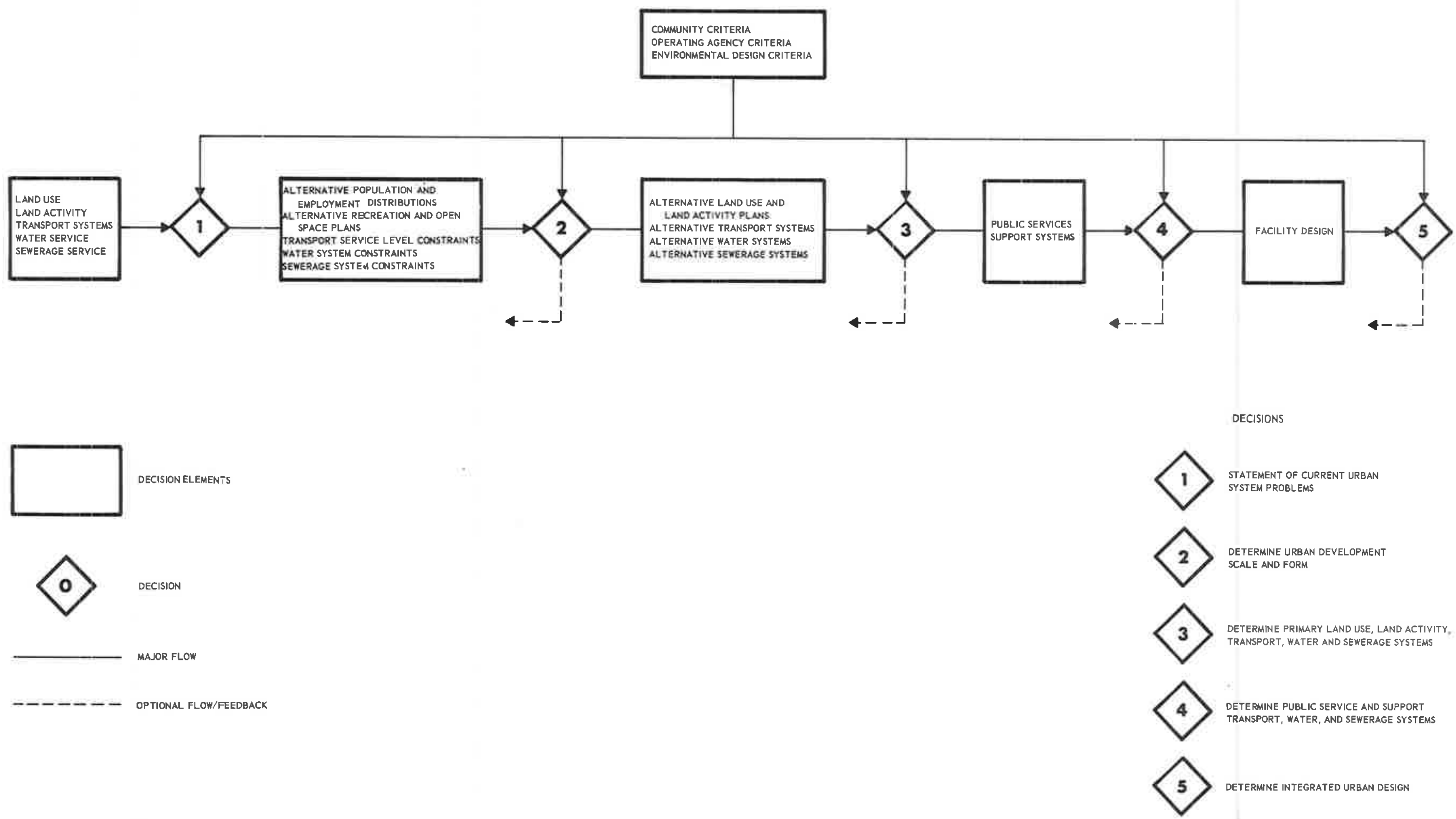


Figure 2. Information flow for major policy decisions.

within major corridors. To meet the increased regional demand requires that additional capacity be added to the regional transportation system.

Providing added transportation system capacity in these areas, whether it be through the addition of new major highways or transit lines, represents a complex task, the successful completion of which depends on the decision-makers' full understanding of the implications of each alternative to the region and subarea. This understanding is usually satisfied through the provision of information at critical points in the planning process. At these points, performance criteria and related measures from the viewpoints of the community and the operating agency should be considered. Figure 2 shows in a general fashion this process for very broad decisions on urban form to detailed decisions on integrated urban design. The approach presented in this paper considers some of the informational requirements for transportation decisions (3, 4). The authors feel that the approach and evaluation measures presented are steps toward obtaining an understanding between decision-makers and planners regarding the subarea implications of various transportation alternatives.

APPROACH PHILOSOPHY

Implementation of a future regional transportation system depends on satisfying, to the greatest extent possible, both regional and subarea goals. In the studies for system evaluation, the decision-maker should be shown how well each alternative achieves these goals. Subarea goals usually relate to the achievement of aggregate goals of the property owners while the regional goals are usually oriented toward broader development patterns and operations of the regional systems, such as transportation, water, sewer, recreation, and open space.

A basic premise of the recommended approach is that subarea planning must be carried out as an integral part of the regional system planning if subarea goals are to be effectively considered. In this way, the local planning, which is concerned with the detailing of physical and service facilities, can interact with and help shape the regional system within the subarea.

Figure 3 illustrates the major steps and decision points in the subarea transportation system evaluation. Each of the steps requires interaction between the region and subarea before a major decision point is approached. The five major points at which there should be agreement by both policy and technical decision-makers at the regional and subarea level are, in sequence, (a) subarea land use and land activity forecasts, (b) corridor location for major highway system components, (c) corridor location for transit lines, (d) location of transit stations, and (e) locations of primary and secondary highways.

To be able to make these technical decisions requires an understanding of subarea and regional implications for the following: (a) differences in scale of economic development, (b) expansion of the capacity of the existing arterial street system, (c) alternative interchange locations, (d) alternative station locations and functions (automobile-oriented vs pedestrian-oriented), and (e) alternative central area parking arrangements.

Each of these items is viewed differently by the regional operating agency and the community. Therefore, analyses must be carried out so that both viewpoints are examined. It is interesting to note that in many European countries, presentation of information at public hearings includes integrated urban design alternatives that highlight the pros and cons from each of the major viewpoints discussed. This differs from the typical U.S. approach of separate hearings for each element of the plan.

The next section describes the application of the integrated plan evaluation approach for the Bethesda-Chevy Chase subarea. In this case example, local viewpoint evaluation measures and criteria were developed to reflect community impact, land service, transport service, and economic cost. Community impact factors are concerned with measures and criteria that reflect the effects of the transport system on the physical and social environment, such as existing parks, vacant land, developed areas, and various community programs and services such as police, fire, and schools. Measures considered under land service illustrate how the various alternatives promote

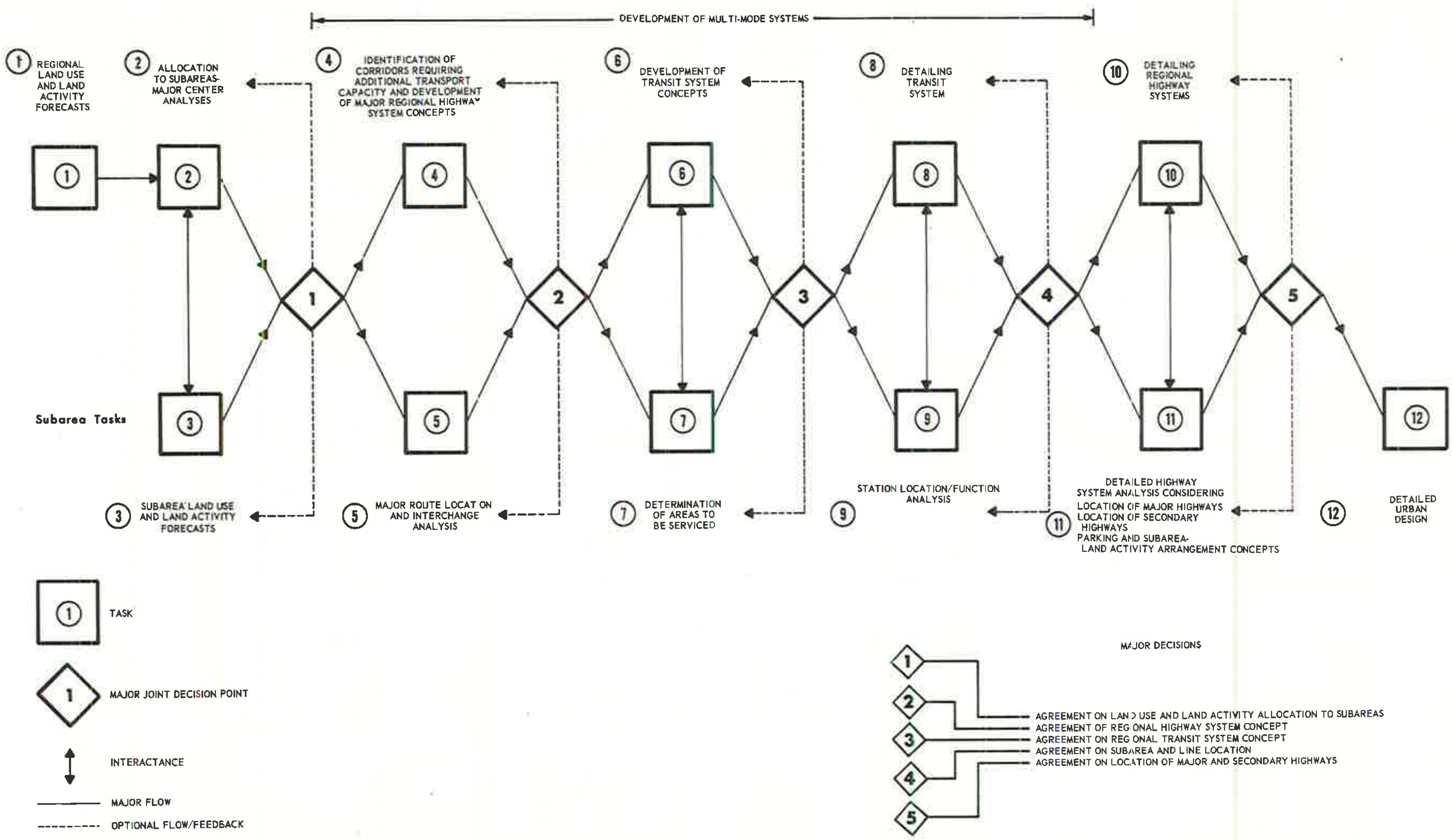


Figure 3. Transportation decision-making process for subareas.

the development and implementation of a particular land development concept. The measures that a community considers with respect to the level of transport service usually are concerned with accessibility and system efficiency. The economic measures, on the other hand, deal with such factors as construction, operating, and user costs within the subarea or financial programs that have been well documented (9, 12).

BETHESDA-CHEVY CHASE EVALUATION

The comprehensive planning analysis undertaken for the Bethesda-Chevy Chase area was conducted in parallel with the evaluation of alternative regional rail systems by the Washington Metropolitan Area Transit Authority. Several regional agencies disagree with the decision that has been reached in the District of Columbia on the regional freeway system; however, results of the subarea analyses provided useful information for certain major decisions concerning the location of the rail rapid transit stations within the northwest corridor of the metropolitan region and the Bethesda subarea.

Figure 3 does not indicate the many technical decisions that were required at both the regional and subarea level, but it does show the sequence of major decisions that were made during the study. The location of the transit stations (and consequently the corridor line) has been agreed on by both the region and subarea. The study has advanced to the point of preparing alternative location plans for the major and secondary highway system.

Data Sources

The 1990 morning peak-hour automobile and transit traffic estimates generated by the regional study were used to analyze transporation needs, costs, and priorities. The methodology followed to obtain the information at a more detailed level for subarea planning is summarized in the Appendix (3, 4, 5). With the completion of this initial data breakdown, it was possible to identify the future transportation problems that will exist at the subarea level and to evaluate the various alternatives considering the viewpoint of the community as well as regional system implications.

Identification of the Problem

As a point of beginning, the future (1990) transportation problems within the subarea were determined by analyzing the key points of capacity deficiency. The results were illustrated by a flow map showing the location and magnitude of the morning peak-hour deficiencies. This was done on a short-range (1975) as well as on a long-range (1990) basis. The nature of the traffic at the congested points was then determined so that alternative solutions could be developed. Figure 4, an example of one of the steps undertaken, shows the distribution of 1990 morning peak-hour trips that pass through certain selected links on Wisconsin and Connecticut Avenues within the study area. The significant characteristics of these trips are summarized in Table 2.

The results of these analyses precipitated interaction with the region to determine whether additional capacity would be available on the assumed rail or highway system. Also, the population and employment allocations were reevaluated, and a determination made of the additional capacity obtainable on the arterial system from operations techniques such as reversible lanes, progressive signal timing, and intersection widenings.

The interactions with the regional system planners resulted in a revision of the estimated rail patronage caused by diverting a percentage of the longer work trips (greater than 30 min) to the rail system. (It is not the purpose of this paper to present a documentation of the procedure developed to divert highway traffic to the transit system; the approach used was based on experience gained in other large urban area transit studies. Inasmuch as the rail transit system does not exist in Washington, there was, of course, no way to "calibrate" the diversion procedures to the local system.) The results of this diversion (shown in Table 3) had a significant impact on the transit passenger volume handled at certain stations in lower Montgomery County. However,

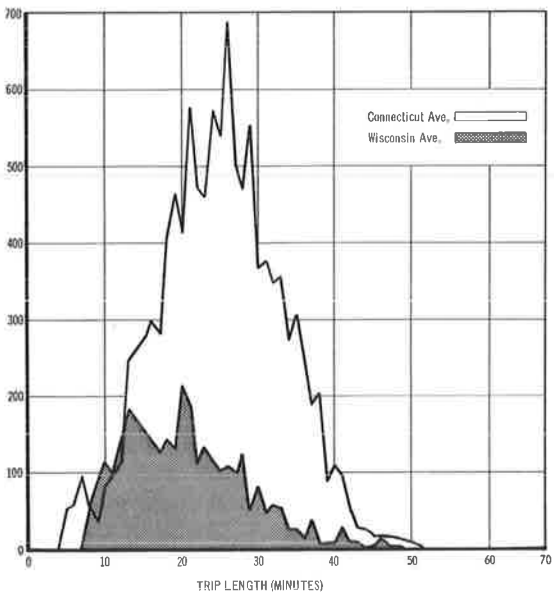


Figure 4. Trip-length distribution on selected links in the Bethesda-Chevy Chase subarea.

TABLE 2

SUMMARY OF 1990 MORNING PEAK-HOUR TRIPS ON SELECTED LINKS

Trip Characteristics	Wisconsin Avenue	Connecticut Avenue
Number of trips	3,400	11,000
Vehicle-miles		
Arterials	24,800	107,200
Freeways	8,700	55,000
Total	33,500	162,200
Vehicle-hours		
Arterials	900	3,500
Freeways	200	1,200
Total	1,100	4,700
Avg. trip length (min)	17.7	25.3

it still left unused over 50 percent of the transit line capacity within the subarea. With the revised patronage estimate and an understanding of the additional capacity available in the existing system, it was then possible to formulate and evaluate alternative ways of reducing the remaining deficiencies.

The Alternatives Studied

The determination of alternative station locations and the development of alternative highway networks evolved after discussions with regional and local decision-makers. For the most part, the alternatives were developed in series from preliminary evaluations of preceding systems. In this way, each succeeding alternative would bring a consensus on a system closer to hand. In some cases, policy-makers deviated from a testing of series alternatives and requested that certain highway system links be incorporated into the alternative for testing purposes. The reason for these departures was to ascertain transportation impacts so that strategies could be developed for links that were critical to the subarea plan. Certain of these departures took the form of short-range (1975) traffic assignments and analyses. The key transit delineations tested are shown in Figure 5; the major highway alternatives are illustrated in Figure 6.

TABLE 3

DIVERSON OF AUTOMOBILE TRIPS TO RAPID TRANSIT BY MODE OF ARRIVAL IN 1990, WISCONSIN AVENUE LINE

Station	A (Without Diversion)				A_1 (Includes Diversion)			
	Total Persons	Walk	Bus	Auto-mobile	Total[a] Persons	Walk	Bus	Auto-mobile
Rockville	920	230	456	234	1,960	230	456	1,274
Halpine Road	1,540	200	714	626	2,139	200	714	1,225
Outer Beltway	—	—	—	—	—	—	—	—
Nicholson Lane	1,140	133	480	527	1,423	133	480	810
Parkside	480	90	167	223	665	90	167	408
Grosvenor Lane	—	—	—	—	—	—	—	—
Pooks Hill	1,040	130	740	170	1,060	130	740	190
Nat'l. Inst. of Health	—	—	—	—	—	—	—	—
Bethesda	3,950	572	3,108	270	3,950	572	3,108	270
Friendship Heights	1,340	412	883	45	1,340	412	883	45
Total	10,410	1,767	6,548	2,095	12,537	1,767	6,548	4,222

[a]This diversion includes approximately 2,000 person trips diverted from the congested Connecticut Avenue corridor.

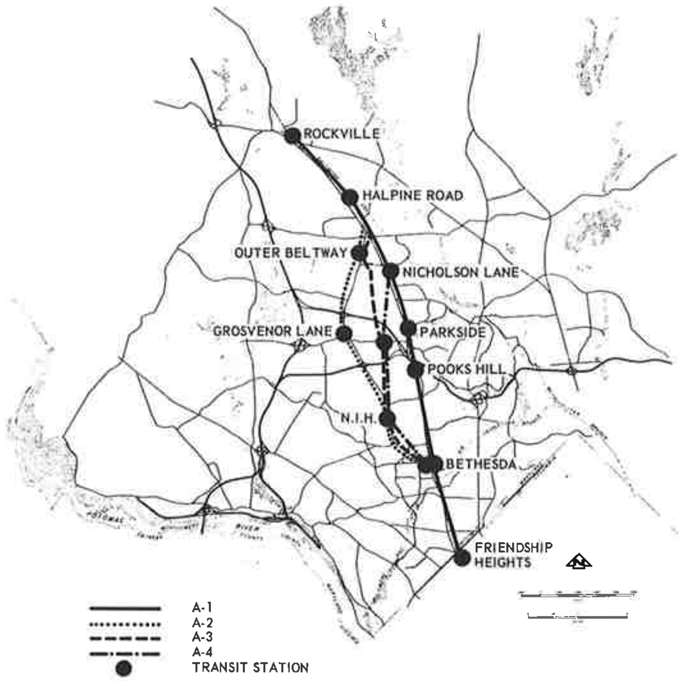


Figure 5. Alternative transit lines tested for Bethesda-Chevy Chase subarea.

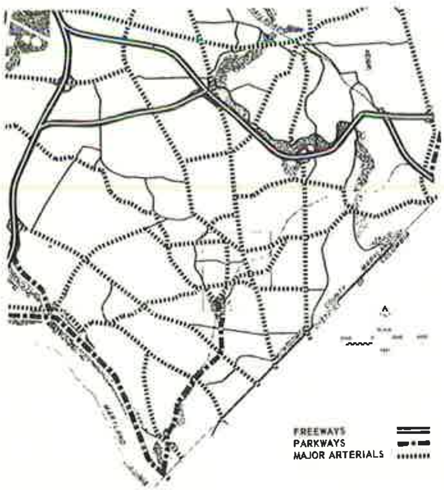
Measures and Criteria Considered

To evaluate the alternative rapid transit station locations and highway alternatives, measures reflecting community impact, land service, transport service levels, and economic costs were developed.

Community Impact—The need for a methodology that will consider the impact of transportation systems on the communities through which they pass or terminate are obvious to those concerned with the planning of urban transportation systems. Numerous freeway controversies throughout the country and in this planning area have developed with regard to the location and design of major transportation facilities. The viewpoint of this community regarding new transportation facilities was expressed at various meetings that were held with key citizen groups. What evolved from these meetings was concern over the following: (a) the number of residential homes and businesses that would be displaced by a transportation facility; (b) the land area that would be required for transportation use that would reduce the tax base; (c) the heavy through traffic on commercial distributor roads in the existing business district; (d) the transportation system by-products, such as pollution and noise; (e) the flexibility of the short-range transportation system to expand to higher capacity levels or to be integrated into alternative future regional freeway system configurations; (f) access of key generators to the system in the peak-hour; and (g) the maintenance of basic neighborhood integrity.

The first two measures, building displacement and land area for transportation use, were obtained from aerial photos and land area measures. The percentage of through traffic removed from existing streets in the business district was derived from analyses of peak-hour traffic flows, deficiencies, and selected link assignments.

Transportation by-products (pollution and noise) were difficult to quantify because little has been done to model the production of noise or pollution by various facility and



ALTERNATIVE 1

ALTERNATIVE 2

ALTERNATIVE 3

ALTERNATIVE 4

Figure 6. Alternative highway systems tested for Bethesda-Chevy Chase subarea.

traffic combinations. Research conducted by Michigan State University (6) has shown, however, that the average fuel economy for passenger vehicles is related to the number of stops and the average speed for various types of urban highways as indicated in Table 4. Therefore, the alternative highway system with the lowest average speed and greatest number of stops was considered to emanate the greatest amount of pollution. Each alternative was, therefore, qualitatively ranked by these two measures.

Research conducted by the California Division of Highways (7) indicates that, for a given volume of traffic, the noise level in the vicinity of the facility varies with facility design. In particular, depressed facilities generate less noise than do at-grade or elevated facilities. Inasmuch as certain alternatives contained depressed facilities, this criterion was used to qualitatively rank the alternatives.

The flexibility of the new facilities in the system to expand to higher capacity levels was also considered by the community. This was brought about by the community's concern for delays in the construction schedule or uncertainties in the long-range (1990)

TABLE 4

AVERAGE FUEL ECONOMY OF PASSENGER VEHICLES ON MAJOR URBAN HIGHWAYS

Type of Urban Highway	Average Fuel Economy (mpg)	Average Speed (mph)
Freeway	17.4	46.0
Nonsignalized urban arterial	20.0	36.9
Signalized urban arterial with median		
1 or 2 signals per mile	18.7	30.6
3 or more signals per mile	16.1	25.0
Signalized urban arterial without median		
1 or 2 signals per mile	16.6	26.1
3 or more signals per mile	16.1	23.0
Signalized downtown arterial	9.1	9.5

Source: Highway Traffic Safety Center, Michigan State Univ., East Lansing, 1957-1958.

TABLE 5

ACCESSIBILITY OF MAJOR EMPLOYMENT CENTERS TO FUTURE POPULATION

Major Employment Center	Mean Opportunity Times (min) for Highway Alternatives			
	1	2	3	4
Bethesda	6.17	6.34	6.33	5.85
Chevy Chase Lake	8.10	8.10	8.05	7.19
Friendship Heights	6.51	8.00	7.65	7.50
River Road	7.52	7.52	7.52	6.73
Army Map Service	9.45	9.45	9.45	8.06
Total study area	6.51	6.58	6.52	6.28

traffic forecasts that are predicted on assumed freeway networks and development scales. Therefore, a unit to express this became the miles of actual street capable of expanding to higher capacities within the right-of-way. Consideration was also given to the flexibility of the subarea system to tie into future possible alternative freeway configurations.

Land Service—The business and industrial interests in the community were concerned with the secondary effects that the systems afforded them in terms of (a) accessibility of major employment concentrations to future development; (b) availability of development opportunities around rapid transit stations; and (c) development scale possible over and above the economic forecasts. To date, there are no satisfactory measures of these effects that are generally recognized for use in subarea evaluation. Therefore, certain measures were calculated to reflect these land service objectives. The accessibility of major employment concentrations to future development was developed by analyzing the trip length distribution generated by use of the gravity model formula:

$$T_{ij} = \frac{E_i (P_j + E_j) t_{ij}}{\Sigma (P_j + E_j) t_{ij}} \qquad (1)$$

where

T_{ij} = interaction between zone i and j,
E_i = employment forecast for zone i,
P_j = population forecast for zone j,
E_j = employment forecast for zone j, and
t_{ij} = future morning peak-hour travel time from zone i to j.

A morning peak-hour, skim-tree matrix reflecting each highway alternative and its congestion was developed, and the average trip length from the major employment concentrations was generated. Table 5 indicates how the mean trip times generated from this distribution (opportunity trip lengths) varied for the major employment concentration for each of the highway alternatives. Alternative 4 was the most accessible of those examined because it had the lowest mean opportunity trip length.

Figure 7 indicates the cumulative distribution of opportunities around the business district for each highway alternative. There were three times as many opportunities within 4 minutes with alternative 4 than there were with the other alternatives. Though seemingly theoretical, the measures provided not only an evaluation metric but also a tool to generate alternative highway networks to provide better access to major employment concentrations—a goal of the study.

The ability of the transit station to generate development opportunities has been observed in major cities such as Toronto, Canada, that contain rail rapid transit systems. The criterion for the placement of the rapid transit station within the planning area was postulated to be related to the amount of developable land that would be adjacent to a new station. There were several sites where these new stations could be placed to service the patronage that would be generated. A study by the land-use planners was conducted to identify vacant land and areas containing one-story structures that could be

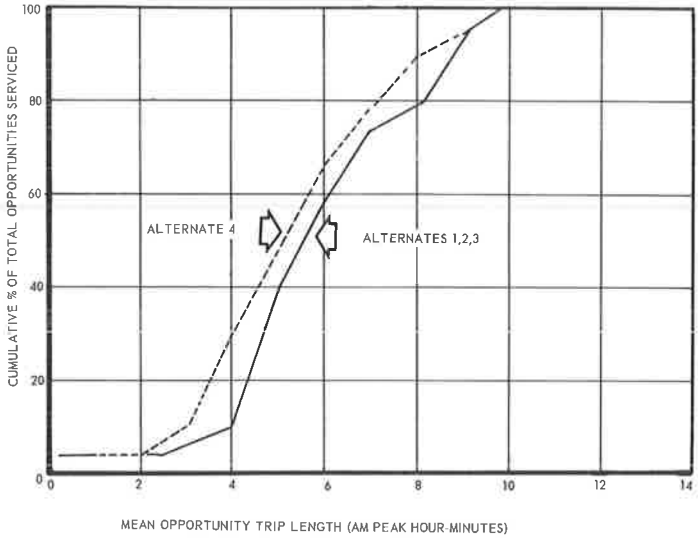


Figure 7. Accessibility of the business center to population and other employment.

economically replaced. Each transit line (Fig. 5) was then evaluated with respect to the cumulative percentage of developable land that surrounded it (Fig. 8). Of particular concern was the amount of developable land within 1,500 to 2,000 ft of the station. Alternative transit lines A2 and A3 had the maximum potential in this regard.

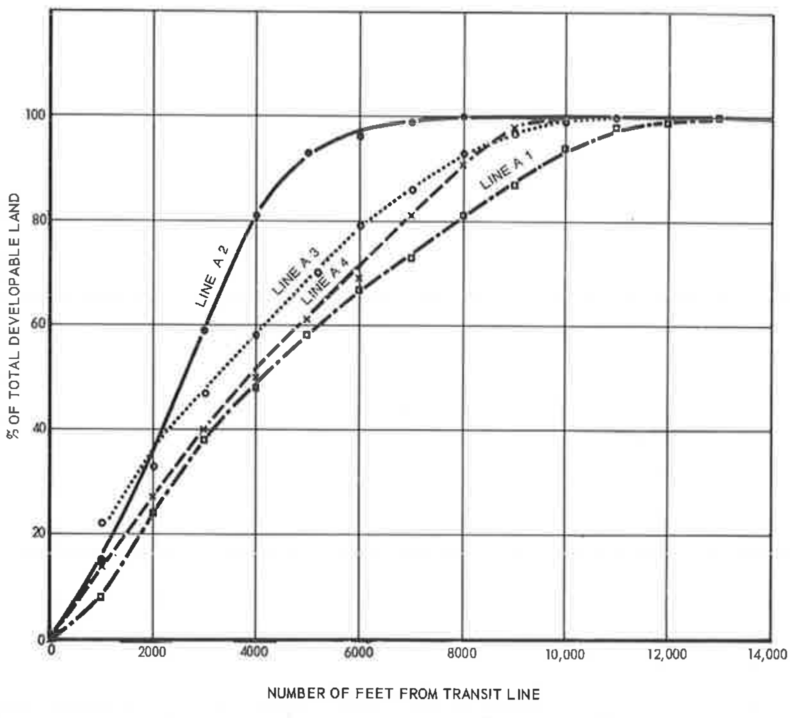


Figure 8. Percentage of developable land in proximity to rapid transit stations in Bethesda-Chevy Chase subarea.

A third metric to reflect the ability of the transport system to service land was its capacity to contain a larger scale of development activity because of additional road capacity. This development scale was estimated by formatting the peak-hour trip table to a major center, calculating the through traffic, and estimating the amount of additional traffic that could be carried in the peak hour. This additional traffic was then converted (through estimates of automobile occupancy, directional split, and percentage by transit) into economic development that could be accommodated in the area.

Transport Service Levels—In addition to concern for standard measures of future traffic congestion (such as vehicle-miles of peak-hour capacity deficiency on the highway network, highway peak-hour travel times from key traffic generators, and plots of congestion surrounding rapid transit stations), there was also concern for mobility levels and access opportunities. The measures to reflect these were (a) accessibility of the subarea population to job opportunities in the planning area; (b) accessibility of emergency vehicles to population and employment; (c) person-miles of travel to and from the rapid transit station; (d) miles of streets carrying transit-station traffic; (e) average trip length of person trips to the rapid transit stations; and (f) uniform distribution of person arrivals at any one station on a given transit line.

The accessibility of the subarea population to job opportunities within the planning area was generated by means of the opportunity distribution described previously. In this case, however, the population in the zone was used as the production index, and the attraction was the total employment within the zones. No discernible differences were found for this measure. Because of the high median family income and mobility within the planning area, this issue was not of major concern. However, the metric may prove useful in studying low-income areas where these concerns are more pronounced.

The access that the transportation system affords emergency vehicles such as fire, police, and ambulances is of major concern to the community that will be serviced by such vehicles. Peak-hour congestion can limit severely the ability of these vehicles to respond to an emergency situation. The comprehensive planning study pinpointed the locations where these major services would be generated. By means of the gravity model distribution formula, the accessibility that these service centers provided the subarea population in the peak hours was developed using the following distribution formulas for police and fire services:

Police

$$T_{ij}^{P} = \frac{P_i (P_j + E_j) t_{ij}}{\Sigma (P_j + E_j) t_{ij}} \tag{2}$$

Fire

$$T_{ij}^{F} = \frac{F_i (P_j + E_j) t_{ij}}{\Sigma (P_j + E_j) t_{ij}} \tag{3}$$

where

T_{ij}^{P} = interchange of police service from zone i to zone j,

P_i = population in zone i (police cars are dispatched to cover certain areas; number of cars dispatched was assumed to be related to the zonal population),

P_j = population in the attraction zone,

E_j = employment in the attraction zone,

t_{ij} = zone i to zone j peak-hour travel time,

T_{ij}^{F} = interchange of fire services from zone i to zone j, and

F_i = number of firemen available in the firehouse of a given zone.

The running of these distributions permitted a comparison of the cumulative travel time required for such services for each of the alternatives. These distributions are summarized in Figures 9 and 10. The comparison indicated the superiority of alter-

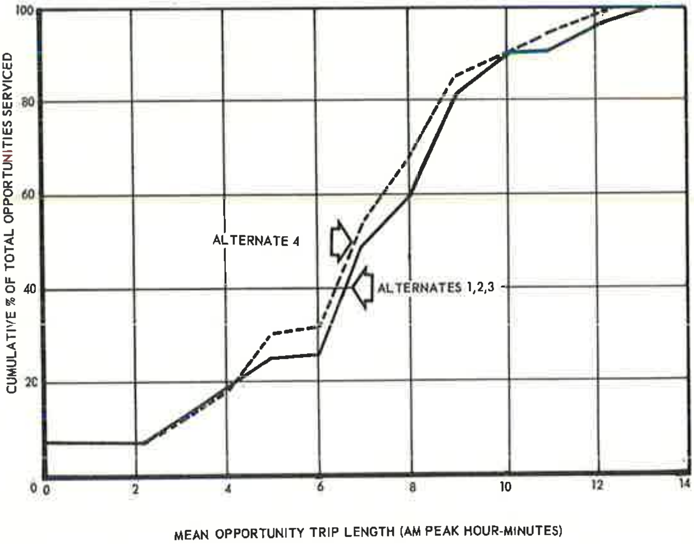


Figure 9. Accessibility of firemen to population and employment.

native 4 over the other highway alternatives. It was also found that the mean opportunity times for police and fire services were 5.5 and 6.9 minutes respectively.

The service that the transit stations provided the users of the planning area was also of concern. This service was measured by analyzing the traffic patterns of the various arrivals and departures estimated for each transit station. These patterns were determined for each transit delineation based on the patronage forecasts shown in Table 6. It should also be noted that the submodal split (bus vs automobile vs walk), which is an input to the regional study, was made after inputs of parking availability and walking generated by surrounding development were developed by the subarea studies. The regional study could not proceed with its traffic estimates until these inputs were furnished. This fortifies, in part, the necessity to conduct the regional and

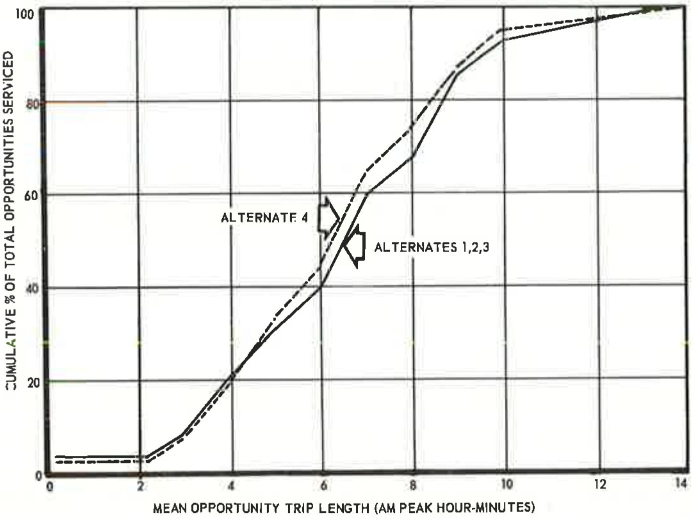


Figure 10. Accessibility of police to population and employment.

TABLE 6

MODE OF ARRIVAL AT RAPID TRANSIT STATIONS

Station	Transit Line Alternatives							
	Total Persons	Walk	Bus	Auto-mobile	Total Persons	Walk	Bus	Auto-mobile
	A1				A2			
Rockville	1,960	230	456	1,274	1,960	230	456	1,274
Halpine Road	2,139	200	714	1,225	1,489	200	624	665
Outer Beltway	–	–	–	–	2,290	350	570	1,370
Nicholson Lane	1,423	133	480	810	–	–	–	–
Parkside	665	90	167	408	–	–	–	–
Grosvenor Lane	–	–	–	–	995	420	167	408
Pooks Hill	1,060	130	740	190	–	–	–	–
Nat'l. Inst. of Health	–	–	–	–	1,660	130	1,280	250
Bethesda	3,950	572	3,108	270	3,350	572	2,568	210
Friendship Heights	1,340	412	883	45	1,340	412	883	45
Total	12,537	1,767	6,548	4,222	13,084	2,314	6,548	4,222
	A3				A4			
Rockville	1,960	230	456	1,274	1,960	230	456	1,274
Halpine Road	1,489	200	624	665	2,139	200	714	1,225
Outer Beltway	2,290	350	570	1,370	–	–	–	–
Nicholson Lane	–	–	–	–	1,423	133	480	810
Parkside	–	–	–	–	–	–	–	–
Grosvenor Lane	1,095	520	167	408	1,095	520	167	408
Pooks Hill	–	–	–	–	–	–	–	–
Nat'l. Inst. of Health	1,660	130	1,280	250	1,660	130	1,280	250
Bethesda	3,350	572	2,568	210	3,350	572	2,568	210
Friendship Heights	1,340	412	883	45	1,340	412	412	45
Total	13,184	2,414	6,548	4,222	12,967	2,197	6,548	4,222

subarea studies concurrently. The person-miles, miles of street carrying transit station traffic, and average person-trip length to each station were straightforward measures after the pattern and trip generation were determined. The uniformity of station arrivals on a given line required a new measure, however. This measure was defined as

$$U = |X - \overline{X}|$$

where

U = uniformity of station arrivals on a given line,

X = ratio of individual station patronage to the sum of the patronage for the five stations (percentage) along the line, and

$\overline{X}$ = average station patronage (percentage).

In simple terms, this measure is a standard deviation that indicates disproportionate station arrivals. The larger the standard deviation, the more uneven would be the number of arrivals at a station and the waiting time within a station—both of which would cause additional congestion at certain over-crowded stations.

Economic Cost—This part of the evaluation consisted of a straightforward comparison of construction and user costs for both systems. User costs included the standard estimations of operating, accident, and time costs. The standard methodology and basic considerations of an economic evaluation are discussed elsewhere (15, 16). Also, the ability of the various jurisdictions (federal, state, and county) to finance the recommended improvements was considered a constraint.

Evaluation Summary

With an understanding of the quantifiable and nonquantifiable measures that were of concern to the residents and employers of the subarea, it was then possible to summarize these measures and criteria as indicated in Table 7. This type of information display accompanied with the appropriate graphics proved to be the most effective device for the evaluation of the alternatives. The criteria required a maximization or minimization of the quantitative or qualitative rankings indicated.

TABLE 7

SUMMARY OF EVALUATION MEASURES AND CRITERIA[a]

Measure	Dominant Mode (S)	Criteria	Transit System Alternations				Highway System Alternatives			
			A1	A2	A3	A4	1	2	3	4
Community Impact										
1. Number of structures displaced	highway/transit	minimize		(tunnel)			0	250	30	50
2. Land area taken for transportation use (acres)	highway/transit	minimize	3	3	3	3	33	157	79	126
3. Percentage of through traffic removed from existing streets entering Bethesda CBD	highway	minimize					0	1.3	11.5	31.4
4. Estimation of transportation system by-products, quality of atmosphere and sound level	highway	minimize					3	3	2	1
5. Flexibility of system to expand to higher capacities (miles of street capable of expanding to higher capacities)	highway/transit	maximize					0	0	2.4	2.4
Land Service										
1. Accessibility of major employment centers to future population [mean opportunity times (min)]	highway	maximize					6.17	6.34	6.33	5.85
2. Percentage of developable land within 2,000 feet of rapid transit stations	transit	maximize	23	35	35	25				
3. Scale of development possible under the capacity of a particular scheme (transit, population possible within 2,000 feet of stations; highway increase or decrease of employment within Bethesda)	highway/transit	maximize	29,000	38,000	39,000	36,000	960	NA	-360	2,000
Transport Service Levels										
1. Peak-hour (a.m.) congestion (miles of capacity deficiency)	highway	minimize					19	20	18	17
2. Travel time (a.m. peak hour) from major traffic generators	highway	minimize					4	2	3	1
3. Congestion surrounding transit stations (with existing street system)	transit	minimize	3	2	2	1				
4. Accessibility of fire and police vehicles to population and employment	highway	maximize					2	2	2	1
5. Person-miles to and from rapid transit stations	transit	minimize	(base)	-930	-674	-850				
6. Miles of street carrying transit station traffic	transit	minimize	12.4	10.6	10.6	10.6				
7. Average trip length of automobiles to and from the station (miles)	transit	minimize	4.5	3.8	3.8	3.8				
8. Standard deviation of person arrivals for rapid transit stations on a given line	transit	minimize	51.8	35.2	33.6	34.2				
Economics										
1. Cost of transit	transit	minimize	3	4	1	2				
2. Cost of highways	highway	minimize					1	4	2	3
3. User costs	highway	minimize					NA	NA	NA	NA

[a]For measures ranked qualitatively, 1 indicates the alternative that best satisfies criteria.

Decision-Making Technique

Once the measures and criteria are established for the alternative subarea transportation system, the difficult task, as always, is that of making the decisions. The professional in this role usually does one of two things: (a) makes a recommendation based on a weighting or rating calculation of the measures or (b) lets the policy-makers do the deciding.

In the case of the Bethesda-Chevy Chase study, the first approach was attempted after a review of the literature (8 through 14). In this approach, an overall weighted index was used to evaluate the alternatives. This proved ineffective because the decision-makers had different weighting values and hence could not agree to or accept a common weighting scheme. Furthermore, because transportation planning is a continuous process, each alternative that is generated should contain the accepted elements of the plan that preceded it and make improvements in reducing negative community impact and in increasing land and transport service levels or economics with each succeeding alternative. Unlike regional plan alternatives, the alternative systems are not as broad because of the constraints (objectives) imposed by the community. A review of the work done by the Harvard Transport Research Program (14) indicated that usage of such a weighted index, representing the overall value of a particular alternative, "...implies a rather strict set of conditions on both the value set and the performance measures. The set of performance measures must be an exhaustive set containing all of the relevant consequences without any repetitions. It must, therefore, be mutually exclusive and collectively exhaustive."

It is further stated that "...in practice, obtaining a final objective measure may be a monumental task although ...it is conceptually straightforward." This approach sums up the difficulty in trying to obtain a decision from people who have different weighting schemes and who often consider measures that are interrelated and, therefore, are not mutually exclusive. Furthermore, because planning is an inexact science where variations in the estimates can occur, the sensitivity of the weighted index becomes of concern. The tools to evaluate the variations that can occur in the weighted index due to the variations in the input measures do not exist.

The second procedure of providing the information to the decision-maker and letting him decide is also ineffective. The planner must communicate the measures accompanied with the margin of error and an estimation of interdependency with other measures if he is to relate the pros and cons of one alternative over another.

The technique that appeared to be most workable in the Bethesda-Chevy Chase example was a conveyance of the measures with their accompanying criteria and an evaluation of how each succeeding alternative could improve on the one that was previously developed. In addition, the measures were kept uniform throughout the analysis and contain the data sets that are, for the most part, mutually exclusive. In this way the needs were stated, and the systems to meet those requirements were developed with the decision-makers in series rather than in parallel. Therefore, the evaluation technique, regardless of its technical efficacy, is understood and acted on by those whose responsibility it is to choose.

SUMMARY

This paper has presented an approach and measures for the evaluation of alternative transportation systems for established and well-developed subareas of the metropolitan region. It is a starting point toward the determination of the factors that represent the viewpoints of the community that must be considered at key points in the technical decision-making process.

The approach for evaluating subarea plans suggests that subarea and regional planning be done concurrently, interfacing at key decision points in the process. Furthermore, the approach suggests usage of information generated by the region and subarea derived from a common data base for land use and activity scale and traffic forecasting procedures.

The measures and criteria presented relate to the local viewpoint regarding negative community impact, land service, levels of transport service, and economic considerations. Certain new measures are presented that indicate how rapid transit, highway systems, and intermodal transfer points can be measured in the interest of the community as well as the agencies that must own and operate the regional systems. The measures developed included (a) impact of transportation facilities on community objectives; (b) impact of transit stations on developable land and the service they afford to the transit users; (c) accessibility that the system affords the residential interests through the quantification of through traffic reduction, access to major employment concentrations, and access of emergency service vehicles; and (d) accessibility of major employment concentrations to the areas that they are attempting to service. The paper also highlighted the difficulties in using utility functions or weighted matrixes in effectively arriving at a transportation plan or generating new systems for testing in the evaluation process.

As a start for further work in this area, it is suggested that new research focus on (a) investigation of a simple set of mutually exclusive performance criteria that could be input to community decisions; (b) measurements of the uncertainties present in the performance criteria noted above; (c) development of new measures for the effect of noise and air pollution for each new facility or the community; and (d) development of measures and procedures to evaluate the effectiveness of testing interrelated parking and traffic control solutions to downtown core area problems.

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Appendix

A SUMMARY OF THE TRANSPORTATION PLANNING METHODOLOGY FOR THE BETHESDA-CHEVY CHASE SUBAREA ANALYSIS

The Bethesda-Chevy Chase subarea analysis was carried out using relevant regional system and travel data developed in studies conducted for the Washington Metropolitan Area Transit Authority (WMATA). This Appendix discusses the data used and the general procedures followed to make the data usable for the subarea analysis. A more detailed discussion of the procedures used in the regional studies is given elsewhere (2, 3).

Traffic Zones

Of the 552 traffic zones established within the Washington metropolitan region, the 23 representing the Bethesda-Chevy Chase planning area were subdivided into 52 zones

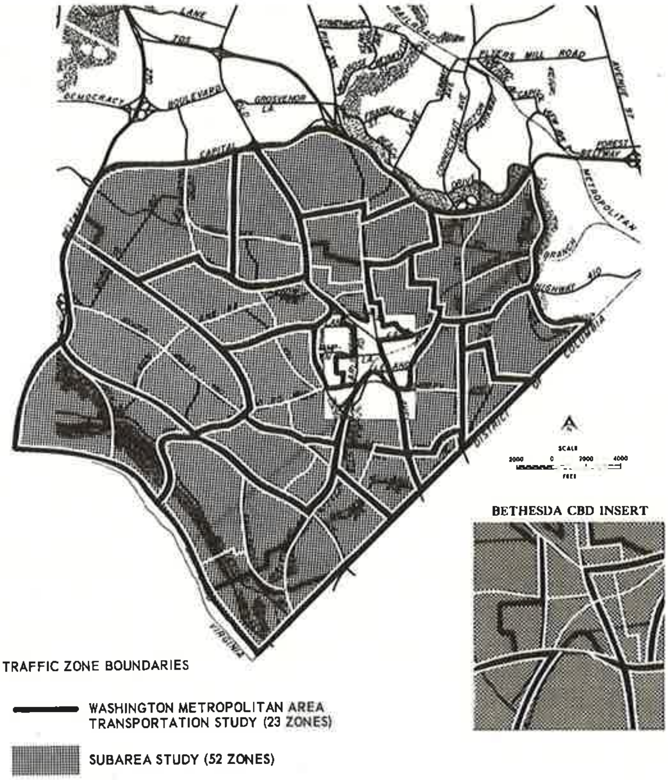

Figure 11. Traffic zones for the Bethesda-Chevy Chase subarea.

(Fig. 11). The 45 zones surrounding the area were split into 64 zones, and the remaining 484 traffic zones plus the 45 external stations were aggregated to 55 super-districts. In subsequent analyses, the zones representing the Bethesda business district were subdivided so that traffic could be assigned as necessary to parking location for alternative circulation systems in the Bethesda business district.

Assignment Networks

The assignment networks developed during the regional study consisted primarily of the freeways and major arterials. As a starting point for the subarea analysis, additional lower order streets were added to the network consistent with the revised zone system. Outside the planning area, the regional networks were simplified by removing streets that were not oriented to intercounty movements.

Trip Tables

The WMATA tables of morning peak-hour automobile-driver trips generated by the regional study were compressed to the zone and super-districts system described above. The morning trips (bus and automobile) to the rapid transit stations were formulated and manually analyzed as an increment over the peak-hour automobile-driver traffic. These trip tables represented the base peak-hour travel patterns used in alternative tests.

Assignment

The assignment of the modified WMATA morning peak-hour trip table to the revised network was accomplished using minimum-path, "all-or-nothing" computer assignment techniques.

Peak-hour travel times were calculated to account for the slower speeds in the peak hour due to increased traffic congestion. Because the volume/capacity (v/c) ratio is a measure of congestion, it was calculated for each network link and used to determine the link speed. If the v/c ratio was less than 0.6, it was assumed that congestion was not severe enough to lower the off-peak operating speed. If the v/c ratio was greater than 1.5, it was assumed that extreme congestion was present and the peak speed was lowered to 5 mph. For v/c ratios between these two values, the peak speed was obtained from a series of curves relating the v/c ratio to speed.

Discussion

GERALD D. MACKIN, Texas Instruments, Inc.—The authors have addressed a problem area that is becoming increasingly apparent in the urban environment: how does one make decisions when there are numerous subjective parameters, low confidence in forecasts, and many people involved, all of whom would probably react differently to different planning decisions? As pointed out in the paper, the best transit or highway system is readily determined from a pure performance and cost standpoint, but the impact on the community has been traditionally assumed nonquantifiable.

It is agreed that the decision-making process is difficult but that it must be accomplished to satisfy future demands. Therefore, the following alternatives are apparent: (a) utilization of an urban planning expert to make the decision, (b) a public relations campaign to help realize the benefits of a new system, although it will cause hardship on some, (c) a model that would quantify the unquantifiable, or (d) some combination of these.

A model could be constructed to evaluate various systems, the need for which has been determined, for whenever a decision is made, someone will either benefit or lose, including the decision-maker, and it is possible to minimize the loss. The model would have to be exceedingly flexible to factor in many variables, such as aesthetics, displacement of people and business, social, economic, and political impact, cost, performance, and utilization. The units could be dollars, or some nondimensional units of utility or value.

Although the model could be easily constructed, its inputs admittedly would require creative research and continual reiteration. The subarea problem demonstrates the importance of geographical and jurisdictional partitioning, in addition to the conventional functional (user, supplier, operator), organizational, and socioeconomic groupings.

As thorny as the subarea problem is today, it promises to get worse at an increasing rate as our urban explosion accelerates. The health of our cities, particularly the central core, depends on regional planning that appropriately and effectively integrates subarea planning, although this is not unique to transportation, and it does argue strongly for increased research along the lines presented in this timely paper.