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# The Future of Public Transportation A Preliminary Evaluation of Some Alternatives

*by*

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IT IS NECESSARY for many planning purposes to have an effective means of projecting the use of public transit on a local or national level, and for estimating how it might change with alternative technical or institutional approaches. This paper discusses the results of a study of the nationwide use of public transit given certain assumptions as to the service objectives, financial support and available equipment.

The methodology used permits the investigator to consider the effect of a range of alternative assumptions as to national growth patterns and personal income on travel demand. It permits consideration of conventional or innovative systems with different performance capabilities and capital and operating costs.

This paper describes some of the necessary input data and assumptions including the stratification of urban areas by city size, population density, and other significant parameters. The traveling public is characterized in terms of the trip objective, per capita income, auto availability and trip time and cost objectives.

Some examples of transportation system costs are included to illustrate the relative system costs and the key factors influencing the costs of new transportation systems. Summaries of several studies of the comparative service levels and costs of conventional innovative transit systems are included.

Three national transportation use projections were prepared to illustrate the use of the methodology and provide base lines for further evaluation of alternative transportation development strategies. The three cases are:

- Case I Continuation of present trends.
- Case II Increased use of present modes.
- Case III Effective use of selected new modes.

The projections of transit use in these cases are based on a rational extension of the available information but should be considered to be examples of possible trends rather than quantative projections. Institutional factors will probably have a greater influence on the actual developments than the technical and economic factors which are more easily evaluated by analytical models.

This paper describes the salient conclusions of these studies. Additional information on the methodology and studies of specific applications which were used in the case study are available from the author.

## CASE STUDIES OF NATIONAL TRANSIT USE

Three projections of possible future use of urban transportation were prepared to illustrate the use of methodology described in subsequent sections, and to provide a baseline for further studies.

Case I The present trends for bus and rail systems, assuming no new actions are taken to improve the use of the present systems.

Case II The increased use of conventional modes, improved service, new rail lines, etc., to maintain the same percentage of urban trips by transit as existed in 1970.

Case III Effective use of selective advanced transit systems.

These projections provide a rational basis for the comparison of alternate trends in the future transportation of the nation; however, they should be considered as examples rather than predictions of future use. The projections do not consider such important factors as the possible availability of government support for operating subsidy or for the development of new technology. The economic assumptions for advanced systems are based on reasonable projections of present information, but will not be achieved without extensive development.

If no actions are taken to improve the capabilities of the present systems, a continued decrease is almost inevitable. If the present modes are improved, and more extensively supported (by capital and operating subsidies for example), then there may be a significant increase in the use of public transporta-

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tion. Conceivably, this could reduce the need for new and innovative systems. However, if the capabilities of improved versions of the present systems are not adequate to significantly increase the use of public transit, then new and innovative systems may become necessary, not as competitive systems to displace the existing modes but to fill needs which they alone can satisfy.

Each of these three alternatives was evaluated in terms of the total person trips, nationwide, which would be attracted as a function of time. The evaluations were made in terms of person trips as this is the form in which statistical data is most readily available and represents the gross social need for travel. Estimates of actual passenger miles, which are more important from the standpoint of system design, and from the standpoint of pollution and congestion, can be prepared from available data on average trip lengths.

In preparing the projections of future transportation use, several primary modes and their adaptations were considered:

- Transit buses, urban and dedicated rights-of-way
- Rail rapid transit
- Dial-a-bus
- Personal rapid transit.

These modes were selected because they included all of the major modes in use at present plus their logical developments, and representative versions of innovative new modes which may be developed in the future. Other modes could have been considered and should be in equivalent future studies.

While the use of new technologies may provide economic advantages, the changes may not be apparent to the passengers, and thus the use of new technology should be considered as an evolution in the present modes; for example, an urban tracked air cushion vehicle is, in effect, an upgraded, mode modern, higher speed subway car.

For this reason, the two new systems considered in the case studies are those which provide significantly new forms of service: the personal rapid transit systems, and the demand responsive bus systems also known as dial-a-bus and demand jitney.

The personal rapid transit system considered in the case studies assumes that a single vehicle is dedicated to each trip for a passenger or his traveling party. It travels by automatic control, on a minimum time path, between the station of origin and the selected destination. The projections of future use of personal rapid transit require that certain technical and economic assumptions be made. For the discussions which follow, the following criteria were assumed:

- Acceptable performance, safety and reliability.
- Dispatching control systems near optimum.
- Intervehicle spacing for 2,000 vehicles per hour per lane.
- Construction costs one-half to two-thirds of rail.
- Operating costs per seat mile equal to conventional bus.
- Acceptance by the public of driverless vehicle.

These objectives are more conservative than some estimates, which have indicated capital costs as low as one-fifth of the equivalent rail systems and vehicle flows as high as 20,000 vehicles per hour. The extent of the probable use of PRT systems was estimated from the stratification of the cities based on relative costs per passenger and probable modals assignments for specific areas of application. It should be emphasized that the cost per seat mile is not the determining parameter, rather cost per passenger moved. The system with the lowest cost per seat mile may not attract as many passengers as a system with higher costs, and thus may not be as economically feasible.

The demand bus systems were considered in this evaluation because they provide a service compatible with the PRT systems (Reference 14) (i.e., origin to destination on demand) and can be used in areas where the fixed facilities of PRT systems cannot be justified. The development of demand bus systems may supplement either PRT or conventional mass transit systems.

The economic assumption used in this evaluation to establish the areas of effective use for the demand bus assumes that the fare charged ranged from 50¢ to $1.00 per ride and that the average trip length was less than two miles. The remainder of a single person trip would be on a conventional bus, rail system, or by PRT.

### A. Case I—Continuation of Present Trends

These evaluations indicate that, if no major changes are made in the operation and use of public transportation, a continuing decrease in ridership may be expected over the next 20 years. Rail years. Rail use will decrease somewhat less proportionately than bus, but both will decrease in relative and absolute terms. The results are shown in Figure 1 and Figure 2.

### B. Case II—Increased Use of Present Modes

In order to estimate the possible increase in the ridership on public transit,

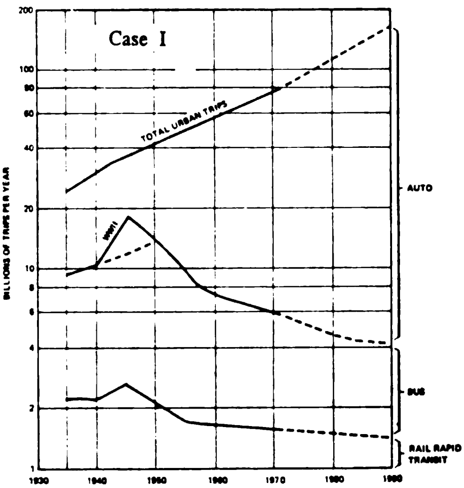
| Case I | 1970 | | 1990 | | 70-90 |
|---|---|---|---|---|---|
| | BP /Y (1) | % | BP /Y | % | % |
| Bus | 4.36 | 8.0 | 2.4 | 2.5 | -45 |
| Rail | 1.57 | - | 1.3 | | -17 |
| Auto | 71.0 | 92.0 | 158.0 | 97.5 | 123 |
| Total | 76.93 | 100.0 | 161.7 | 100.0 | 110 |

(1) Billion Passenger Trips Per Year

Figure 1

which would result from more effective use of present modes, a second evaluation was made. The objective was to retain, through 1990, the present share of the urban trips by public transit by the addition of rail lines, new bus operations and other improvements in order to achieve this goal. This is a reasonable approximation of the maximum ridership which can be attracted to conventional transit. The assumptions made included:

- An increase in the use of bus systems by doubling the per capita mileage of buses and cutting the fare in half.
- An improvement in the use of bus systems by the construction of a network of busways.
- The construction of essentially all the major proposed rail transit systems.




Use of Public Transit 1930-1990 - Present Trends

Figure 2

The increase in bus use was based on two assumptions. First, the bus mileage per capita was doubled in all urban areas. This could increase the frequency of service or could provide new services. In order to estimate the effect of such increases in service, a simplified modal split model shown in Figure 18 was used. This indicated that the added frequency of service would probably have little effect on the ridership (i.e., less than 5 percent) on given lines. However, new routes could attract perhaps 10 percent of the total trips previously using automobiles. The second assumption included a reduction in fare which would probably have beneficial effect on ridership, and in some cases, the ridership could be doubled by reducing the fare 50 percent.[1] The study did not evaluate the specific means of obtaining these increments or the actual subsidy requirements for the increased service.

Another assumption used in projecting the possible increase in the use of buses was the use of dedicated rights-of-way to provide a class of service not now available in most cities. The length and ridership of the busways was estimated from the stratification (Figure 12) of cities by population class and density. Busways were assumed to be built from the center of the cities to the suburbs. The length varied from 25 miles for cities of 200,000 to 300,000 to nearly 57 miles each for cities of 600,000 to 700,000. These were not all new construction but represented the dedicated use of lanes on existing expressways and public streets as well. Busways were not assumed where rail exists or where rail had been seriously proposed.

The improvement in rail service was estimated from the data on systems proposed by local transit authorities. It was assumed that approximately 408 miles of system (1,020 miles of single track) were built. This represents a 105 percent increase in total service miles. The possible cities for such systems included:

(Reference 22)

| System | Miles of System | Cost | No. of Cars |
|---|---|---|---|
| Atlanta | 50 | 1.32 Billion | N/A |
| Baltimore | 65 | 1.70 Billion | 400 |
| Seattle | 47 | 1.30 Billion | 300 |
| Miami | 45 | 1.50 Billion | 380 |
| Detroit | 81 | 1.10 Billion | 400 |
| Los Angeles | 64 Estimate | | |
| Buffalo | 14 Estimate | | |
| St. Louis | 42 Estimate | | |
| | 408 Miles | | |

In addition, it was assumed that the routes in San Francisco and Washington were successfully completed and in effective operation and that minor extensions were made to some of the existing rail transit systems, in particular, in Philadelphia, New York and Chicago. These added 175 miles of route.

For both the rail and bus systems, it was assumed that new equipment with improved performance and passenger accommodations was used. This equipment was assumed to be equal to, or better than, the best in use, or projected for use, in the near future on American transit systems.

The ridership of these rail systems was based on the data on the actual, or projected ridership, in urban areas of similar density and geographic characteristics. The net result would be a significant increase in the total use of public transit systems as shown in Figure 3 and Figure 4.

The problems which appear to limit the future growth of ridership on conventional transit have been summarized previously. They include:

- Speed—usually half or less than the automobile.
- Accommodations — mass, crowded, uncomfortable, etc.
- Access—passengers must wait in unprotected or unsightly points.
- Service—covers a limited portion of the metropolitan areas.

The automobile also provides a convenient vehicle for transporting goods and provides effective service in low density and suburban areas where public transport is not effective.

Given these limitations it is not surprising that the increasingly affluent American prefers to use his automobile for transportation even when it may be more expensive and in some cases slower than public transit.

## C. Case III—Effective Use of Representative New Modes

This case study was developed to illustrate the possible impact of new transportation concepts on the use of public transporation. It assumed that the future of public transit of all classes would be based on service and cost and not specific legislation for transit, or against the automobile. It assumed that the design and construction process

| Case II | 1970 | | 1990 | | 70-90 |
|---|---|---|---|---|---|
| | BP /Y | % | BP /Y | % | % |
| Transit Bus | 4.36 | 5.7 | 8.72 | } 7.22 | +100 |
| Express Bus | - | | 3.13 | } | |
| Rail | 1.57 | 2.3 | 2.88 | 1.78 | +85 |
| Auto | 71.00 | 92.0 | 147.29 | 91.00 | +108 |
| Total | 76.93 | 100.0 | 162.02 | 100.00 | 111 |

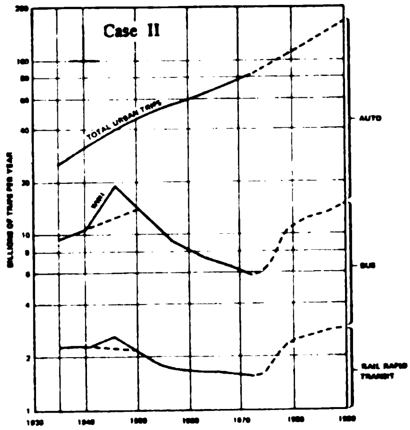



Figure 4
Use of Public Transit 1930-1990 - Expanded Rail and Bus Systems

for the new modes, and extensions of present rail systems be limited primarily by the time required to design, develop and build the equipment. Realistically political and other institutional factors will be expected to cause additional delays.

In order to make effective transportation more attractive, improved forms of service will be required. The systems must provide faster service (trip times competitive with the automobile) and provide a quality of service acceptable to a large section of the population, including those who now prefer their private automobiles. A large number of new systems have been proposed for this purpose. However, in evaluating these systems, care must be taken to identify the systems which provide service improvements, and separate them from the concepts which merely represent the application of new technology to existing types of transportation service.

For this case study the personal rapid transit systems and dial-a-bus systems were assumed to be widely applied and further expansion in express or dedicated lane bus service was assumed.

The usefulness of each category of system was estimated from a series of studies of representative transportation system applications, based on the stratification of cities by size and population density, and the relative service and economic characteristics of the modes. These studies, which are described in Reference (23) of this report, include:

- A parametric study of service corridors which represent a range of lengths and population distribution typical of most U.S. cities.
- Conceptual designs of systems for specific applications to establish rela-

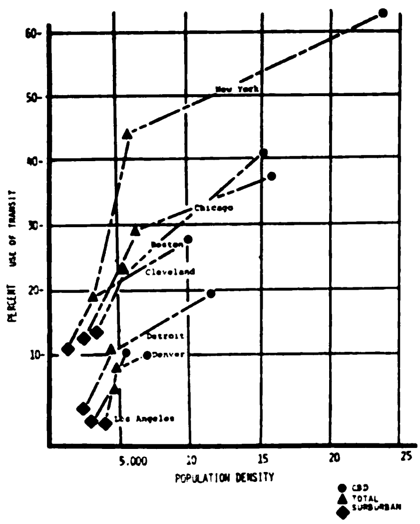



Figure 5 Reference 3

Use of Public Transit vs. Population Density

tive sizes, costs, riderships, etc., of comparative systems for the same applications.

The estimate of the possible use of a mode was then based on the number of urban areas in which the mode would provide superior service (based primarily on population density, with consideration for the size required for an economic system). A large number of possible modes were considered in related system studies.

Based on these assumptions, it was shown that each of the public transit modes under consideration has a range of effective applications. The areas varied somewhat with the specific city population, density, etc., and some major overlaps do exist. Characteristically, fixed systems are most useful for high density areas and the total use of public transit decreases rapidly in areas with lower population densities. This is illustrated in Figure 5 for several American cities. The results of Case III for the individual city categories, when summarized in a plot against the average population density, are interesting. Figure 6 shows the projected ridership by mode in terms of the percentage of the total urban trips for areas of comparable population density. The results show that the Rail Rapid Transit Systems meet the test of conventional wisdom. That is, their primary application is for areas with population densities over 10,000 per square mile. Personal Rapid Transit Systems find their primary application in areas of somewhat lower density (from 5,000 to 10,000 people per square mile). They have some uses in higher density areas as a feeder to the linehaul system. The relative area of superiority for PRT systems might be greater except for the assumption that the rail systems would be built before the PRT systems became fully acceptable. As a result, rail has been assumed for a number of applications for which PRT might be more suitable. The transit bus, as might be expected, shows a broad and almost constant area of usefulness across the density lines. Only in the very low density areas is the transit bus ineffective. In those areas the demand bus is the only practical means of public transportation (other than the taxi).

When the data of Figure 6 is replotted to indicate the actual number of trips probable within each population density category, the relative usefulness of the transit bus and PRT for a major portion of our urban transportation needs becomes apparent as shown in Figure 7. The results are summarized on Figure 8.

The results of this study were then presented against time with allowance for the development, acceptance, and construction of PRT systems. Figure 9

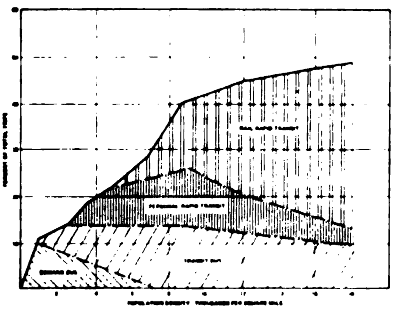


Figure 6

Use of Public Transit vs. Population Density Projection by Relative Use of Modes for 1990

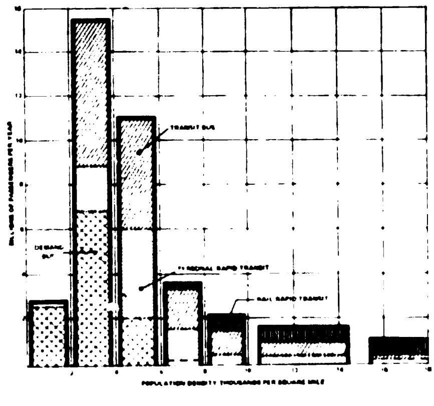


Figure 7

Use of Public Transit vs. Population Density Projection by Number of Trips for 1990

| Case III | 1970 | | 1990 | | 70-90 |
|---|---|---|---|---|---|
| | BP /Y | % | BP /Y | % | % |
| Bus | 4.36 | | 14.8 | 7.81 | +240 |
| Rail | 1.57 | | 2.88 | 1.49 | +83 |
| PRT | - | | 8.75 | 4.50 | |
| Demand Bus | - | | 12.0 | 6.20 | |
| Auto | 71.00 | 92.0 | 150.5 | 80.00 | +112 |
| Total | 76.93 | 100.00 | 188.93 | 100.00 | +147 |

Figure 8

indicates that the total ridership by public transit could increase as rapidly as that of the automobile. These evaluations illustrate the difficulty in making a significant impact on the use of the automobile. The majority of all urban travel occurs in the relatively low density areas where only buses can provide economic public transit. A significant percentage of the total (7 percent) occurs in areas with a population density below 2,000 people per square mile where only the demand bus routed for specific individuals would be useful.

## D. Possible Alternate Urban Developments

The case studies assume that the present trends in urban development; sprawling suburbs, decaying CBD's and the development of multiple centers of commercial and industrial activities in the metropolitan areas will continue. New and improved approaches to urban design have the potential of significantly alternating these trends. New cities could be designed with overall population mobility requirements in mind. They could be designed to provide transportation for those unable to use the automobile, and reasonable alternative choices for those who can.

Most actions to restrict the use of

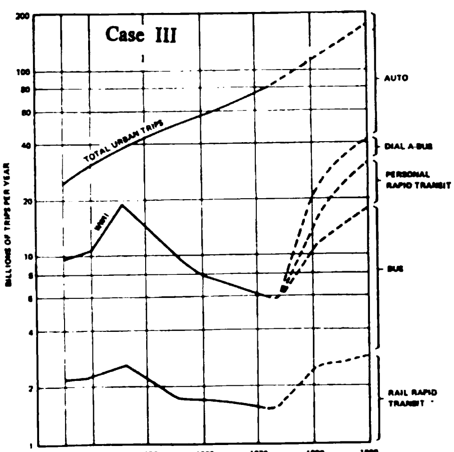



**FIGURE 9**

**Use of Public Transit 1930-1990 — Expanded Rail and Bus and Two Innovative New Systems.**

the automobile are directed at the high end of the density scale central business districts, etc. Barring the automobile from all of the CBD's in cities over 800,000 population would reduce the use of the automobile by less than one percent. All urban trips with CBD origin or destinations account for only about 12 percent of the total trips and less than 20 percent of any specific trip would actually be within the CBD.

If 75 percent of the anticipated growth in the center cities and 50 percent of the anticipated growth in the suburbs were to be redirected to new towns of about 250,000 population we would require 200 new towns by 1990. If these towns were designed to provide an effective balance of transportation systems and access for all inhabitants to needed activities they might double the use of public transportation over the cases previously described.

New approaches to transportation may be developed for new towns. While access to the towns by automobile and conventional public modes will continue to be necessary, the internal transportation systems can be integrated into the design of the community. Where the locations of houses and apartments provide sufficient density, accessible to transportation centers, minitransit systems may be used. These may be effective in attracting new residents and business organizations to the projects by minimizing the need for a second (or first) car, and by providing convenient access to the commercial establishments. In developments with lower density, dial-a-bus systems or transit buses may provide the most effective internal transportation. Another attractive alternative may be the limited performance personal vehicle. Small, ultra-light vehicles, which derive from bicycle rather than automotive technology, can be designed to be compatible with pedestrians and automobiles. If the pathways are designed to exclude the conventional automobile, safe, convenient area (1-3 mile radius) transportation can be provided for a broad section of the population. The ultra-light vehicle would be about one-sixth the size of a standard automobile and weigh only a few hundred pounds with passengers. It would permit the development of new urban configurations and architecture.

However, since there appears to be insufficient economic incentive for private developments on this scale, and no national policy to encourage major public developments, the probability of sufficient new town developments to significantly change these trends appears to be slight.

## METHODOLOGY FOR PROJECTION OF NATIONAL DEMANDS

A simplified methodology was devised to provide the basis for projecting of the total national use of existing and new urban transportations systems as a function of the changes in national need, population growth, and system economics.

### A. National Demand Model

The methodology can be used to estimate the total number of trips in all urban areas as a function of time (years). Input information required includes the cost and service characteristics of the new system, the development time schedule for the systems, and the status of existing systems.

A simplified diagram of the logic model for this approach is illustrated in Figure 10. It consists of four primary elements:

- A means of establishing the performance, size and other parameters of the candidate systems.
- A means for describing the urban transportation demand in generalized terms including: — A description of the national urban environment by a stratification of all major urban areas considering such factors as metropolitan area population, population density, etc. — A description of the traveling passenger including such factors as age, income and his reason for traveling (home to work, etc.).
- A means for describing the competitive modes of transportation auto, bus, rail, and for considering alternative operating and fare strategies for these systems.
- A method of evaluating the modal choices of the passengers on a gross national basis, or for appropriate stratifications of urban area, population, etc.

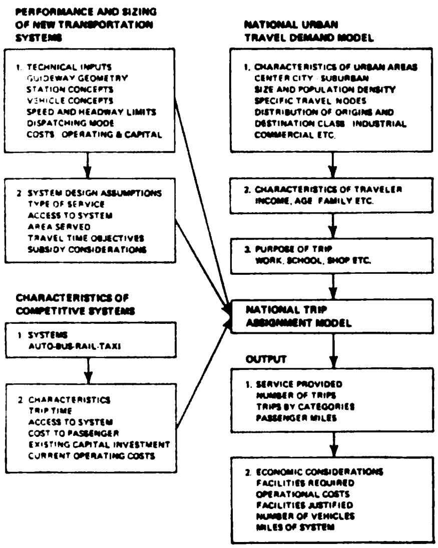



Figure 10

Simplified Logic Diagram for Projection of National Uses

### Transportation Strategies

The analytical models are structured to permit the investigator to consider alternative strategies for the future development of urban transportation and to project the probable results of selected strategies in terms such as the number of riders, cost of transportation services or the requirements for new transportation equipment. Typical strategies which might be considered include:

- The introduction of a new class of transportation equipment.
- Operational subsidies for the support of transportation systems.
- Free or minimal fares.

Alternatively, certain service objectives could be established and the ability to meet objectives determined, for example, for a selected percentage of all urban trips to be by transit. The investigator could then predict if the goals could be reasonably met, and the requirements in terms of systems, equipment, and capital or operating subsidies to meet the objectives.

Examples of the use of this procedure are included in this report. The examples should be considered to be indicative of the relative level and types of changes rather than quantitative projections of actual ridership as a result of the simplifications used, and the unavailability of certain necessary information.

### Required System Assumptions

The required technical inputs include the concept of the system, its performance limitations and the anticipated capital and operating costs. In addition, certain assumptions must be made: including the type of service, area to be served, and trip time objectives.

Alternative assumptions may be tested by the evaluators to establish economic and service trends related to the design and use of the systems. Typical engineering design factors which can be considered in the design of the model include:

- The Vehicle Design Limitations: The physical design parameters of the vehicle, ranges of passenger capacity, speed capabilities, dimensions, entry and exit conditions, seating and other features which influence performance or utility, can be investigated by the use of the model. Parameters such as speed may be defined as limits.
- **Control System Limitations:** Control system performance may be speci-

fied in terms of: — Vehicle position and monitoring (for bus). — The minimum intervehicle spacing (for rail). — The vehicle scheduling or dispatching logic. — Safety or malfunction provisions.

Intervehicle spacing parameters will limit the number of vehicles which a single section of one way track can transport. In most cases the actual capacity of the system will be somewhat less than the theoretical capacity due to the scheduling and merging limitations. Use of block systems as a safety precaution will further restrict the volumes. Traffic congestion and associated street designs will likewise restrict the performance of bus and other highway systems.

The dispatching systems can be several types. In simple line haul (or mechanically linked) systems, the vehicle will operate on a time schedule (e.g., one vehicle every 90 seconds) and will operate along a line connecting one or more stations sequentially along that line. For complex network systems a number of control logics are possible up to and including random or demand scheduling concepts which can be used with small vehicles in which each trip is dedicated to a single person or traveling party and the vehicle travels directly from station to origin to selected destination station. The model can be used to predict average trip times with several alternative control approaches.

• Travel Time and Access Objectives: In order to establish the operational characteristics and size of the systems certain performance objectives may be assumed. These may be defined in terms of the percentage of the people who can walk to the pick up location, the number which can use a bus, or stated average trip times. The model permits biasing the objectives in favor of those living in certain areas of the city, or with certain income or other characteristics. Travel time objectives (stated in terms of percent of the trip time by automobile or elapsed time) cannot always be physically attained, although some of the more innovative systems may permit attaining elapsed time considerably lower than the automobile. The evaluator may modify the objective assumptions to consider a range of the en route speeds, and establish the relative sensitiveness of the concept to speed.

• Station Concepts: The stations or stop locations (in the case of a bus) for various systems can vary significantly in configuration and number. The station assumption includes influence of passenger throughput on size and cost, and the physical constraints of the stations which may influence the design or costs of other elements of the systems.

• Guideway Geometry: The design of the guideway will limit the performance of the vehicles, (i.e., top speed, radius of turn, etc.). The costs of guideways are typically poorly defined, and a range of cost assumptions may be required in the evaluation.

This approach will not distinguish between two similar modes providing similar service but using different technologies. For example, at lower speeds a rail car and one on airbearings will provide similar performance.

### Stratification of Urban Transportation Demands

The demand for urban transportation was estimated by the consideration of two functions. First, the size of urban areas of the country which were stratified for ease of computation. Second, the trip demand based on a categorization of the population income, auto availability and purpose of trip.

• The Stratification of Urban Areas: For ease of computation 757 urban areas over 25,000 population in the United States were grouped by population size (1960 census) and density (where there is significant variations in the areas of cities of similar populations). The urban and suburban areas were considered separately for all cities over 100,000 population.

• There are 633 cities between 25,000 and 100,000 population. These were combined into six groups based on population (i.e., 25 to 50 thousand and 50 to 100 thousand) and the highest and lowest ten percent in average population density.

• There are 119 cities between 100,000 and 1,000,000 population. The locations of these are shown in Figure 11. The premilinary studies have been based on the categorization of these into 50 cases including both urban and suburban areas, and a range of population densities as shown in Figure 12. For

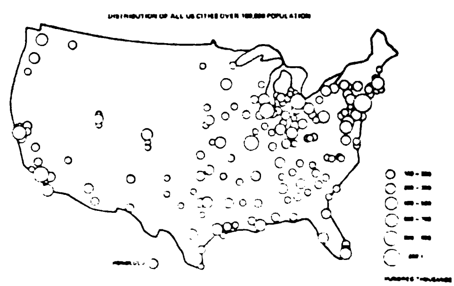


Figure 11
Distribution of U.S. Cities

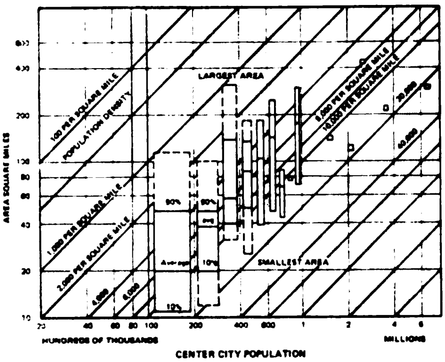



Figure 12
U.S. Urban Areas - 1970 Population and Area

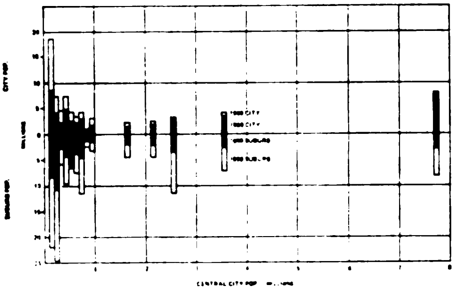


Figure 13
Urban Stratification and Population Growth - 1960-1990

cities below 500,000 population the upper and lower ten percent in population density were used as well as the average density to provide for the comparison of systems which may be designed for special low or high density application. For cities above 500,000 only the upper and lower cases were used.

• Since there are only five center cities over 1,000,000 population, they were treated as discrete cases. The center city and suburban areas were considered separately. The anticipated growth of each of these categories was estimated from previous projections of urban growth by area (Reference 11).

## Passenger Trip Generation Rate

The second factor in this approach, travel demand projections, is a function of characteristics such as disposable individual wealth, available transportation facilities and the size and shape of the communities. Travel demand functions are categorized by trip purpose (school, work, etc.), and by the characteristics of the traveler (age, income, family size, access to automobile, etc.). Various possible parameters for the projection of the future per capita travel demand could be considered. For example, from previous studies a positive correlation was found between per capita income and average person trips per capita and a useful negative correlation was found between income and the percent of personal trips by transit (Figure 16).

The demand for urban travel was estimated by a macro projection of per capita urban travel as indicated by increased per capita expenditures for personal consumption. As Figure 14 indicates, there is a correlation between per capita expenditures and the rate of urban trip generation per capita for all modes. This approach can be used to estimate future total person trips by relating the trend curves to the estimates of future personal income from Reference 20 and the population growth.

A range of possible ridership—1980 and 1990—projections is shown in Figure 15. The rates of travel, combined with the probable variation in population growth in the urban areas from the same reference, were used to estimate the range of possible trip generation. H is the high combination of projected income and total population, L is the low combination of projected income and population. N represents the average. An alternative method of estimating the total trip generation, based on the change in travel as a function of the size of the urban area and personal income and number of automobiles available. (Figure 14) provided the fourth estimate shown in Figure 15. This latter projection, indicated as A, was used for the basic estimate of the total urban trips per year in the subsequent discussion.

The use of public transportation, however, has been decreasing rapidly in spite of the increase in the total number of urban trips. Two techniques were used to estimate the future use of public urban transportation from historical data. First, a projection of the trips per year by a simple trend analysis of rail and bus trips based on the rates over

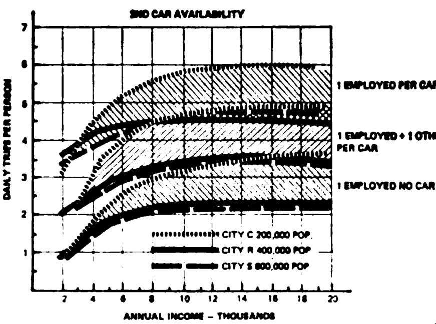



Figure 14 Reference 3
Urban Travel Projection

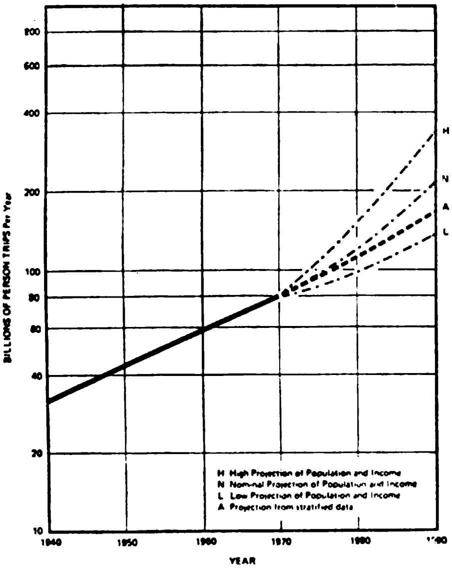



Figure 15
Trip Demand vs. Income

the last 20 years, and second, a correlation between the percent use of public transit and per capita disposable income. Figure 16 illustrates the relationship of per capita disposable income and the percent use of public transportation. The estimate for the period 1980-1990 was made by projecting the present rate of decrease in use of transit for the next 20 years, then plotting the results against per capita income.

It is important to point out that the required capacity of a transit system is established more by the morning and evening peak hours than by the total demand. For simplicity, a peak hour equal to ten percent of the total daily demand was assumed for the case studies.

The morning and evening rush periods are primarily work related trips, and tend to be longer than the personal business or social trips which may be distributed throughout the day.

The characterization of total transportation demand requires that the trip purpose also be considered, recognizing that there will be differences in the predominate types and distribution of trips for different modes. Figure 17, for example, illustrates a projection of automobile trips for 1980's. Transit trips would tend to be predominately work-related, with less, but approximately equal use for family business and recreation. Little, if any, transit ridership would fall into the work-related (travel between appointments, sales, etc.) or the pleasure ride categories.

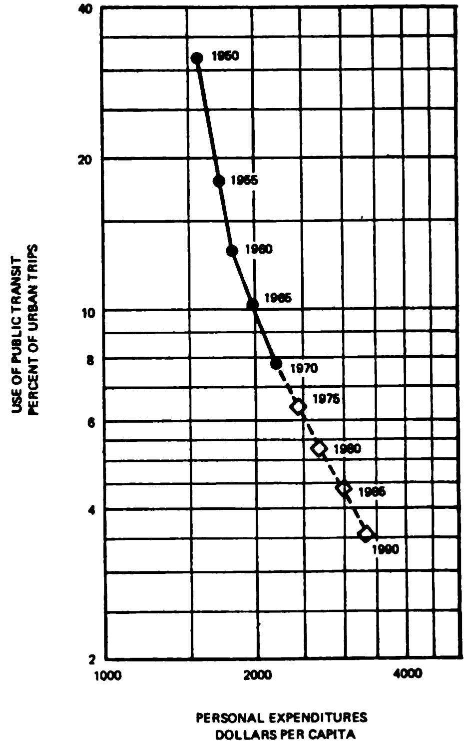



FIGURE 16

**Use of Public Transportation—Percent of Total Trips vs. Personal Expenditure.**

**Characteristics of Modes**

The characteristics of the primary modes are included to evaluate the relative attractiveness of the existing systems and proposed new transportation system concepts. For this purpose, the primary factors of each of the competitive systems, automobile, bus, rail, taxi may be considered in terms of their influence on the trip assignment model. The primary factors include:

- Average trip time (including waiting).
- The average trip costs perceived by the traveler.
- The actual cost to the traveler (including taxes and depreciation on an automobile).
- The cost to the community of the service (including subsidy if provided).
- The value of the existing capital assets which might not be required or would be obsolete by a new system.

Consideration was given to evaluation of a logical range of some of the input considerations (for example, transit fare, automobile taxes, etc.). The model may consider changes in the automobile trip time. For example, should the new mode of transportation attract a significant number of trips from the automobile and thus reduce traffic congestion.

### Trip Assignment Model

The prediction of the division of trips between conventional transit, the automobile and an innovative mode is provided by a modal assignment model which has submodels based on the travel choice characteristics for various classes of riders, various trip purposes and for specific classes of communities. The basic relationships of the trip assignment model with respect to trip time and perceivable cost are illustrated in Figure 18. This relationship was developed by an evaluation of data from several area studies, and was used to represent average riders. No consideration was given to factors such as security and quality of accommodations which, while probably significant in their effect have not been adequately investigated. (References 7, 18).

From the model relationship the number of trips by automobile, and by transit may be predicted, considering either a proposed new transportation system alone, or the use of the system in concert with existing transit modes. Several approaches can be taken to the evaluation of modes in parallel. In the method used in the case studies, the individual urban areas classes were investigated to establish which systems would provide the lowest cost service, per passenger, in each class of urban area and the single best system considered in each class. The selection of the most economic concept may be based on the overall costs including the remaining value of existing transit facilities which may be obsoleted. In other cases, the selection parameter may be based on maximum attraction of riders for a given capital investment in new transportation facilities.

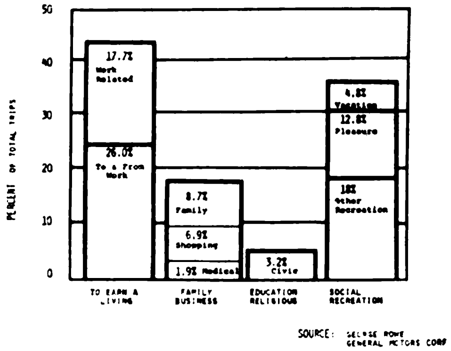



Figure 17

Distribution of Trips by Type 1980 Estimate

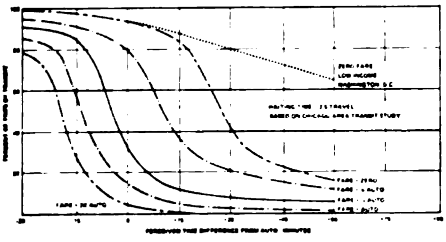


Figure 18

Representative Modal Assignment

The model will permit consideration of the effect on system use and economics of various fare strategies for the new (or existing) transit system. Subsidies can be assumed to vary the fare from no fare, to full operating and capital recovery fare levels.

In many cases, the information required for complete and accurate operation of this model does not exist (for example, the attraction of a significant improvement in passenger accommodations or the induced demand due to improved travel time and costs). In other cases the new mode of transportation will provide for significantly improved urban mobility, and this increase in mobility may induce additional travel demand. These and similar factors can be incorporated into the model when adequate information becomes available.

Preliminary tests of the basic logic of the national transit use model have indicated that it can predict the actual 1970 transit ridership from 1950 and 1960 data. The prediction was reasonably accurate ($\pm$ 5%) for the overall national projection of use of bus and rail.

## SUMMARY AND CONCLUSIONS

- The methodology discussed in this paper can provide a useful rationalization of the future trends in the use of various urban transportation modes.
- There is inadequate data on a number of the major factors influencing the direction of future developments in public transportation to provide a high degree of confidence in any specific projection.
- Factors which require additional consideration include: — Local governmental and institutional requirements and delays. — The relative attraction of new forms of transit service including privacy, ride quality, direct service, etc. — Probable legal and technical constraints on the automobile. — The possible development of alternative urban growth patterns and new towns.
- Public Transit is required to provide mobility for those unable to use

their automobiles and for access to those areas where the automobile is ineffective.

- There appear to be no major technical barriers to the development of new types of transportation services. Where equipment development is required the time scales are of the same order as those required to design and construct the basic systems.
- The case study projections indicate that it will be difficult for conventional transportation systems to maintain their present share of the urban transportation.
- Case study projections indicate that the total use of the automobile will not be reduced by any reasonable extension of the use of conventional or innovative transit systems.
- Effective use of new modes of public transit could result in an increase from less than 6 billion passengers per year to more than 36 billion passengers per year by 1990. This is equivalent to more than tripling the percent of trips by transit.
- An extensive program of new town development or the development of new patterns of urban growth appear to be the only influences which would significantly change these trends.
- Legal actions against the automobile could increase the use of public transit. However, unless city forms are changed, it is unlikely that a significant total reduction in the use of automobiles would result as no existing form of transit is effective for many of the trips now made by automobile.

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## FOOTNOTES

1 Simpson & Curtin formula of one-third percent per percent would indicate a much lower increase in ridership.