# METHOD FOR EVALUATING METROPOLITAN ACCESSIBILITY

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Improving the quality of urban life requires not only the provision of employment, medical, educational, and recreational opportunities but also a convenient means of access to these facilities for all citizens. This study reports on a prototypical application of a new methodology, called Special Area Analysis (SAA), designed to assess the quality of accessibility in metropolitan areas. Starting with a definition of accessibility in functional terms, this SAA develops measures that focus on the level of accessibility afforded by Boston's present, planned, and programmed urban transportation systems to such essential urban activity centers as major employment districts, medical, recreational, and educational facilities, the central business district, and the airport. In addition, the methodology is applied toward an evaluation of the level of accessibility afforded to specific population subgroups such as low-income and zero-car households. This study demonstrates that the SAA methodology is a useful evaluation tool for use by metropolitan area transportation planning agencies.

•ACCESSIBILITY has generally been defined as some measure of spatial separation of human activities. Because transportation systems connect spatially separated activities, accessibility is of interest in planning for transportation systems. This paper reports on the development and application of a method to analyze metropolitan accessibility conditions.

The method grew out of an interest by the U. S. Department of Transportation in exploring possibilities for conducting accessibility analyses as part of the metropolitan area component of the 1974 National Transportation Study. The Department supported development of the necessary computer software and the conduct of a pilot study in the Boston area after it had initiated the necessary conceptual and organizational work itself. The pilot study is called a Special Area Analysis (SAA) because it is a special set of information that supplements the more aggregate type of analysis done in the National Transportation Study. [The accessibility studies reported here represent only one component of Special Area Analysis. Other methodologies in the SAA package include air quality analysis, noise analysis, and dislocation impact analysis (1). ]

The purpose of this project was twofold:

1. To demonstrate the feasibility and desirability of the SAA accessibility methodology, and
2. To provide useful information to transportation planning agencies at the local, state, and federal levels.

This Special Area Analysis focuses on the level of accessibility afforded by Boston's present, planned, and programmed urban transportation systems to such essential urban activity centers as employment districts, medical, recreational, and educational facilities, the central business district, and the airport.

Computer software for the study was developed under separate contract funded by the U. S. Department of Transportation. Production runs with the software were made by the Urban Planning Division of the Federal Highway Administration. Conduct of the study thus involved the cooperation and participation of three state agencies, one regional

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agency, several DOT agencies, and several private consultants.

## METHODOLOGY

It was decided to measure spatial separation by travel time over highway and transit networks separately. Cross-modal comparisons could then be made and results could be expressed in the easily understood and commonly experienced terms of travel time. In addition, it was decided to use cumulative percentages of population within various travel time contours of important metropolitan activities as the central expression of accessibility. This is a functional measure of accessibility. It defines the percentage of resident population that has access to specific functional human activities (e.g., jobs, medical facilities, recreational facilities).

Thus there are three essential components of the functional accessibility measure: the locations and characteristics of the resident population, the locations of important metropolitan area activity centers, and the characteristics of the existing transportation system. Changes in accessibility may be caused by changes in any one or more of these components. Therefore, it is difficult to ascribe access changes precisely to any one of the component factors unless two of them are known to be constant over the relevant analysis period.

It should also be noted that the accessibility measure employed in the SAA does not directly describe the actual use of particular modes in the metropolitan area. It simply measures the availability (in terms of the travel times by auto and transit) of transportation services to specific population subgroups. In Boston's Special Area Analysis, a notion of modal use is indirectly included in the accessibility measures because the auto travel times employed in the analysis are adjusted to account for congestion effects and the transit travel times employed reflect existing frequency of service.

In view of this discussion, it is important to point out the usefulness and limitations of the SAA accessibility data. In its present form, the SAA provides a general picture of regional access conditions by auto and transit in selected analysis years. This is particularly useful to state and federal planning agencies in comparing access conditions in different cities.

For planning agencies at the state and local levels, the SAA can give some indication of transportation system goal achievement if goals can be stated in terms of accessibility measures. Thus a comparison of the accessibility consequences of alternative transportation system plans can be related to transportation system costs to derive measures of relative cost-effectiveness in access terms. It should be remembered, however, that the Special Area Analysis accessibility measures are aggregate measures and as such are of limited utility for subarea or subsystem evaluation. The accessibility measures are probably best applied as total plan evaluation tools and as a device for comparing accessibility conditions in different cities.

In the Boston pilot study three separate sets of accessibility conditions were examined: 1970 and two alternative sets for 1980. The analysis therefore shows whether metropolitan access conditions change given two alternative courses of action by 1980. The two 1980 conditions are called planned and null. The planned situation basically reflects decisions made in the Boston Transportation Planning Review, whereas the null situation is simply an extrapolation of existing urban activity location trends with no improvements in the transportation network.

Because the pilot study was experimental in nature, designed to provide information for a number of concerns, an additional element was added. This was conduct of the analysis at a more detailed level to determine if the accessibility results were sensitive to the degree of network aggregation. All 1980 analysis was done at an aggregate level of 104 districts (essentially cities and towns, with selected larger cities broken into smaller parts). The 1970 analysis was performed for the 104 districts and a disaggregate network consisting of 339 zones. Census tracts are the common denominator for both sets of network data, so the 339 zones can be summed into the 104 districts. The 1970 highway and transit networks—skim trees or interzonal and intrazonal (district) travel times—were developed at both the zonal and district levels.

Accessibility measures in terms of total study area population were developed for all combinations of functional activity type, mode, analysis year, and areal split (i.e., inner city and suburbs). In addition, for both the aggregate and disaggregate base case (1970) networks, accessibility measures were developed for several stratifications of the study area population. In particular, the population subgroups considered were population by age group, total households, households by income class, households by car ownership, total labor force, and labor force by employment type. Table 1 summarizes the data and tests conducted.

## STUDY RESULTS

The computer software produces the modal travel times and urban activities data in an easily readable and efficient format. In addition to tabular output, the software produces frequency distributions and graphs of the accumulated percentages of population within 1-minute travel time intervals of each activity.

From the software output for the Boston tests it is possible to conduct the following types of analyses:

1. Accessibility conditions offered by alternative land use and transportation systems;
2. An intermodal comparison of accessibility levels offered by highway and transit networks;
3. The effects of network and zonal aggregation in the study; and
4. A more detailed analysis of existing accessibility conditions for subgroups of the population (e.g., different income, car ownership, labor force groups).

Moreover, it is possible to conduct each analysis in terms of inner, outer, and total SMSA areas. Each of these analyses was done with the Boston test data and documented in a report to DOT. Selected results are reported here.

### Accessibility Conditions Offered by Alternative Land Use and Transportation Systems

Relatively small differences in accessibility between the existing conditions and the two future conditions are to be found in the study output with respect to the present and future highway networks (Fig. 1). This is due, in large part, to the fact that few additions were made to the highway network in the selected plan. The plan has a strong transit emphasis. Figures 2 and 3 show transit graphs of total population access to major employment centers from total and outer SMSA areas. The greatest impact of the planned transit improvements is in the outer SMSA, where transit extensions reduce travel times to major employment centers. These figures also indicate that transit accessibility deteriorates in the 1980 null network relative to the 1970 existing system. This deterioration is largely the result of a shift of residential location outward from the inner city over the 10-year period. Thus in the 1980 null network a larger proportion of the total study area population is located in the outer SMSA, where transit service is relatively poor.

### Comparison of Highway With Transit Accessibility

Accessibility within the Boston SMSA by auto proved to be markedly superior to transit access for all of the activities examined in this SAA. Despite the presence of a relatively comprehensive existing transit system and the promise of even greater transit service in the future, each of the three networks—the 1970 base case, the 1980 null, and the 1980 selected plan—exhibited a similar pattern of auto dominance.

There are several reasons for the auto's comparative access advantage: the ubiquitous nature of its infrastructure, its minimal access requirements, and its higher average line-haul speeds. These are generally well-known facts. What is more interesting is the variation in the modal access differential by subarea (inner and outer SMSA) and by activity type. As can be seen in Figures 4 and 5, the access time differences (in this case shown for employment access) between the two modes are greatest in the outer SMSA area. This is because transit access in the outer SMSA deteriorates markedly from the level of transit service in the inner SMSA.

It should be noted that outer SMSA transit access is characterized by particularly

**Table 1. Study elements.**

| Functional Activity | Mode | Time Period | Networks | Stratification |
|---|---|---|---|---|
| Employment | Transit | Base (1970) | Aggregate | S[a] |
| | Auto | | Disaggregate | |
| | | 1980 Null | Aggregate | Population |
| | | 1980 Plan | | |
| Medical facility | Transit | Base (1970) | Aggregate | S[a] |
| | Auto | | Disaggregate | |
| | | 1980 Null | | |
| | | 1980 Plan | Aggregate | Population |
| Airport | Transit | Base (1970) | Aggregate | S[a] |
| | Auto | | Disaggregate | |
| | | 1980 Null | | |
| | | 1980 Plan | Aggregate | Population |
| Recreational facility | Transit | Base (1970) | Aggregate | S[a] |
| | Auto | | Disaggregate | |
| | | 1980 Null | | |
| | | 1980 Plan | Aggregate | Population |
| CBD | Transit | Base (1970) | Aggregate | S[a] |
| | Auto | | Disaggregate | |
| | | 1980 Null | | |
| | | 1980 Plan | Aggregate | Population |
| Educational facility | Transit | Base (1970) | Aggregate | S[a] |
| | Auto | | Disaggregate | |
| | | 1980 Null | | |
| | | 1980 Plan | Aggregate | Population |

[a]Population, population by age group, households, households by income group, households by car ownership, labor force, labor force by skill category.

**Figure 1. Comparison of highway network accessibilities to major employment centers, total SMSA.**

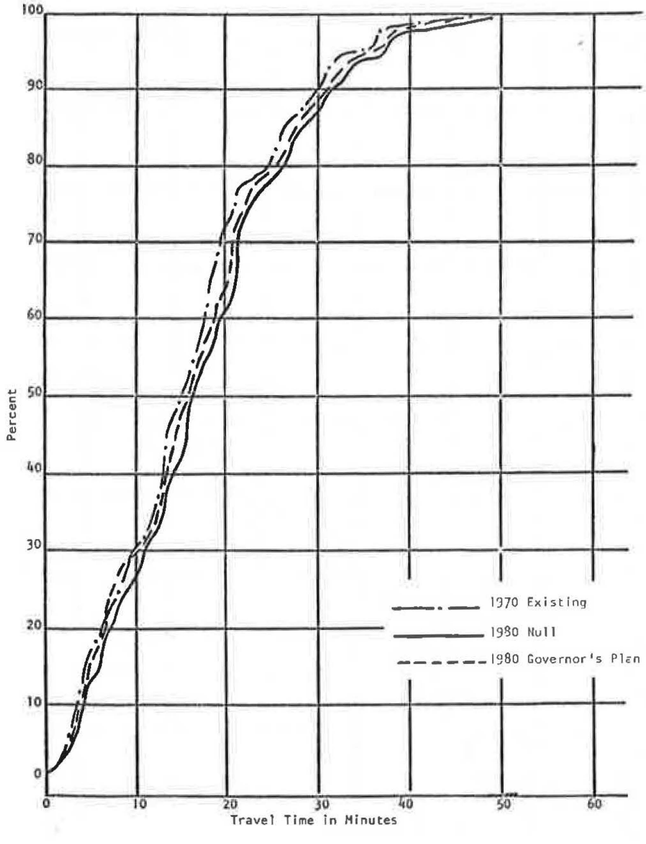


Figure 2. Comparison of transit network accessibilities to major employment centers, total SMSA.

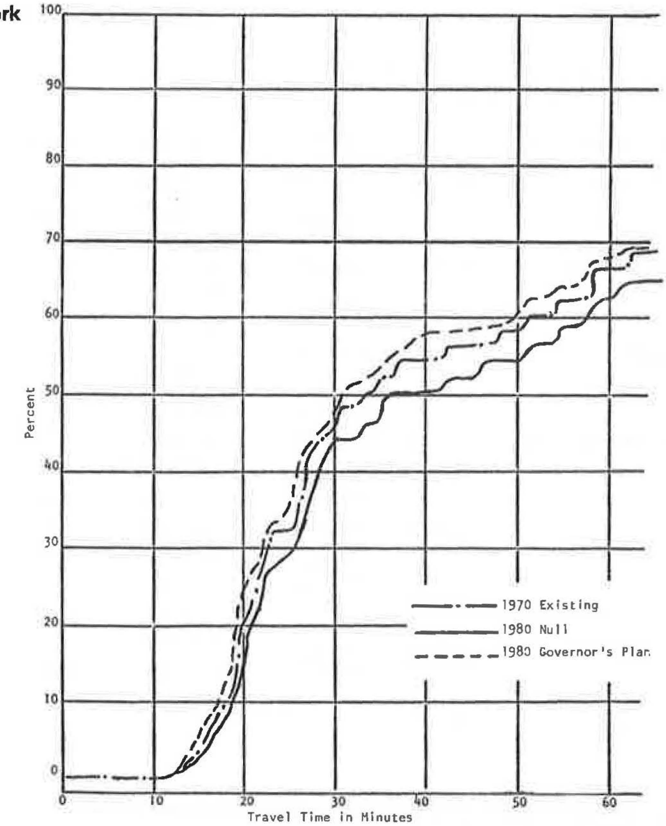



Figure 3. Comparison of transit network accessibilities to major employment centers, outer city.

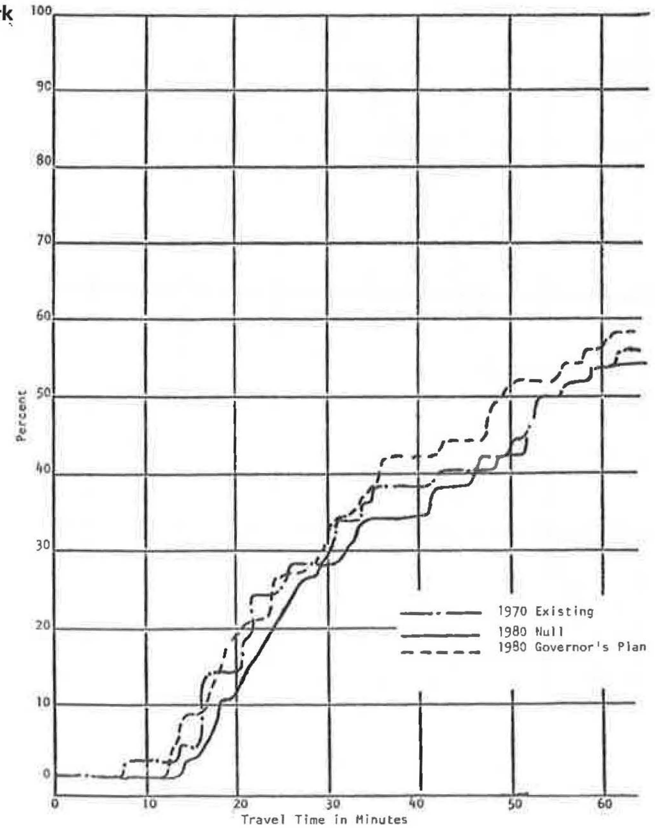


**Figure 4. Comparison of modal accessibilities to major employment centers, 1970 existing system, outer city.**

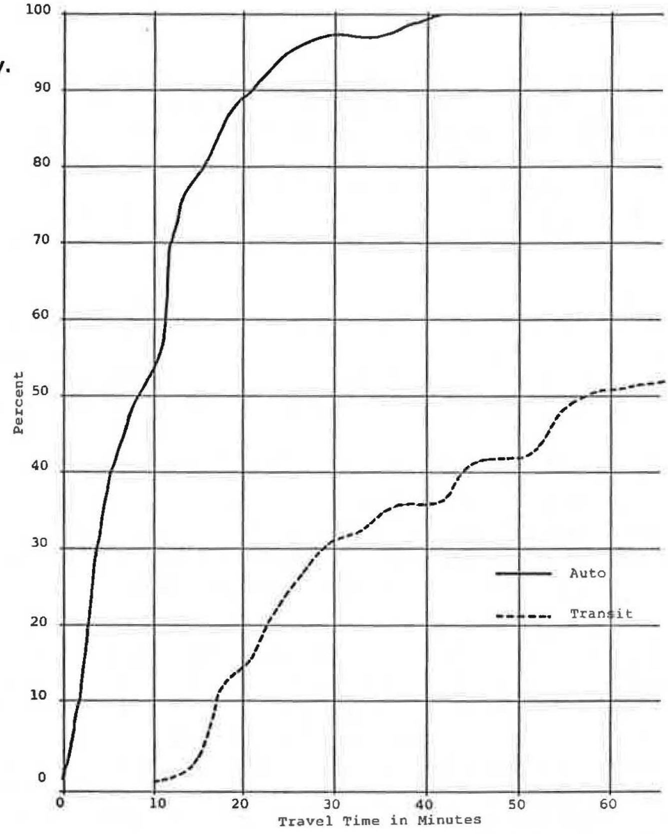
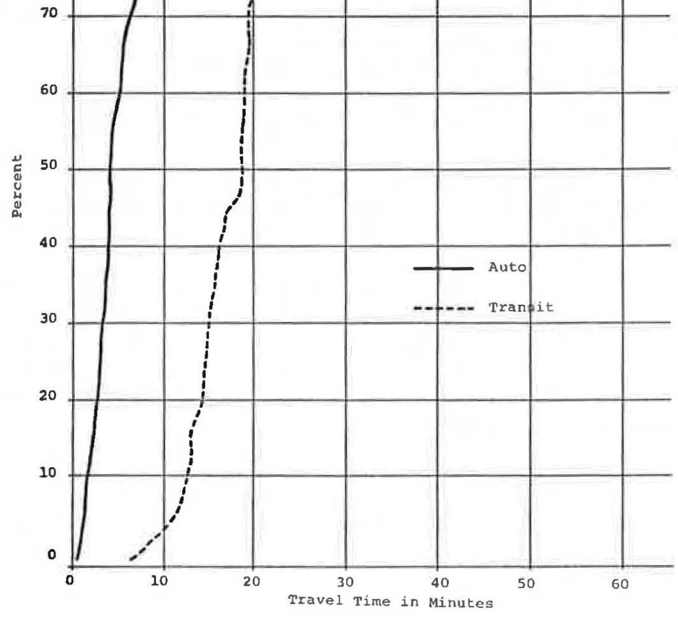



**Figure 5. Comparison of modal accessibilities to major employment centers, 1970 existing system, inner city.**



long access-to-station times and, in some cases, an outright lack of transit services in the outlying areas. The first characteristic is manifested by the small percentage of outer SMSA residents accessible to employment centers in short transit travel times; for example, the 20-minute transit travel time contour captures only 15.8 percent of the outer SMSA population compared to 71.6 percent of inner SMSA residents. And the lack of outlying area transit service is clearly shown by the 40 percent of outer SMSA residents who are inaccessible to a major employment center within travel times approaching $1\frac{1}{2}$ hours.

Although auto accessibility to employment centers is better for inner SMSA residents than for the population in the suburbs, the access time differences between the two areas are relatively small. The curves for employment access by auto rise steeply for both the inner and outer SMSA areas. The 20-minute auto travel time contour captures 100 percent of the inner SMSA population and 89.1 percent of the outer SMSA population.

## Effects of Network and Zonal Aggregation

Figures 6 through 9 show the cumulative accessibility plots (on the entire SAA study area) from the aggregate and disaggregate analysis on four SAA activities: the CBD, airport, employment centers, and major recreational facilities. Examination of these plots reveals several interesting comparisons:

1. For three of the activities—airport, CBD, and employment—the disaggregate cumulative accessibility plot generally rises more steeply than the aggregate plot for both transit and auto. The reason for this is that in the disaggregate network the minimum interzonal travel time to these activities is lower than the closest district pairs in the aggregate analysis. Thus the disaggregate cumulative accessibility plots begin rising at lower travel times than corresponding aggregate network plots. For example, minimum transit access time to Boston's Logan Airport is 22 minutes in the aggregate network (from East Boston) and 15 minutes in the disaggregate network (also from East Boston).
2. Accessibility to major recreational facilities (Fig. 9) exhibits the opposite behavior: For both transit and auto, the aggregate cumulative accessibility plot rises more steeply than the corresponding disaggregate plot. In this case, the large number of major recreational facilities (44 out of the 104 aggregate network districts contained a major recreational facility) results in a large percentage of the population reaching a major recreational facility at the coded intradistrict travel times. In general, the intradistrict travel times are lower than the corresponding interzonal travel times of the disaggregate network.
3. The differences between the aggregate and disaggregate network cumulative accessibility plots can be quite large for both the transit and auto accessibility analyses. For example, the 10-minute auto time contour around major employment centers captured 80 percent of the population in the disaggregate network as compared to only 32 percent of the population in the aggregate network. Transit access exhibited marked differences between the two networks for airport access, where the 30-minute time contour captured 6 percent and 40 percent of the respective aggregate and disaggregate network populations.
4. As expected, the aggregate network cumulative accessibility plots exhibited a greater degree of "lumpiness" than the corresponding disaggregate cumulative plots.
5. There seemed to be no systematic difference between the cumulative accessibility plots from the two networks. The plots describing access to the CBD and recreational facilities were similar for the two networks. In contrast, aggregate and disaggregate analyses of airport and employment access differed markedly. It is difficult to trace the precise causes of the discrepancies between the two network analyses because the actual accessibility plots depend partly on the derived weighted skim tree times and partly on the actual distribution of population among zones in the disaggregate network comprising aggregate SAA districts.

## Existing Accessibility Conditions for Subgroups of the Population

To gain a better understanding of the level of mobility afforded by Boston's existing

**Figure 6. Cumulative accessibility for CBD.**

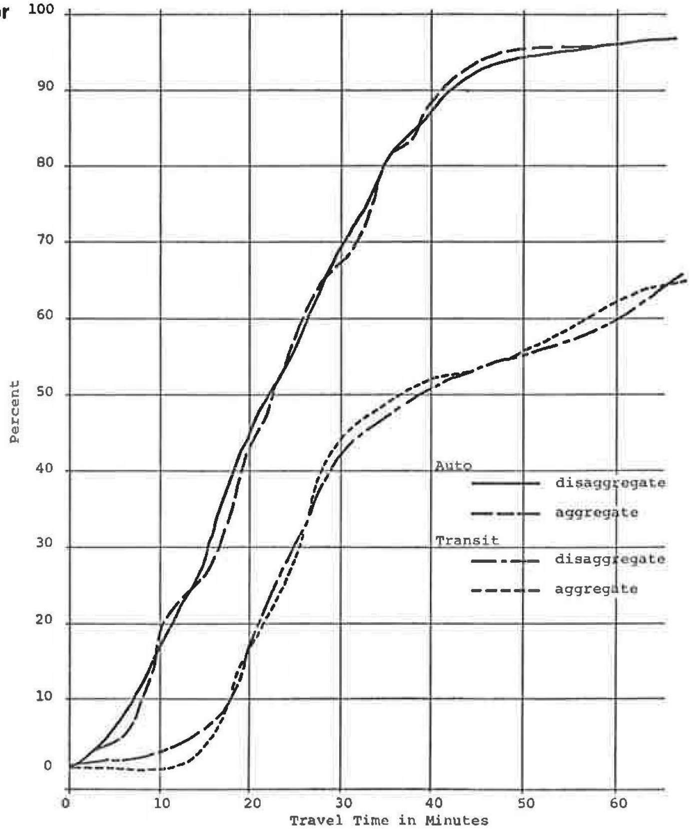



**Figure 7. Cumulative accessibility for airport.**

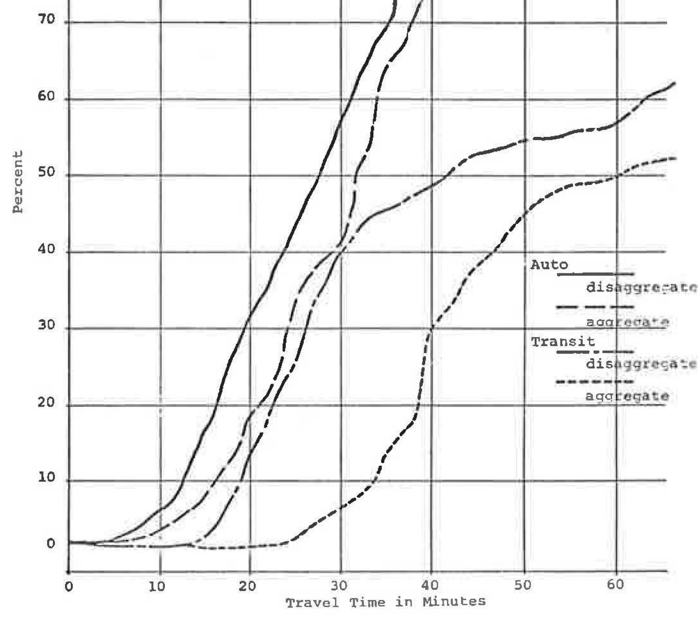


Figure 8. Cumulative accessibility for employment centers.

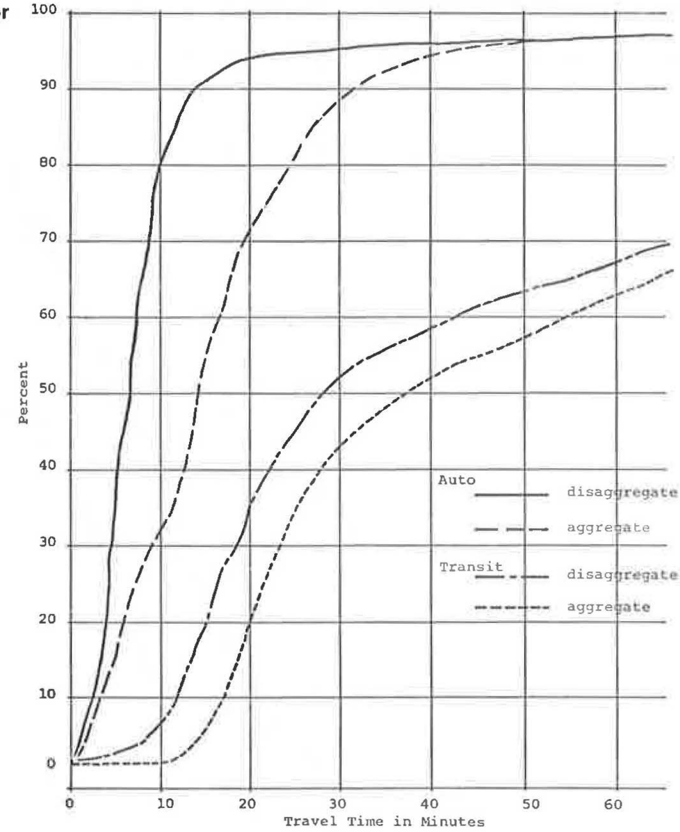
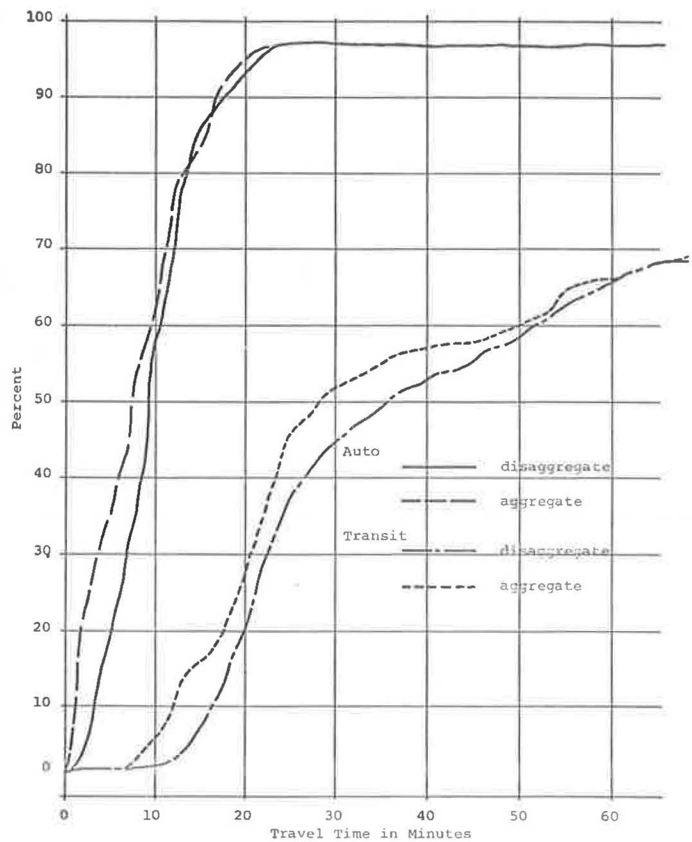



Figure 9. Cumulative accessibility for recreational facilities.



transportation system, given the spatial location of major activity centers and the characteristics of the resident population, this Special Area Analysis investigated the functional accessibility of specific population subgroups. In particular, access to each of the six major metropolitan activities was explored for four classifications of population: age group, income category, car ownership, and labor force skill category. Various income groups' access to major employment centers is reported here, analyzed at the district level.

Three income categories were employed in this SAA: low income ($0-$6,999), medium ($7,000-$9,999), and high income ($10,000 and over). The population was split into income classes according to zonal median incomes and within-zone income distribution. In the former classification, the entire population of each zone was considered to be in the low-, medium-, or high-income category depending on the median income of the zone. The latter classification apportioned the population of each zone among the three income categories in accordance with the intrazone distribution of household income.

Figures 10 and 11 show the transit and auto accessibility to the CBD using the within-zone income distribution classification. In each case, the low-income resident population appears to have the best access (i.e., the cumulative accessibility curve for low-income population lies above the curves for medium and high income) to the CBD. These access differences are most pronounced for transit travel to the CBD, where the 30-minute travel time contour captures 36 percent of the high-income population and 62 percent of the low-income population (Fig. 10).

The observed pattern of accessibility stratified by income category is not surprising in view of the characteristics and spatial location of Boston's resident population. Like most major U.S. cities, Boston's low-income population is concentrated in the city core and inner-city industrial towns. Median household income tends to rise with distance from the city core. This is clearly illustrated by the cumulative accessibility plots in Figures 12 and 13, where the population was stratified according to median zonal income. In this case, the difference between the percent of low- and high-income population accessible to the CBD for selected time intervals is as high as 95 percent.

The foregoing figures raise two other important points. First, the accessibility analyses for the two methods of determining population income stratification (i.e., according to zonal median incomes or within-zone income distribution) differed markedly. The classification scheme incorporating within-zone income distribution is clearly preferable to the zonal median population classification because the latter seriously overstates the quality of accessibility of the low-income population. This distortion was particularly manifest in Boston's SAA, where the zone size (and thus the within-zone income distribution) was relatively large.

A second point raised by the foregoing figures involves a caution on the interpretation of the cumulative accessibility plots. Although low-income residents appear to benefit from relatively good access to major metropolitan activity centers, it should not be concluded that an adequate level of transportation service necessarily exists for the economically disadvantaged. The apparent access advantage of low-income residents results primarily from their locational proximity to the CBD. However, in recent years there has been an increasing number of low-skill jobs locating in suburban areas and an increasing concentration of specialized, professional, and managerial jobs in the CBD. Thus, while the bulk of low-income (and presumably low-skill) population is within easy reach of the city core, they may be far removed from a growing source of low-skill employment in the suburbs. A necessary complement to the SAA is an investigation of the primary locations of employment and labor force by skill category. Ultimately, plans for upgrading urban transportation systems must be based on a detailed analysis of specific transportation corridors and the characteristics of activity centers and the resident population within these corridors.

## CONCLUDING REMARKS

Regional accessibility, as measured by the percent of population within various travel time contours of significant regional activities by transit or auto, allows several types

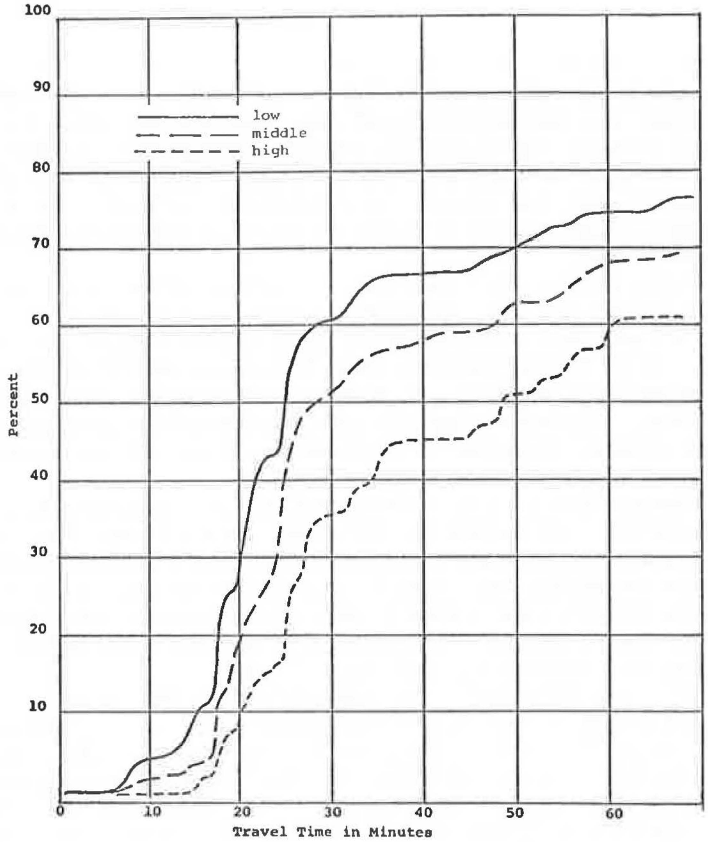



Figure 10. Transit accessibility to CBD by income distribution.

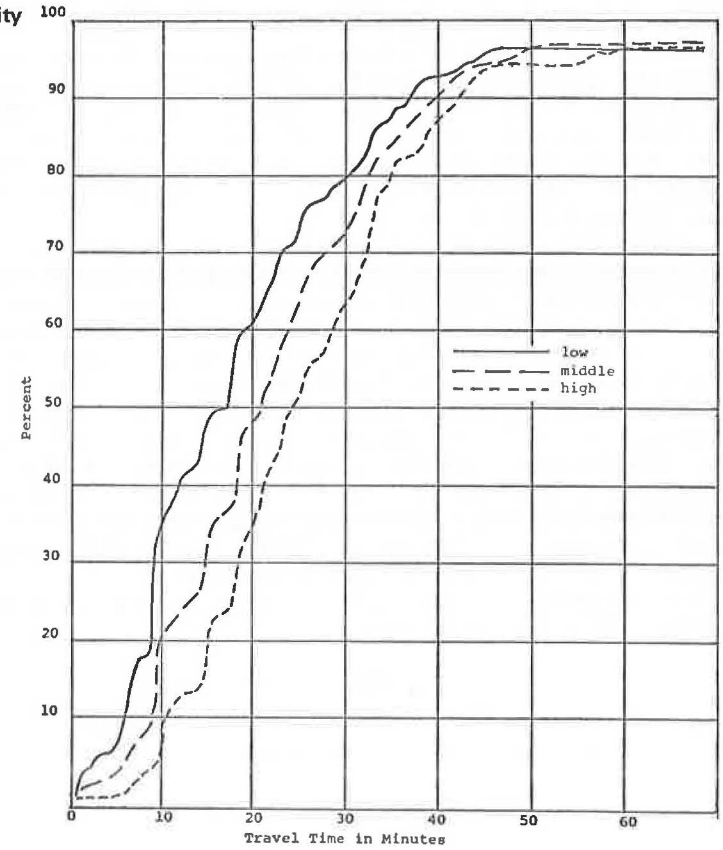



Figure 11. Automobile accessibility to CBD by income distribution.

Figure 12. Transit accessibility to CBD by median income.

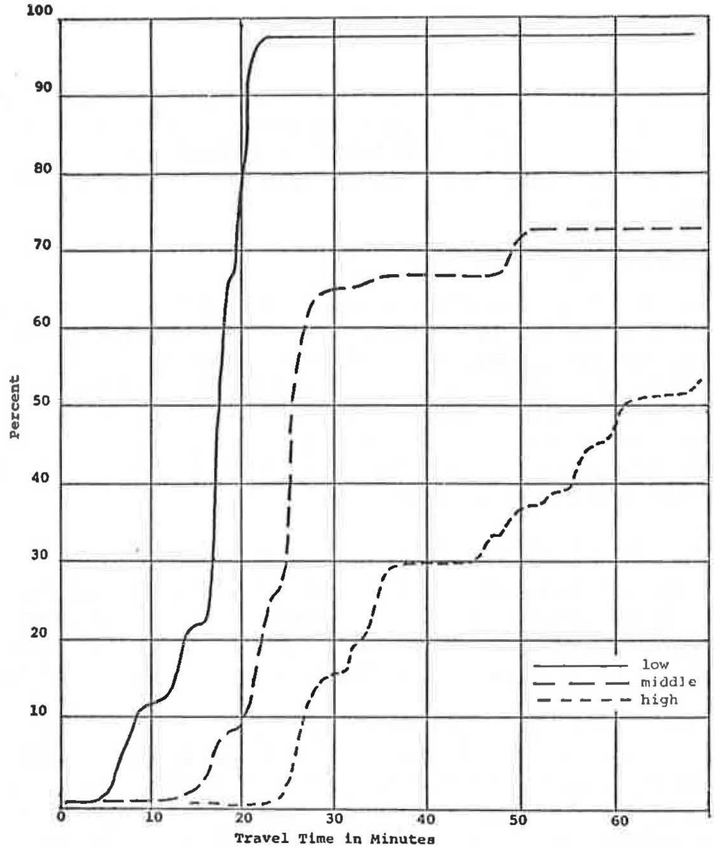
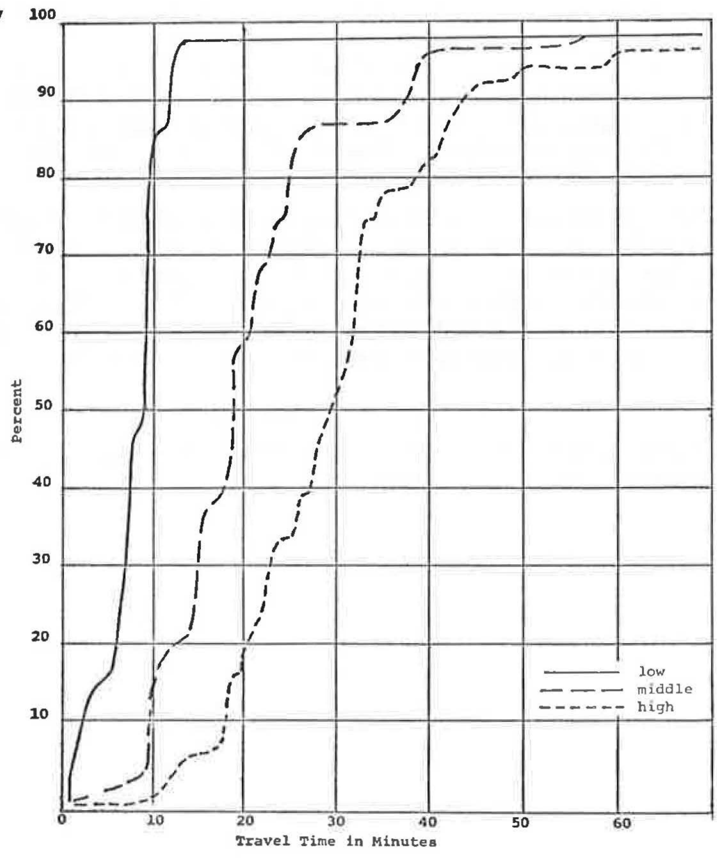



Figure 13. Automobile accessibility to CBD by median income.



of useful analyses to be made. First, a general picture of regional access conditions can be drawn. Second, some indication of goal achievement can be obtained if goals can be expressed in terms of the access measures. Third, plan comparisons can be made and related to costs to give some measures of relative cost-effectiveness in access terms.

## Regional Access Conditions

Mean access travel time by mode, frequency distributions of percent of population within selected travel time intervals of major activities, and cumulative accessibility curves disaggregating inner from outer SMSA areas are all summary measures of regional access conditions. Because the measures encompass three elements—location of origin subjects, location of destination activity objects, and the connecting transportation system—they are of more use for evaluating area-wide plans than for evaluating each of the elements separately, even though it is possible to devise tests in which only one factor at a time is varied.

## Cost-Effectiveness Analysis

If the accessibility measures are considered to be system outputs, they could be related to the various costs each system incurs and compared with each other in cost-effectiveness analyses of alternative plans. Cost would have to include transport system costs and costs associated with the land development or urban activities distribution pattern.

The importance of gaining an understanding of urban accessibility—particularly for low-income center-city residents—cannot be overestimated. Improving the quality of urban life requires not only the provision of employment, medical, educational, and recreational opportunities but also a convenient means of access to these facilities. Recent trends in urban land use and transportation supply have tended to exacerbate the lack of accessibility faced by urban dwellers. In the postwar period, we have witnessed

1. A marked suburbanization of urban services, especially employment opportunities;
2. A decline in the quality of public transportation service;
3. A generally sluggish response by public transportation authorities in establishing new routes geared to the emerging patterns of employment and residential locations; and
4. Constraints on the availability of housing for certain racial and low-income groups in the suburbs.

Taken together, these trends have led to an increasing degree of isolation for large numbers of our urban population. The issue then is this: If, relative to their ability to pay, large numbers of urban dwellers suffer excessive transportation costs in obtaining and maintaining employment and in reaching educational, recreational, and medical facilities, public action may be justified. The Special Area Analysis focuses on an analysis of this issue, both for present conditions and for future plans and programs.

## REFERENCE

1. Final Manual: Special Area Analysis. Urban Planning Division, Federal Highway Administration, Aug. 1973.