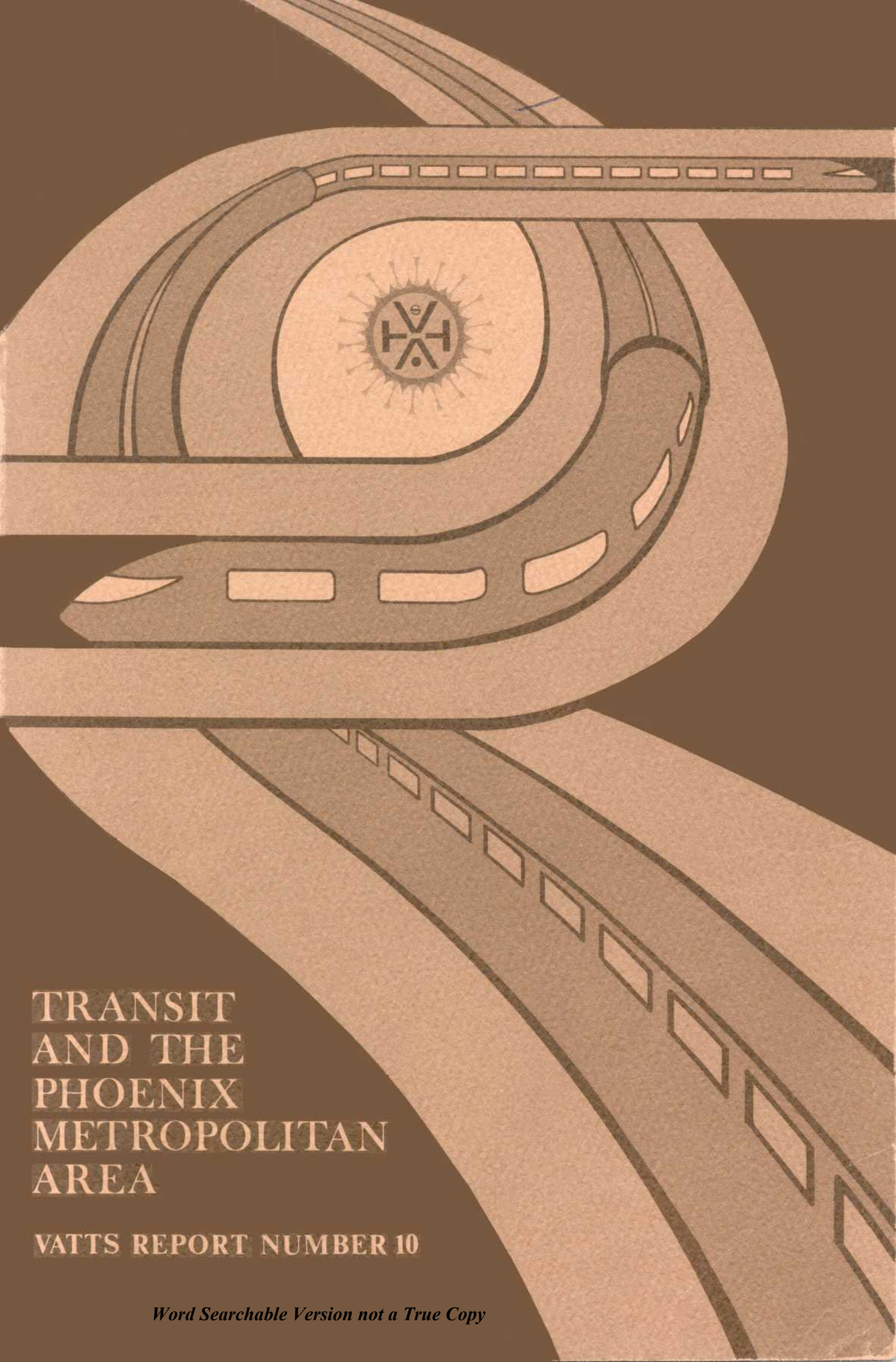

TRANSIT AND THE PHOENIX METROPOLITAN AREA

VATTS REPORT NUMBER 10

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Transit and the Phoenix Metropolitan Area

Prepared by

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for

Valley Area Traffic and Transportation Study

Phoenix Urban Area of Maricopa County, Arizona

A Standing Committee of the Maricopa Association of Governments

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SUMMARY

Important Considerations in the Valley

The purpose of this document has been to present the basic factors concerning urban transit, demand, technology, and usage. The object was not to solve a specific problem or evaluate a specific proposal or system. It is hoped that it will give the reader a better understanding of urban transportation – why it occurs, how it may be modified, and, to some degree, how it is viewed by the individual citizen.

Although no solution to the Phoenix transit problem was sought or obtained, this summary will set forth some of the basic questions and considerations which should be incorporated into future transport planning for the Valley area. It is not meant as a review of the material which follows, much of which is to provide the reader with indications of the consequences of particular answers to the following questions.

Most fundamentally, the appropriate people and agencies need to make the basic decisions regarding the future growth of the Valley with regard to size, dispersion of land use, development of core areas, etc. These decisions will set the basic patterns and demands for transport, and to a very large degree, define the transport technology which will best meet the demands. Future transportation systems should be designed to serve these basic factors as related to the Valley. Once these decisions are made, it is equally important that there is the determination and mechanism to guide urban development in the desired direction. It is irrational to plan transport facilities on the basis of land use expectation that have little chance of fruition.

Secondly, the location of any system must serve the demand. Systems which join only major retail or industrial areas will not receive great usage. The basic travel demand is from the home to a non-home location and return. This is the service which needs to be provided by any viable system. The more directly it can serve the home, the more attractive it is likely to be.

The alternative transit systems available in conceptual and prototype stage are extensive. They range from high-capacity, high-speed rapid transit to those providing more flexibility and privacy than today's automobile. There is no need for local or state agencies to develop new technology; however, they should determine which is best suited for their needs.

In the light of recent legislation, an imminent problem for many communities will be the public financing of transit operations. Questions must be answered concerning the degree to which non-revenue funds shall be used. Should they provide capital improvements or should they also supplement operating expenditures? Who should, preferably, pay? Should non-revenue funds be used to support outmoded systems which have no likelihood of ever being self-sufficient?

If public ownership of transit systems becomes prevalent in the Valley, can new methods of revenue collection be developed? These would need to be as efficient and equitable and less objectionable than the fare box.

What specific actions can be taken to make transit more attractive to the user? What operational changes are needed to meet one or more of the guidelines set forth at the end of Chapter IV?

Those making decisions regarding transit must realize that they are not planning for "others" but for the entire community. What is generally attractive to one group of urbanites will probably be attractive to most others. Specific groups will use a relatively less attractive system only as long as they are restricted by social or economic forces. A system provided for "others" that "I" may improve the quality of "my" preferred mode will not be effective.

Finally, what can the Valley, with other urban areas and the state government, do to encourage or bring about innovation? If the individualized bi-modal system, such as the StaRRcar, has potential for this type of urban area, then what can be done within the next decade or two?

These are but a few of the important questions involved in urban transportation planning. It is hoped that this will provide a basis for further informed discussion. Rapid change is difficult to accomplish, and the future seems remote, but it must be remembered that the year 2000 is closer than 1940.

CHAPTER I

The Urban Mobility Problem

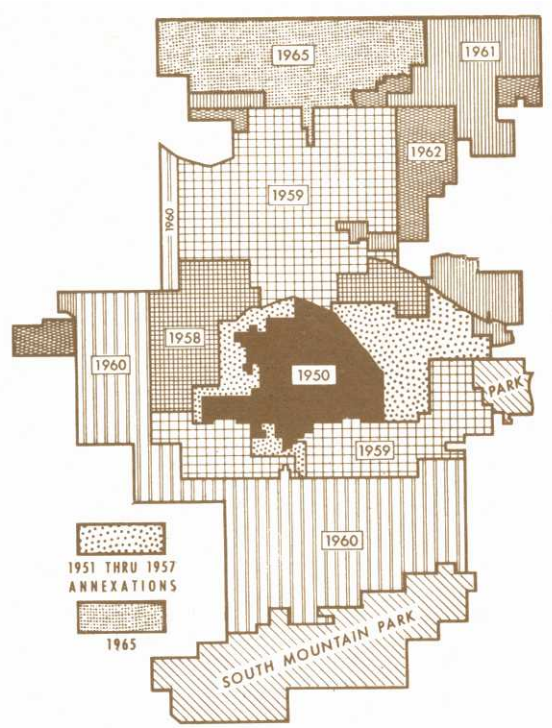
Phoenix 1970

This chapter is concerned with the fundamental factors which cause a demand for urban transportation and the variations of this demand within the Phoenix metropolitan area. The basic premise is that transportation is not an end in itself, but a response to the demands of the people in this urban complex.

The period since World War II has been one of most rapid growth for the State of Arizona and the Phoenix area. This growth has occurred in the form of low-density residential developments accompanied by decentralization of many retail, service, and industrial activities. The area included in the City of Phoenix has grown as significantly as its population. In 1950, the City of Phoenix had an area of 17.1 square miles with a population of 107,000. In 1970, the preliminary census figure for the 247.9-square-mile city indicated a population of 580,275. The annexation and population history of the incorporated city since 1950 is presented in Figure 1. The population growth of Maricopa County is also presented.

A major characteristic of this growth has been the development of only a few areas of high residential density. An examination of population densities (people per square mile) revealed that in 1950 there were only three square mile areas with densities over 7,500. In 1965, there were also only three square miles, although they were not the same three areas. Square mile areas with densities of 5,500-7,500 people per

FIGURE 1



Growth of Phoenix and Maricopa County

July 1	PHOENIX INCORPORATED CITY Area (sq. mi.)	PHOENIX INCORPORATED CITY Population	MARICOPA COUNTY Population
1950	17.1	106,818	331,770
1955	29.0	155,000	465,000
1956	35.8	170,000	500,000
1957	36.3	179,000	540,000
1958	52.6	242,000	580,000
1959	110.0	364,000	620,000
1960	187.4	439,170	663,510
1961	189.8	452,000	726,500
1962	220.2	468,000	758,000
1963	222.7	483,000	792,500
1964	222.7	494,000	819,100
1965	245.7	504,000	834,700
1966	246.2	511,000	850,500
1967	247.3	519,000	872,100
1968	247.6	528,000	900,000
1969	247.7	546,000	930,000
1970	247.9	580,275*	963,132*

* (preliminary)

Source: Valley National Bank, *Arizona Statistical Review,* Page 9–September 1969.

GENERALIZED EXISTING LAND USE PHOENIX, ARIZONA

DECEMBER 1968

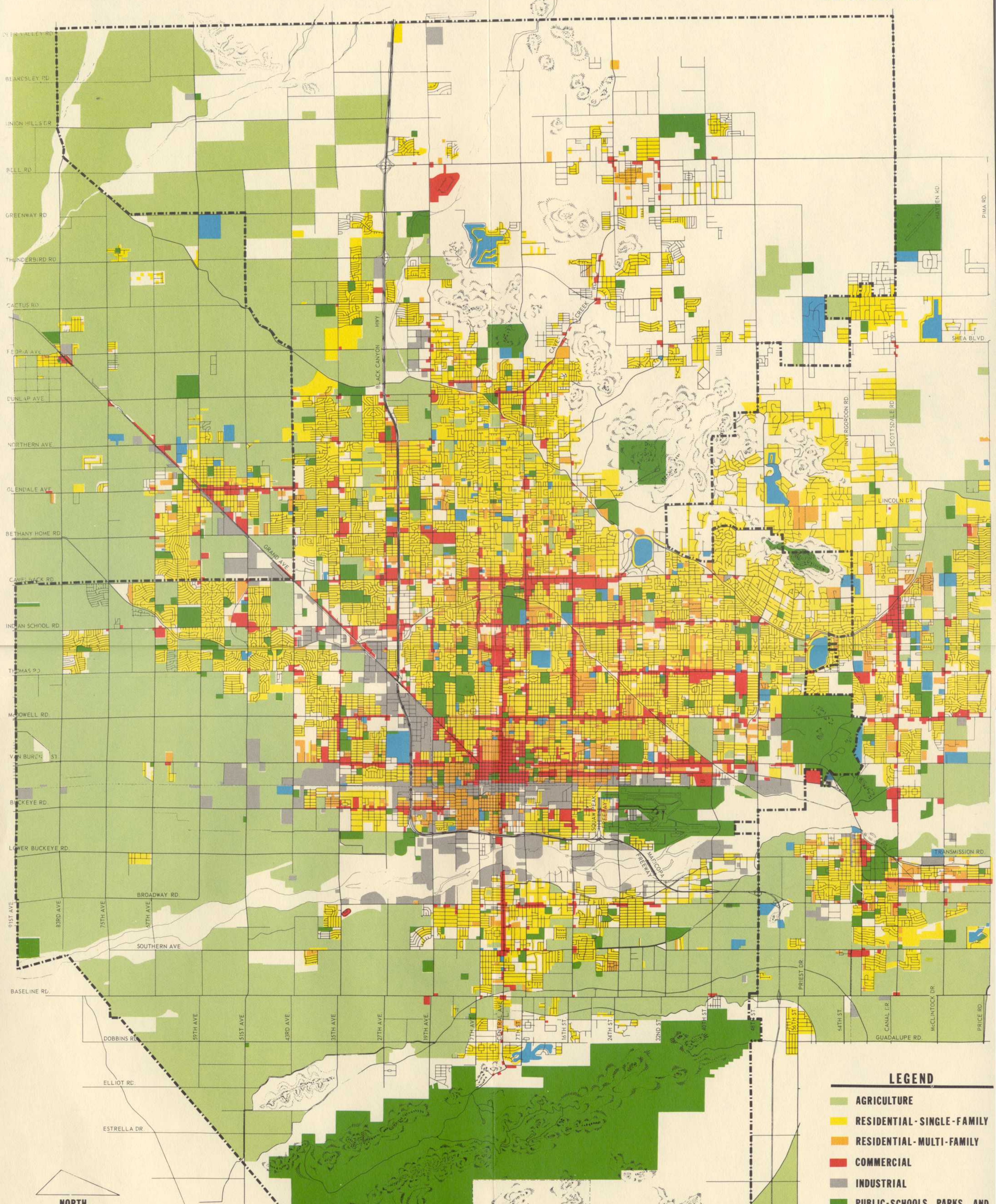


FIGURE 2

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Source: City of Phoenix Planning Department, *The Comprehensive Plan – 1990*, Pages 29-30 – November 1969.

square mile numbered seven in 1950, nineteen in 1960, and twenty-one in 1965. The typical densities of 3,000-4,000 persons per square mile are characteristic of the single family developments in Phoenix. A majority of the incorporated area of Phoenix presently has less than 2,000 persons per square mile.[1] The 1968 land use is shown in Figure 2. This land use map indicates some concentration of centralized commercial and industrial activities. The central area is also important with respect to employment and retail sales volume. Figures 3 and 4 indicate the retail sales volume and employment for a typical month in 1964. These figures depict not only incorporated Phoenix, but most of central Maricopa County including all areas where contiguous urbanization is expected in the foreseeable future. The population of Maricopa County is projected to increase to 2,460,000 by 1995. Paralleling this population growth, an estimated 1,340,000 vehicles will be registered by 1995. The projected growth of population and vehicle registration is presented in Figure 5.

Today the major transportation emphasis in the Phoenix area is the movement of people and goods by motor vehicle. Based on the expansion of present trends, the average person will travel 16 miles per day in 1995. The 4.8 million daily auto-driver trips forecasted for 1995 will have an average duration of about 16 minutes per trip. This represents about 37 million vehicle-miles of travel daily. The auto-driver trips and vehicle-miles of travel forecasted for 1980 and 1995 and the 1964 data are presented in Figure 6.

Public transportation service and usage is quite limited in this urban area and, thus, the automobile has been the dominant mode. Forecasts indicate that this will continue to be the case in 1995. Forecasts of transit usage based on existing facilities, which are minimal in terms of the overall daily transportation pattern, would be highly speculative. Consequently, the planning agencies are faced with the much more challenging and difficult problem of determining the proper role of transit in the Phoenix metropolitan area virtually independent of the existing conditions.

Before undertaking such basic decisions, it is important that those concerned have a basic understanding of problems and implications of public transit. Thus, the object of this report is to bring together the pertinent facts, philosophy, and research regarding transit.

Characteristics of Urban Travel

In order to understand urban transportation demand, it is necessary to be familiar with the basic purposes which call forth this demand. The

FIGURE 3

1964
Retail Sales Distribution

Source: Valley Area Traffic and Transportation Study (unpublished data).

FIGURE 4

1964
Employment Distribution

Source: Valley Area Traffic and Transportation Study (unpublished data).

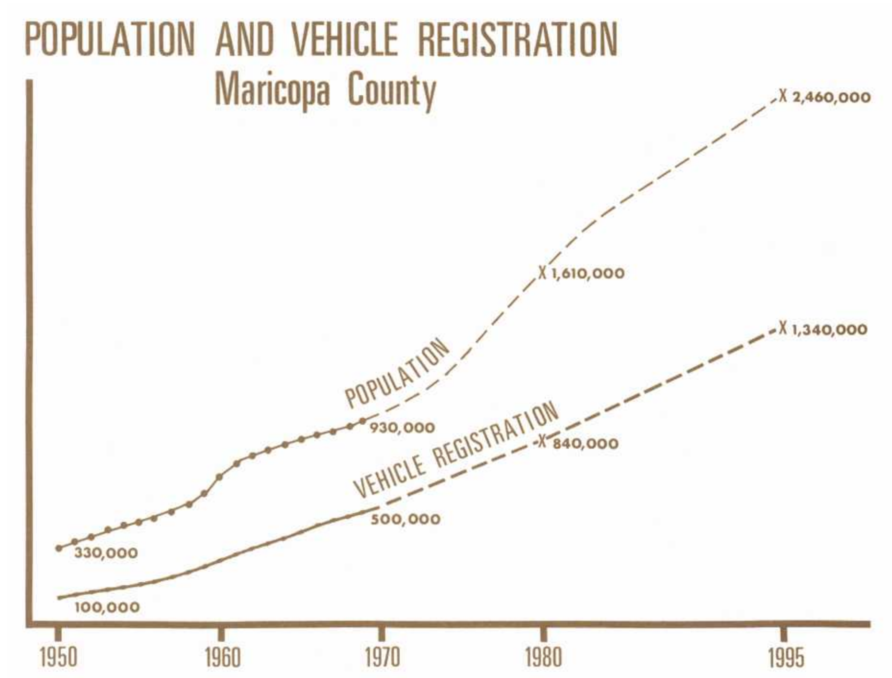
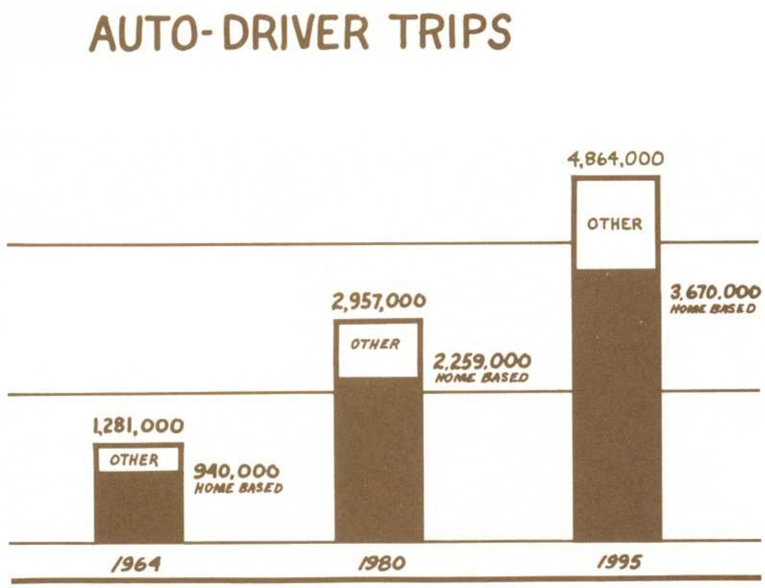


FIGURE 5

Source: Valley Area Traffic and Transportation Study (unpublished data).

urbanite does not travel only for the sake of travel. His travel represents a response to demands placed upon him in order that he may conduct those functions which are important to his social and economic well being. The individual will choose the mode, route, and the time which will best fit his needs and provide him with the greatest satisfaction or the least cost. Thus, it is the social and economic structure of an urban area which is of primary importance in determining the transportation demands and evaluating the feasibility of various alternatives to meet these demands. To a great extent, this social-economic structure is best reflected in land use patterns and intensities. These must be combined with the economic profile of the community since transportation does incur costs.

The willingness and ability to pay for increased urban transportation will vary with the level of real income. In general, individuals are willing to spend more for transportation (in terms of buying more transportation) as their income increases. With regard to intra-urban travel (travel within an urban area), there is probably some level at which an



AUTO-DRIVER TRIPS PER PERSON

1964	1.6
1980	1.8
1995	2.0

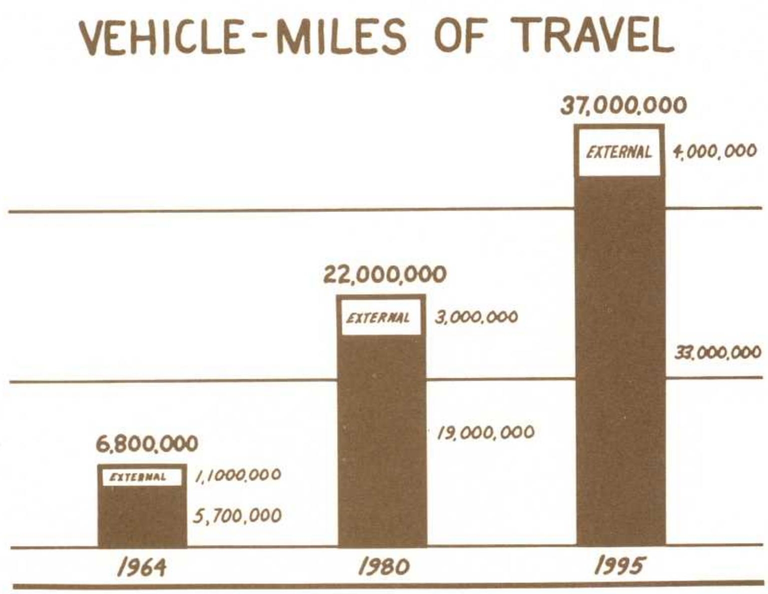


FIGURE 6

Source: Valley Area Traffic and Transportation Study (unpublished data).

increase in income will no longer produce a proportional increase in urban travel. The total transportation expenditures may continue to increase, but this will take the form of travel outside of the urban area (often recreational travel).

Residential land use is the most prevalent in the urban area. The home is the focal point of an individual's activities. The residential location represents the most probable beginning and ending point of urban travel during the normal 24-hour period. In addition, the home and the characteristics of the home including density, location, and car ownership are probably the best social-economic indicators of the demand for transportation.

Any trip may be defined as having an origin and destination. Within the urban area, the home represents either the origin or destination of the vast majority of all trips. These are often referred to as "home-based trips" and represent about 80 percent of all urban travel. If this seems high, it must be remembered that the vast majority of urban trips today are single purpose in nature. Thus, the typical trip is from home to work and, then, from work to home, or from home to a shopping center and immediately back home.

If one uses the usual definition and defines the purpose of a trip by the activity at the destination, then the normal distribution of trips by purpose would be as indicated in Table 1. These purposes include the home or residential purpose plus the more conventional activities categorized as work, shop, social-recreational, etc. As can be seen from the table, the work trip represents a substantial portion of the total urban transportation. It must be remembered that these are only the trips to work. For every trip to work within a 24-hour period, there is also a trip from work, most of which will be destined to the residential location. Thus, approximately 40 percent of urban travel is work oriented. (Some confusion may result in that similar comments may be made for all other purposes and this would seem to total 200 percent. This is not the case but stems from the fact that each trip has two ends – an origin and a destination.) It will be shown later that the work trip is extremely important for two reasons: 1) because of the timing of the trip, i.e., the time of day in which the trip is made and 2) because of the fact that most transit operations serve the work trip demand rather than others.

Table 2 indicates the normal distribution of land use in metropolitan areas. Comparisons of Tables 1 and 2 illustrate the importance of commercial and industrial activities. Twenty percent of the trips are destined to work locations, yet only 6.5 to 7 percent of total land area is industrial.

Even if the 2.5 to 3.5 percent devoted to commercial land use were included, this would still be significantly less than 20 percent and also would not include the 9 percent of business trips. A similar statement should be made for shopping trips which account for approximately 10 percent of total travel destined to approximately 3 percent of total land area. Thus, the intensity of generation of transportation demand varies with land use. This is what should be expected since there are underlying economies which lead to the concentration of people to achieve industrial and retail efficiencies.

TABLE 1
Typical Urban Trip Characteristics

Activity at Destination	Percent of Trips
House (Residential)	40%
Work	20%
Shop	10%
Social-Recreational	11%
Business	9%
School	3%
Miscellaneous	7%

TABLE 2
Typical Urban Land Use Characteristics

Land Use	Percent of Total Developed Land
Residential	37.0 - 43.0%
Commercial	2.5 - 3.5%
Industrial	6.5 - 7.5%
Railroad	4.0 - 5.0%
Streets	27.0 - 30.0%
Parks and Playgrounds	4.0 - 7.0%
Other	10.0 - 11.0%

Source: *Arizona Academy, Thirteenth Arizona Town Hall on Traffic and Highways,* Pages 50 and 52—August 1968.

The preceding generalization is valid, but it is important to realize that within any category (industrial, business, commercial) the intensity of activity may vary considerably. It is intensity that is the best measure of transport demand. Thus, indices such as retail area, retail sales, number of employees, etc., are commonly used in the evaluation of an individual location.

As previously indicated, the land use most important in determining the overall transportation demand is the residential area. This indicates the income level and, therefore, probable car ownership of the inhabitants. Generally, as income increases, the number of trips also increases. However, most of the increase occurs in non-work trips. Any family, with even moderate income where one or more of the individuals is employed, must use some form of urban transportation to reach the employment site and return. However, as disposable income increases, the number of work trips would not necessarily increase. Therefore, the increase in transportation usage is one of an increased number of shopping, recreational, social, and other trips. This is, normally, accompanied by an increase in car ownership.

Thus, there are two important points: first, that the work trip in urban areas will normally increase in proportion to the increase in population (the trip per capita figure being relatively constant), and second, that with increasing affluence, the number of non-work trips per capita will increase. Current transit systems are predominantly work-trip oriented, and, therefore, do not benefit from the increased demand for urban transportation due to increased income. In addition, there is substantial evidence which indicates that transit usage decreases rapidly with increased car ownership. Figure 7 indicates the increase in car ownership as a function of income.

These relationships need to be modified by two urban characteristics. The first is the existing public transportation system. Where a substantial

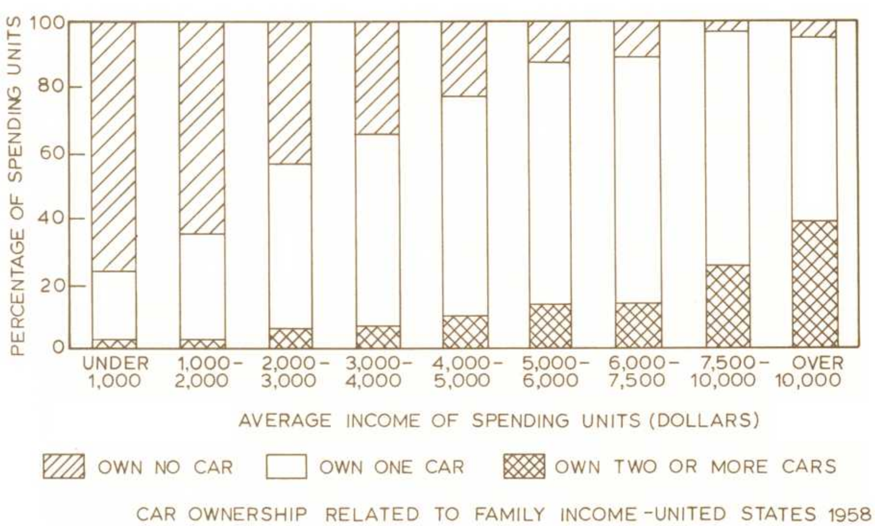


FIGURE 7

Source: Unpublished thesis of William E. Leonhard entitled *A Study of the Effects of Income on Trip Characteristics for Tucson, Arizona*, Arizona State University, June 1968.

public transport system is in existence, car ownership rates will be less for the lower income levels since these families will use transit for their urban mobility. In areas with minimal transit facilities, even very low income families tend to purchase an automobile though it may take a substantial portion of their income. Recently, studies of urban mobility and the poor have been conducted in areas without substantial transit operations. These indicate that although buses or other special transport provisions may help in locating a job, the newly employed, low income person soon becomes an automobile owner and forsakes the public transportation system. A basic unanswered question is whether this phenomenon is a reflection of the desires or psychological needs of the individual or a reflection of the fact that few transit systems can serve the total demand for transport in such cities.

The second major urban characteristic which affects the car ownership and income relationship is the availability of center-city, high-density residential units for medium- and high-income families. Where these are available, they have a lower car ownership rate than one would find in lower density residential areas. The reasons for this may be: 1) the expense of maintaining a multiple-car family (primarily, because of parking) and 2) the availability of taxis and/or public transportation to meet some of the travel demand.

In conclusion, it is vehicle ownership, social-economic status, and land use intensity which will normally account for the variation of trip-making to and from specific locations in an urban area.

There is obviously an additional trip characteristic which has an important impact on the transport system. This is the length of the trip. Since urban transportation planning basically concerns the planning of major systems (transit, freeways, and arterial streets), the length of the trip is an important factor. A short shopping trip may never leave the residential area and may, therefore, never appear on a freeway system or be susceptible to transit usage. This trip, then, becomes relatively unimportant in the evaluation of the total system. However, a long trip will have a substantial proportion of the total length on the freeway, arterial, or transit system. Thus, the longer the trip, the greater impact on the system. This is especially true if the trip occurs when the system is already overcrowded.

There is an important relationship between average trip length and trip purpose. This is illustrated in Figure 8. Trip length can be measured in either travel time or distance. The majority of planning studies use travel time as the better index.

As indicated in Figure 8, a high percentage of shopping trips are very short whereas work trips tend to be much longer. It is characteristic that work trips are the longest of all urban trips. This is expected since the individual is trying to optimize his economic position. Thus, in normal shopping, one will normally be destined for the closest retail location which provides the needed goods. If this is a loaf of bread, the trip may be quite short. If it is the week's groceries, it may be somewhat longer. If it is a very unusual shopping need, such as the purchase of a new automobile, the trip or trips may be longer than the average work trip.

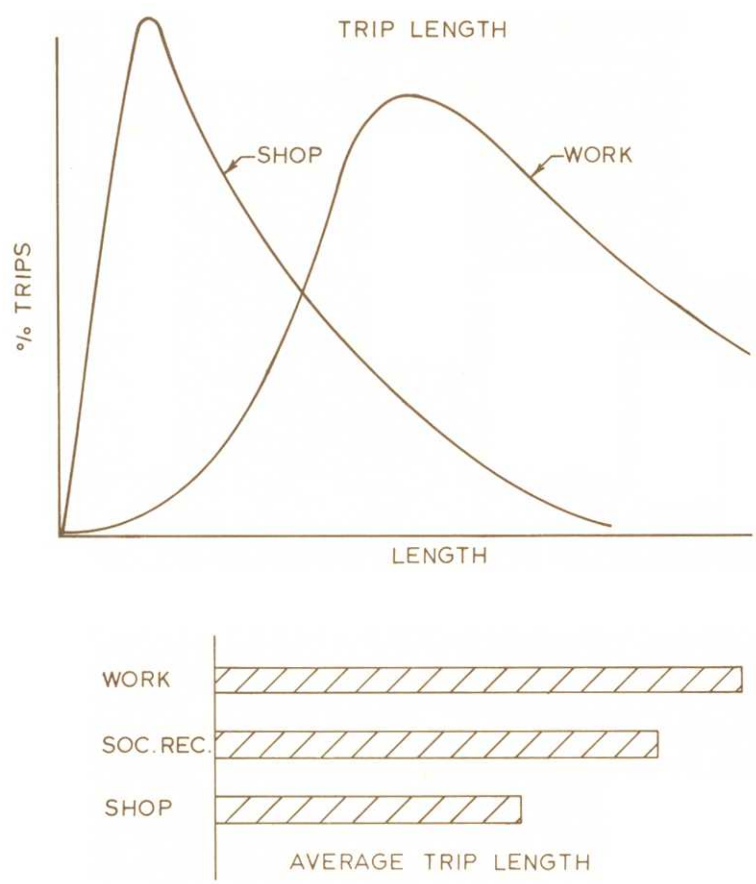


FIGURE 8

Variation of Trip Length by Purpose

Source: *Arizona Academy, Thirteenth Arizona Town Hall on Traffic and Highways,* Page 60–August 1968.

It is the work trip, however, which is of extreme importance. One does not necessarily accept the job which is located closest to his home since to do so would, normally, mean a loss of income over that which could be obtained from traveling somewhat farther. There have been theories that there should be a close relationship between place of residence and place of employment because of the regularity of the travel between the two. However, there is little to indicate that there is a relationship which would minimize transportation costs between the residential location and the work site. A desirable place to live and the job with the best working conditions and highest income are probably two of the most important factors in the life of the modern urbanite. In most cases, he will attempt to get the best conditions possible for both his home location and his work location, and will be willing to spend both time and money in transportation in order to commute between two locations. Therefore, it is not unexpected that the work trip is substantially longer than any other trip in the urban area.

One further characteristic of the trip length is its variation in urban areas of different sizes. It might be expected that as an urban area grows larger, the average trip length would increase substantially. This does not seem to be the case and, generally, there is a very slow growth of average trip length with an increase in population. Many urban trips (shopping, social-recreational, etc.) probably do not increase substantially as the metropolitan area grows. There may or may not be an increase in the length of the work trip depending on the concentration of employment locations within the urban area. This is a function of the characteristics of land use distribution within the area, and this point will be analyzed in a later chapter.

The Urban Transportation Problem — The Peak Hour

The preceding section has discussed the amount of transportation demand and how it varies. It may, truthfully, be stated that the urban transportation problem of today and probably 20 years from now is a problem which occurs two or three hours a day during two peak periods. It is the morning and evening peak period during which the transport facilities are heavily loaded which require improvement. The other 20 to 21 hours of the day find most urban areas with capacity that exceeds the transportation demand. Figure 9 indicates a typical variation of total transportation demand with time of day for the typical weekday. Two things can be seen from this figure: first, the intensity of the two peak periods, and, second, the fact that a substantial proportion of the peak periods are composed of work-oriented trips. The morning peak period rises more sharply and dissipates more quickly than the evening peak period. The morning may be either slightly higher or somewhat lower than the evening peak period depending on the amount and timing of school trips. If school trips are not considered, the morning peak-hour is usually somewhat less than the evening. (For planning purposes, the school trips may distort the overall picture because, although their number is substantial, their length is very short compared to other trips.) When school trips are not included, the work trips will, normally, exceed 70 percent of the peak period trips. The peak period congestion is even more acute than indicated in Figure 9 because of the greater length of the work trip.

The peaking characteristics of transit are even more extreme than for total travel. Figure 10 presents a typical variation in transit trips by time of day. It is not unusual for a transit peak-hour to contain from 15 to 20 percent of the total daily transit trips. This leads to even greater relative inactivity during the off-peak period. Coupled with this is the fact that the use of transit during the weekend falls to a very low level. Thus, transit operators currently have to provide very high capacities for a period which seldom exceeds 15 to 20 hours per week. At other times, because of franchise or other legal commitments, they must provide service during periods which produce few revenue passengers. To understand the difficulty in operating under these conditions, one need only to imagine the economic disadvantages to a factory which would produce a product on a 15-hour-a-week basis. This, in very simple terms, is a fundamental reason behind the shift from private to public transit ownership during the last 25 years.

The transit peak-hours, besides being more pronounced than that for total travel, are even more heavily oriented toward the work trip. They are composed almost solely of work or school trips. It is interesting to note that the evening peak period of transit falls off almost as fast as the morning peak and does not have the gradual decline indicated for total travel. This gradual decline in the later evening hours is a reflection of social, recreational, and possible shopping travel which, currently, is not using transit.

Although it is somewhat difficult to see on the two figures, the morning work peak usually precedes the school trip peak. At 7:00 A.M., approximately 75 percent of the person trips are work oriented and

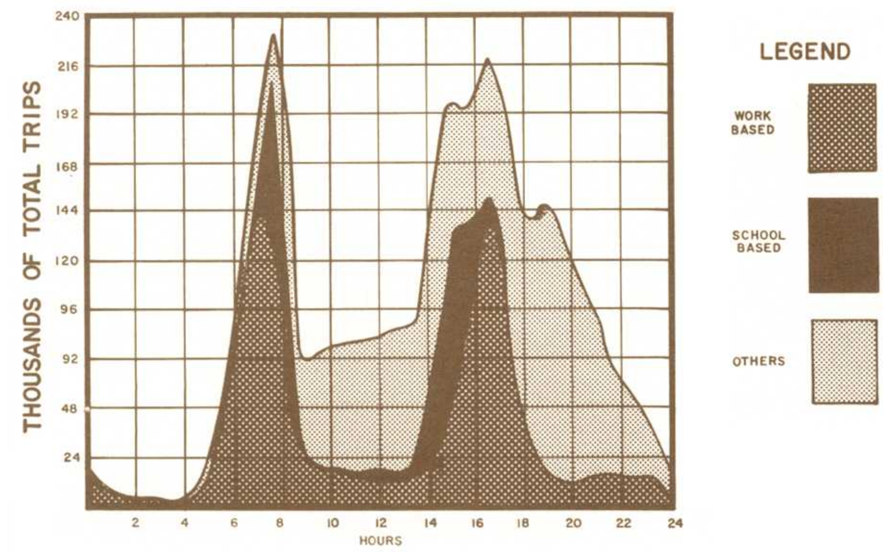


FIGURE 9

Total Person Trips in Motion

Source: Peat, Marwick, Livingston & Co., *Evaluation of a Bus Transit System in a Selected Urban Area*.–Page 8.

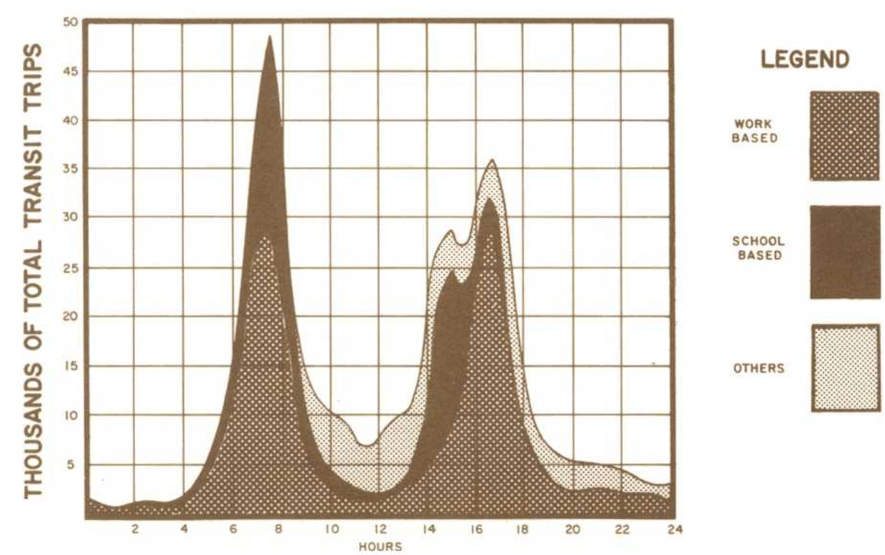


FIGURE 10

Total Transit Trips in Person

Source: Peat, Marwick, Livingston & Co., *Evaluation of a Bus Transit System in a Selected Urban Area*–Page 9.

approximately 20 percent are school oriented. By 8:00 A.M., only about 50 percent of the trips are destined to work and 45 percent are school trips. A similar case exists for transit. The use of commercial buses for the movement of school children would be beneficial to transit operators and save school districts substantial capital investment in buses which are used only a few hours per week. This would probably be possible if one or more of the following could be accomplished: a slight shifting of morning school starting times (so it would not occur at peak), greater ability for transit operators to use split shifts, and the willingness for school districts to find some other way to supplement teachers' salaries (other than as bus drivers).

In conclusion, it is the combination of timing, purpose, and length of urban trips which cause the urban transportation problem. It is the fact that trips are not evenly distributed throughout the day but are concentrated in two periods which overloads the system. That the trips involved also happened to be the longer trips accentuates the problem. The situation for transit is even more acute. It is suggested that a rational attack on the problem would be a more specific analysis of the peak periods than is normally conducted. It is questionable whether the transportation planner need be overly concerned with those trips which occur during the off-peak hours. Thus, the normal procedure of looking at all trips and determining peak-hour factors may be somewhat in error. It might be suggested that an analysis of only the work trip might be easier and more accurate. This may be modified, somewhat, by the fact that much of the growth in urban travel will be growth of off-peak trips. With increasing affluence, it is expected that the peaking characteristics will continue to be modified. Nonetheless, there is no indication that the peaks will not retain their importance.

The Structure of a Trip
(The Skeleton)

In order to further understand the urban trip and to identify the functional advantages and disadvantages of various modes of transportation, it is useful to develop a conceptual framework which will identify the parts of the trip. One method is to divide the trip into four basic components. These are the collection, distribution, line haul, and transfer functions. This is shown, graphically, in Figure 11.

The advantage of this system is that it does indicate functional difficulties and it is also flexible in the sense that virtually any trip (or even a part thereof) can be analyzed. For example, considering a trip from one urban area to another, the collection and distribution would be the ground transportation, the line haul might be the air transportation component and, finally, the transfer would occur at the airport terminals. Further, the ground segment of either end of this trip could in itself be analyzed on the same basis. The individual may have been driven to a central city terminal, taken from there by bus to the airport terminal. In this case, the auto trip from his home to the downtown terminal would be a collection function, the terminal itself a transfer point, the bus trip to the central airport terminal the line haul function, and the distribution would be the processing through the airline terminal. Its application to the more typical urban trip, be it auto or transit, is illustrated in Figure 11.

This concept is also instructive in identifying those portions of the trip which have been improved by advanced technology and those portions of the trip which are most unpopular with the user. Modern technology, as is applied to transportation systems, has increased the speed, efficiency, and capacity of the line haul function. This is true in regional transportation as well as intra-urban transportation. Furthermore, most of the advanced concepts which will be discussed in a later chapter are those which improve in speed or capacity in line haul function. Although an improvement of the line haul function does improve the efficiency of the overall trip, there may very well be a point of diminishing returns with regard to the improvement of this component and the neglect of others. This is currently being realized by the regional and international air transport industry and may be indirectly realized by urban transport users when they make decisions regarding mode.

Improvements in the collection and distribution function have been fewer. These, essentially, use the same technology and the two terms only indicate a difference in direction for a particular trip. The term "flexibility" is often applied to urban transportation. One definition of flexibility is the ability to move the individual from a collection, to a line haul, and back to a distribution function without interfering with the individual and his immediate surroundings. Of the popular forms of urban transportation, the automobile has the greatest flexibility. However, there are possibilities of developing new forms of transportation which will have these capabilities. These will be defined in the next section and further described in the next chapter.

The most difficult portion of the trip to improve through technology

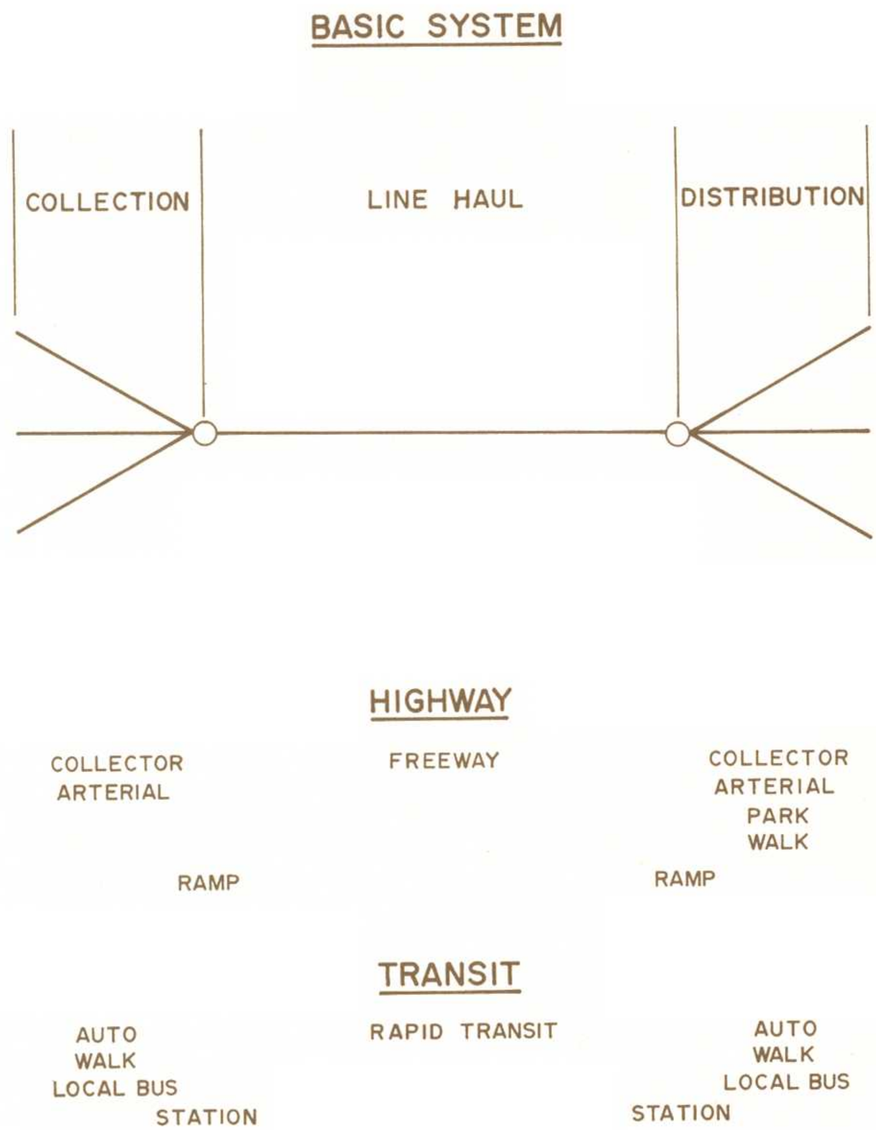


FIGURE 11

Basic Structure of a Trip

Source: *Arizona Academy, Thirteenth Arizona Town Hall on Traffic and Highways*, Page 74–August 1968.

and one to which the user is sensitive, is the transfer point. In many cases, the improvement of the transfer situation often resolves itself into problems of management and scheduling rather than into engineering hardware. In transit trips, the transfer points are the terminals, stations, or bus pickup points. These have long been realized as being major stumbling blocks in the development of efficient and attractive transit. The effect of delays and the need to move from one container and environment to another will be discussed in the section on the non-economic characteristics. All that needs to be indicated here is the fact that the characteristics of the transfer point, although not economically measurable, are often (possibly most often) the deciding factor in the individual's modal choice.

If the transfer point is the most critical and most difficult to improve in regional transportation and urban transit, then it seems reasonable that the same might be true for the auto trip. In the automotive trip, it is the freeway interchange and the immediately adjacent area which represents the transfer point. Recently, more attention has been given to the fact that it is necessary to control the flow of traffic at the interchanges. Several recommendations have been proposed concerning the metering of on-ramp traffic or even the closure of certain ramps at specific times in order to improve the overall system.

Another phenomenon in the interchange area which has not been fully appreciated is the effect on the arterial street system. Prior to the construction of freeways, the arterial streets performed a line haul function, and, therefore, traffic volumes were fairly continuous along the route. If an arterial street extended from one side of the urban area to another, there was a gradual buildup of traffic as it approached the more central area. This would be typical of the current traffic volumes on streets such as Camelback and Indian School Roads. When a freeway is built and, certainly, when an entire system of freeways is built, the arterial street radically changes its function from line haul to collection and distribution. Traffic volumes will be very intense in and around the interchange area, but they may be less at some distance from the interchange than they were prior to freeway construction. The constant buildup of traffic on the arterial gives way to a much more intense variation of traffic increasing rapidly as one approaches a freeway interchange, decreasing as one moves away from it, and, then, again increasing as a second freeway is approached, etc. Besides the engineering effects, this produces secondary economic effects with regard to the economic desirability of various locations along the arterial. It also illustrates the fact that in planning, great care should be taken to protect the interchange area from those developments which would aggravate the already intense transportation demands there.

Both the relative and absolute length of the various portions of the trip (the line haul, collection, and distribution) are of importance when evaluating possible transport modes. The possible combinations are indicated in Figure 12. These include the following cases: 1) where the collection and distribution are relatively short compared to the line haul, 2) where one of the two (collection or distribution) is relatively short and the other is longer and 3) where both collection and distribution are relatively long with regard to line haul.

In all cases where the line haul portion is short in absolute terms (either in distance or time), the total trip is usually short and will lend itself to some form of local and very flexible transportation. As previously indicated, the short trips are not particularly significant when analyzing the overall system. Currently, such trips are made either by foot or automobile, although there is the possibility of using some type of mini-transit as described in the next section. There would almost never be a large enough accumulation of short trips in any one part of an urban area to justify a high capacity system.

Thus, for large system evaluation, it is the three combinations of the longer trips which are of interest. Where the line haul portion is of considerable length, trips from many areas may combine requiring a relatively high capacity system.

In the first alternative, a long line haul with a very short collection and distribution could be satisfied by a fixed rail transit facility where the collection and distribution is normally accomplished by walking or, possibly, some form of mini-transit. Such demand would normally require high-intensity land use development at the origin and destination.

The second type would be typical of the situation of many of the larger and older urban areas which have retained some high-intensity locations and combine these with newer low-density developments. Thus, the shorter end might typically be accomplished by walking, the line haul either by automobile, transit, or commuter railroad. The longer collection or distribution end would normally involve an automobile where park-and-ride or kiss-and-ride would be used if the line haul were

Alternate Arrangements of Trip Types

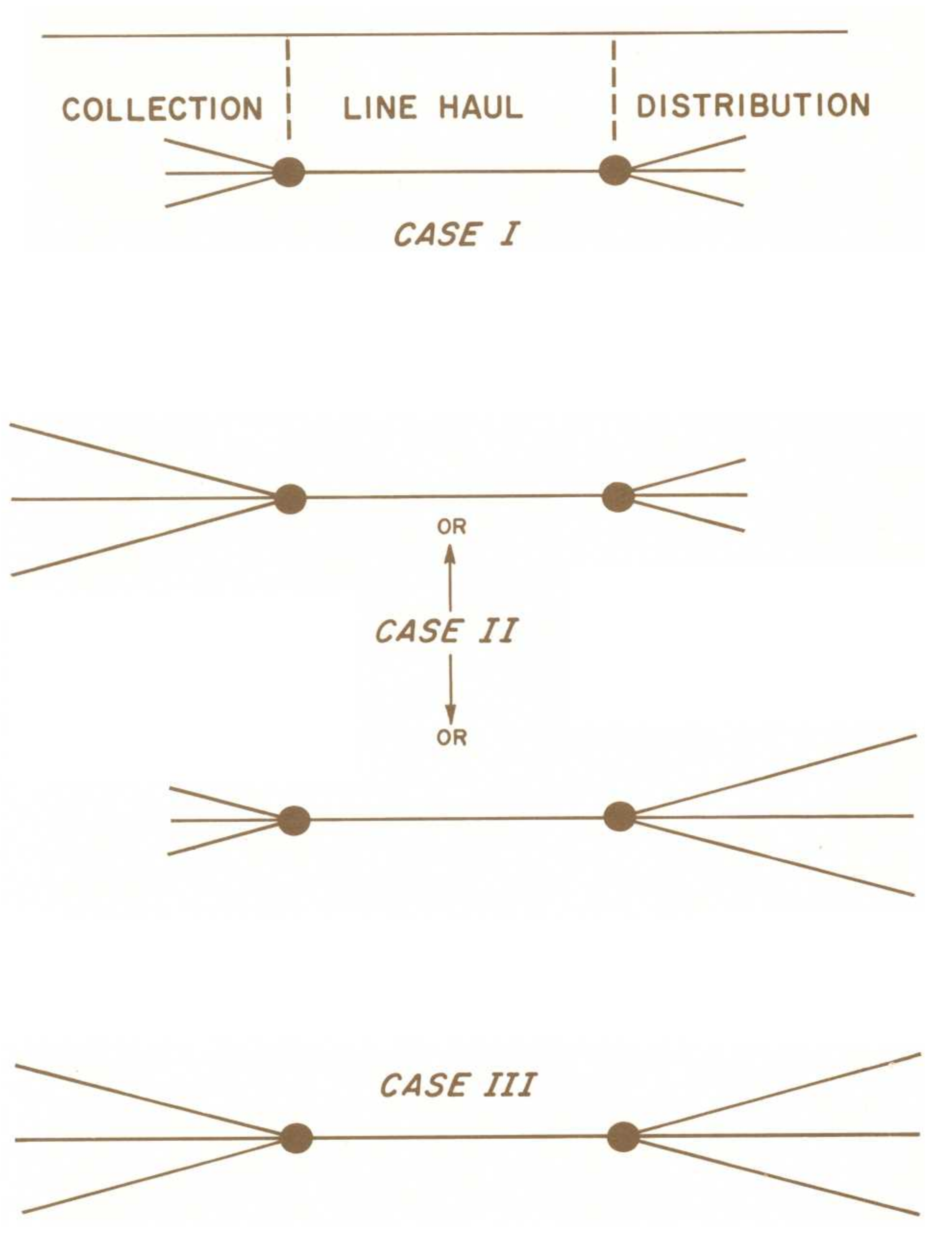


FIGURE 12

transit or railroad. No single form of transportation, which does not require a physical transfer of the traveler from one transportation container to the other, has yet been implemented to efficiently solve this type of problem. The bi-modal forms of transportation described later might or might not be able to meet such a demand. The automobile has storage and other problems at the high density end.

The third alternative is typical of the dispersed urban areas. It is the type of trip which is most efficiently met by automotive transportation; although in the future, it might be equally well fulfilled by other individual or bi-modal systems.

It must be emphasized that the conditions at the transfer point are probably the most important and most difficult to improve. The preceding is meant only to illustrate the abilities of certain general types of transport to meet certain types of demands. In general, the first case can use technology which provides high-speed, high-capacity line haul but may have relatively slow or inefficient collection distribution systems. The third case may allow some decrease in efficiency of the line haul function but requires a more efficient and, probably, faster collection and distribution system. The second set of conditions often is the most difficult and has all of the problems of the first, plus the problems of the third, and no real inherent technological advantages which would tend to balance these.

A Continuous Spectrum

Innovations over the last decade have broadened the choice of transit systems into a continuous spectrum. Recognizing the wide range of this spectrum, transit systems can be grouped according to four major classifications: 1) Rapid Transit, 2) Highway Compatible Systems, 3) Individualized Transport and 4) "Non-Stop" Transit Systems.

Rapid Transit service is, primarily, provided by rail-guided, multiple-seated vehicles operating on exclusive right-of-way without interference from other traffic or pedestrians, usually at speeds above 30 mph, with stops normally spaced one mile or more apart.

Multiple-seated vehicle systems which normally operate on city streets, expressways, and freeways but may be capable of operation on exclusive right-of-way are classified as Highway Compatible Systems.

These vehicles are usually subject to interference by other users of the streets and, generally, operate with frequent stops at speeds of approximately 15 mph.

Individualized Transport includes those types of transport seating six or less passengers. Operation may be similar to either Rapid Transit or Highway Compatible Systems. A system may incorporate one or more modes of guidance and propulsion. Individualized Transport and "Non-Stop" Transit Systems are similar to Rapid Transit when operation is on exclusive right-of-way and to Highway Compatible Systems when on streets and highways.

"Non-Stop" Transit Systems may be similar to Individualized Transport, but the individual units are combined with other units during the trip. These combined units move continuously and do not stop.

The continuous spectrum concept of transit also applies to the available range of propulsion systems, guideway methods, and amount of capital investment.

In the past, particular guideway systems have often been directly related to a particular propulsion system. However, fixed rail systems can use any type of propulsion but most often use DC electrification. The linear electric motor, AC electrification, and gravity-vacuum propulsion are potential future fixed rail power sources. The internal combustion engine has been the major power source for the other systems including the national railroad system. A major research effort is currently underway to develop a non-polluting power source. Batteries, fuel cells, mechanical flywheels, and steam engines are some areas of development. Experimentation also is being conducted using hybrid engines combining several of the above.

A brief discussion of the propulsion systems with emphasis on their state of utilization, application, flexibility, and pollutant emissions follows.

Conventional Propulsion Systems

The internal combustion engine is adaptable to diesel, gasoline, or liquid petroleum gas. The fuel ignition produces high pressure which forces the piston down, producing the mechanical energy to propel the vehicle.

The gasoline internal combustion engine is the major source of air pollution in the transportation industry. It was estimated that 3,000 pounds of carbon monoxide, 200 to 400 pounds of hydrocarbons, 50 to 150 pounds of nitrogen oxides, 5 pounds of aldehydes, 5 to 10 pounds of sulfur compounds, 2 pounds of organic acid, 2 pounds of ammonia, and 0.3 pounds of solids are discharged for every 1,000 gallons of gasoline consumed in 1961. Compared to a gasoline engine, a diesel engine emits one-half to one-fifth the amount of carbon monoxide and hydrogen compounds. Liquid petroleum gas engines are the lowest emitters of these contaminants; however, widespread transportation use of this fuel is unfeasible at this time because of the present limited supply and bulk hauling difficulties.[2]

Pollution control devices are being installed on most gasoline engines to reduce the amount of contaminants emitted. Development will continue in pollution control devices, fuel composition, and alternate combustion processes. However, due to the increasing numbers of personal vehicles in large metropolitan areas, these lower levels of emission may not be tolerable in a few years.

Most urban transit systems which operate on rails are propelled by on-board electric motors. The power is transmitted to the vehicle's motors by an overhead wire system or a third rail. DC motors are most often used in these systems. The San Francisco Bay Area Rapid Transit (BART) tested both DC and three-phase AC third-rail propulsion systems and found no major cost advantages or performance differences and selected the DC system.[3]

"Clear Blue Sky" Propulsion Systems

Low-pollution propulsion systems in the development or conceptual stage include fuel cells, batteries, thermo electric generators, thermionic generators, solar cells, gravity-vacuum, linear electric motors, mechanical flywheels, external combustion engines, gas turbines, and hybrid engines. The most promising of these systems will be discussed in this section. The propulsion systems which dominate the present transportation picture were relatively unknown in the early 1900's, and their present importance would not have been predicted by many, if any, at that time.

In an external combustion engine, the working fluid is converted to a vapor which drives the pistons or turbines for propulsion. The steam locomotive is an example of such a system. General Motors is testing an experimental external combustion vehicle. Its working fluid may be either helium or hydrogen and requires expensive materials because of the high operating temperatures and pressures. Lear Company recently abandoned its estimated $10-million research effort to produce a steam car.[4] A two-year Federally sponsored demonstration project is now being conducted in San Francisco and will test and evaluate steam engine buses.[5]

The battery which must be recharged and fuel cell which must be refueled are both potentials for small vehicle propulsion. Battery-powered vehicles are limited in range and speed; however, experimental high-energy-density batteries may improve these characteristics. Fuel cells provide for the direct chemical conversion of fuel into electric power. The fuel cells with the greatest promise at this time, are expensive to produce and use expensive fuels.

The mechanical flywheel energy storage method involves the acceleration of flywheels from an external electrical source. It has been used in European and Japanese bus systems where the flywheels are accelerated at stops from overhead electric power.[6] Smaller flywheels with greater energy storage capacity are needed.

The primary use of gas turbines for land transportation has been in freight locomotives. Small gas turbines are being studied and tested in rail passenger transportation and in its application to personal vehicles. Its major undesirable characteristic is its high fuel consumption at light loads and during idling. The main advantages of the gas turbine are its low emissions of hydrocarbons and carbon monoxide and its efficient movement of heavy loads.

Development on the linear electric motor has occurred during the last several decades. It appears to have a good potential for use in urban high-speed ground transportation. A rotary motor cut parallel to its axis and laid out flat with the rotor replaced by a flat shuttle constitutes the basic linear electric motor concept. Either the primary or secondary portion of the motor can be placed on the vehicle. However, because of economic considerations, the primary portion – the powered assembly – is generally conceived as being on the vehicle. Power to the motor can be supplied by on-board engines in this arrangement. Placement of the primary on the guideway with electricity supplied directly would reduce the weight and cost of each vehicle. The main application appears to be in propelling air suspension vehicles. This has the advantage of having no power loss or weight added through the use of gears; also, the thrust is not dependent on tractive friction.

The use of gravity or the use of differential air pressures to propel a vehicle has been known for many years. The combined use of differential air pressure for initial acceleration and the use of gravity to accelerate and decelerate a vehicle (similar to a roller coaster) has been proposed for urban transportation. The unique characteristic of this system is a natural acceleration which the passengers do not feel, thereby permitting high average speed. The maximum speed the vehicle would reach depends, primarily, on the depth below the starting elevation. A depth of 21 feet has been proposed for one-fourth-mile station spacing. At this depth, a maximum speed of 49 mph is anticipated. With spacings three or more miles apart and a depth of 900 feet, estimated maximum speeds are in excess of 200 mph. The elapsed time between stations is, primarily, dependent on the slope and ranges from 32 seconds with one-fourth mile spacing to 96 seconds with a three-mile spacing. A three-foot model was tested in California and traveled a 300-foot section in 1.2 seconds. The Department of Transportation is currently reviewing a proposed $10 million full-scale demonstration project.[7]

Design for hybrid propulsion systems combining more than one propulsion method have, generally, involved two basic concepts. The first is the utilization of one form of propulsion while off a guideway and another while on the guideway – for example, a battery-powered vehicle off a guideway which is externally powered electrically while on a guideway. In this combination, the recharging of batteries while on the guideway may be practical.

The other type of hybrid design involves the combination of propulsion systems. The intra-city bus, for example, has operating characteristics requiring large amounts of power for brief periods during acceleration and much smaller demands while cruising, decelerating, and waiting. To provide for such demands, it has been suggested that a vehicle could use a smaller, continuously running, internal combustion engine which would be aided by electric motors when power demands are required. These motors would be powered from batteries which, in turn, would be charged by the engine when the power demands were lower.

Guideways and Capital Investment

The term "guideway" relates to the fixed facilities which guide or help to guide the direction of the vehicle. Streets are guideways since they guide and support moving vehicles.

Operation of transit vehicles on existing streets virtually eliminate the capital investment in guideways. The vehicles could range from a small transit vehicle costing several thousand dollars to larger capacity vehicles ranging from $20 to $70 thousand each. Such a system is flexible, permitting changes in routing at minimal expense. Local and express service can operate on the same routes since passing opportunities are provided. Exclusive lanes can be provided at any time.

Another major guideway concept uses rails to provide exclusive route operation and automatic vehicle guidance independent of the operator. The vehicle can be either supported, suspended, or merely guided utilizing one or more rails. Two rail-supported systems have dominated high-speed transit operations, and are adaptable for construction above and below ground as well as at ground level. Underground construction minimizes the need for outright purchase of right-of-way, but construction costs of $10 million per mile and station costs of $2 million each are not uncommon. At-grade construction costs range from $1 to $3 million per mile and $500 thousand per station, but land must be provided for right-of-way and, as well, grade separation from other transport modes. The use of freeway medians is an economic approach to some of these problems. Elevated construction requires little land acquisition if located above city streets; generally, this has been considered as having an adverse aesthetic impact. Construction costs range from $2 to $5 million per mile, plus about $500 thousand per station. A combination of these three is possible. The main disadvantage of these types of transit guideways is their initial capital cost, long period of planning and construction prior to utilization of the facility, and limited location flexibility. Location flexibility is provided by addition or deletion of guideway mileage or stations.

Other combinations of guideways deviate from the conventional steel-on-steel rail systems by using rubber on wood or rubber on concrete. Many of these systems incorporate rails in an auxiliary role or for guidance purposes only. The utilization of rubber wheel vehicles allows for potential operation on city streets as well as on exclusive right-of-way and decreases the noise level.

Cables and conveyor systems have bad a small role in transit. They have been, primarily, used for short distances and at low speeds.

The air suspension vehicle, which has been used mainly in water transportation, is undergoing tests for potential high-speed ground transportation. Vehicle stability at very high speeds is the main advantage of this method of vehicle support.

CHAPTER II

Conventional Transit

Public land transportation in the United States began with the stage wagon and coach era of the 1770's. Prior transportation (foot, horse, and horse-carriage) continued to dominate with the six-passenger public vehicle used by the wealthy. The city dweller was not provided with this form of local public transportation until 1829, but its acceptance resulted in rapid growth. The horse-drawn street car began to compete with the coaches in the 1850's, and by 1880, there were over 18,000 street cars running over 3,000 miles of track in this country. These forerunners to the motor bus and rail transit operated until 1917. The horse-drawn vehicle was displaced by the cable car and the electric street railway. The cable car began in San Francisco in 1873, and by 1890, the U. S. had over 5,000 cable cars which carried 4 million passengers a year. The cars held 12 to 38 passengers and traveled 12 to 14 miles per hour in outlying areas. Downtown travel was 6 to 8 miles per hour. Operational cable cars were seldom seen outside of San Francisco after 1906.[8]

The electric railroad, utilizing overhead lines, began operation during 1888 in Richmond, Virginia. Use of the trolley spread to many cities in the 1890's using both elevated and subway systems as well as surface lines. Pay-as-you-enter cars eliminated conductors just as today's automatic ticketing and computerized billing hold promise for the future. The ten-cent fare was reduced to five cents for peak hour. This was followed by off-peak reduced fares for school children.

There were other milestones during the late 1800's and early 1900's.

Notably, there were the unsuccessful experiments with battery-powered cars and underground electric third rails in 1857. The railroad which developed into the major inter-urban passenger vehicle of the early 1900's also served many intra-city trips.

The motor bus system may have developed from the 1914 Los Angeles jitney service. Automobile drivers were paid five cents by the riders they picked up. Converted automobiles were used as buses as early as 1905. The first motor bus was available in 1920. Soon after, the motor bus and trackless trolley bus replaced many street railway systems as well as most cable cars.

The automobile era began with four vehicles in 1895 and grew to 3.5 million in 20 years. Its role is dominant in U. S. transportation today. The idea of a personal family vehicle as envisioned as America's dream by an 1841 Act of Congress is approaching reality. However, it is not the horse and buggy of that era. More than one trillion vehicle miles will be traveled by 100 million motor vehicles over the 3.7 million miles of roads and streets in the U. S. in this year. The dream is a reality for all but a few: the young, the old, the poor, and the physically handicapped. These are not the only users of public transportation. They do, however, represent a substantial majority of the users of many public transportation facilities today. In large metropolitan areas with strong central business districts, a higher proportion use transit by choice; however, this is, in part, due to the deficiency of automobile facilities.[9]

Figure 9 indicates the trend in transit patronage since 1920. The peak in patronage occurred in 1945. The 23 billion passengers in that year has since decreased to about 8 billion per year. Operating income has, correspondingly, decreased, and in 1967, the industry operated a deficit of $66 million.

The diversion of riders from mass transportation is no longer rapid; in fact, transit patronage has stabilized at about 8 billion for the last several years. However, the comfort, convenience, and relative speed advantages of the automobile, increased public expenditures for urban freeway systems, and dispersion of urban economic activity still exist and the relative role of transit diminishes daily.

Rapid transit (that operating on exclusive right-of-way) is the only form of public transportation which has not had either a rapid growth or decline in patronage. It exists in only a limited number of cities and there have been no major systems completed since the end of World War II. Cleveland, Philadelphia, and San Francisco will be major tests in determining the future of this form of transportation. Cleveland has just completed an $18 million, four-mile line connecting the airport and the city's center. This is the first rail line in the United States connecting a major city with its airport.[10] San Francisco's 75-mile Bay Area Rapid Transit will be discussed, in detail, in Chapter 3. However, several important generalizations concerning large scale, new rapid transit systems can be made here. Rapid transit cannot be financed out of operating revenue. BART's plan is for operating revenue to offset only the cost of the rolling stock and yearly operating and maintenance costs.[11] Unlike San Francisco, general obligation bonds to help finance rapid transit have been defeated by the voters in Atlanta, Seattle, and Los Angeles.[12] Secondly, it is a long time before a rapid transit system begins operation. In San Francisco, it will take in excess of 15 years of considerable planning, persuasive action, and construction.

As previously indicated, transit has a major peak-hour problem. Transit, today, has very little weekend and night utilization. The peak-hour volume has ranged as high as 22 percent of total daily usage in Cleveland.[13] These high transit peaks require additional rolling stock which otherwise would not be needed if transit usage were more evenly distributed throughout the day. It is estimated that the peak-hour volume requires about four times as much equipment as can be operated productively at other times of the day.

These disadvantages of transit should not lead to an automatic rejection of new public transportation. Today, there are an estimated 15 to 18 million people who are dependent on its service. The main advantage of most transit operations is its potential capacity. However, any new system must compete with the automobile for patronage.

Transit will continue to serve the line haul portion of many trips. A major diversion to existing systems, however, is questionable or, at best, has only a slight possibility. Free public transportation would probably stimulate usage, but, because of the complex origin and destination patterns of the modern city, it would probably attract only a relatively small percentage of the total trips. A change in both public and private vehicular transportation technology is the long-range opportunity. A transportation system with the line haul capacity and speed of rapid transit used by all transportation vehicles, would be such a change – for example, vehicles utilizing both existing streets and freeway networks for collection and distribution of trips coupled with an automatically controlled line haul facility. The introduction of freeways realizes some of this improvement for personal vehicles and bus transit operations.

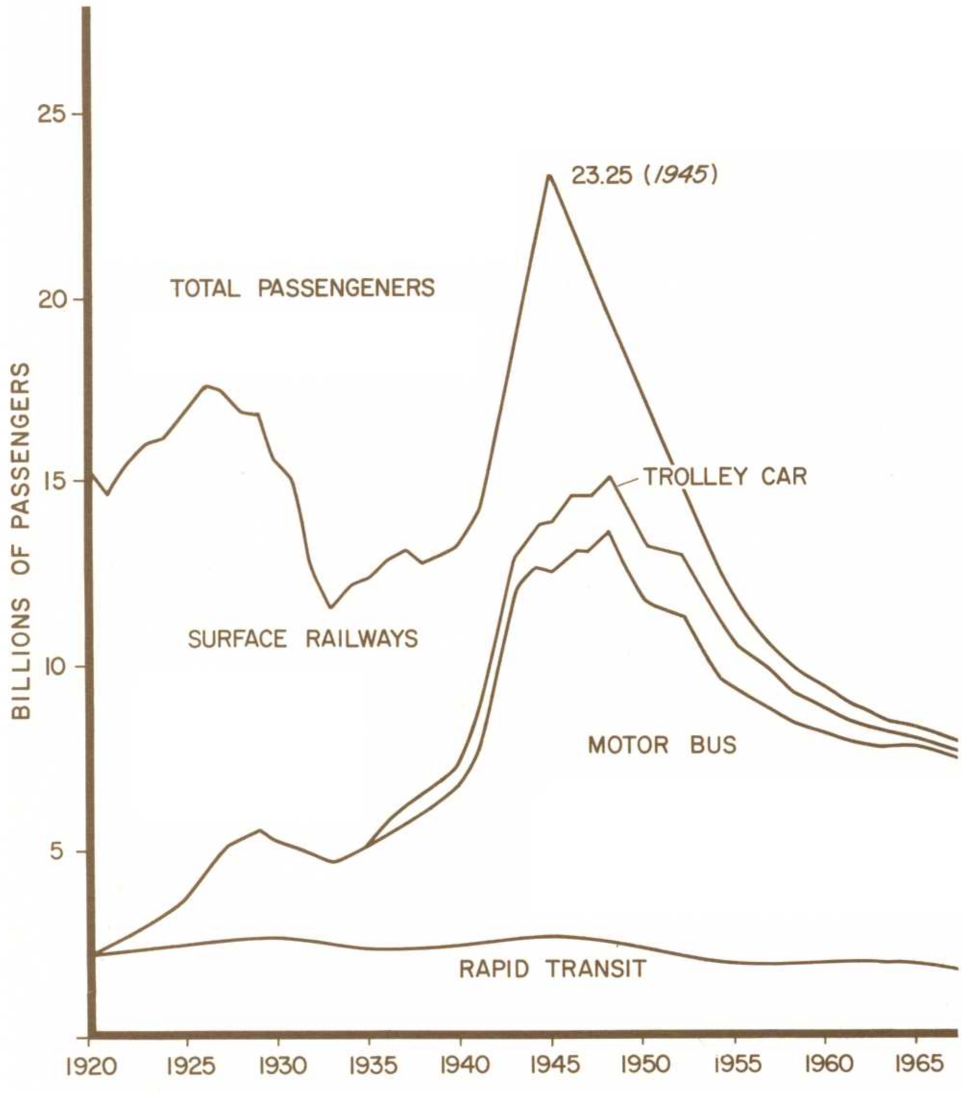


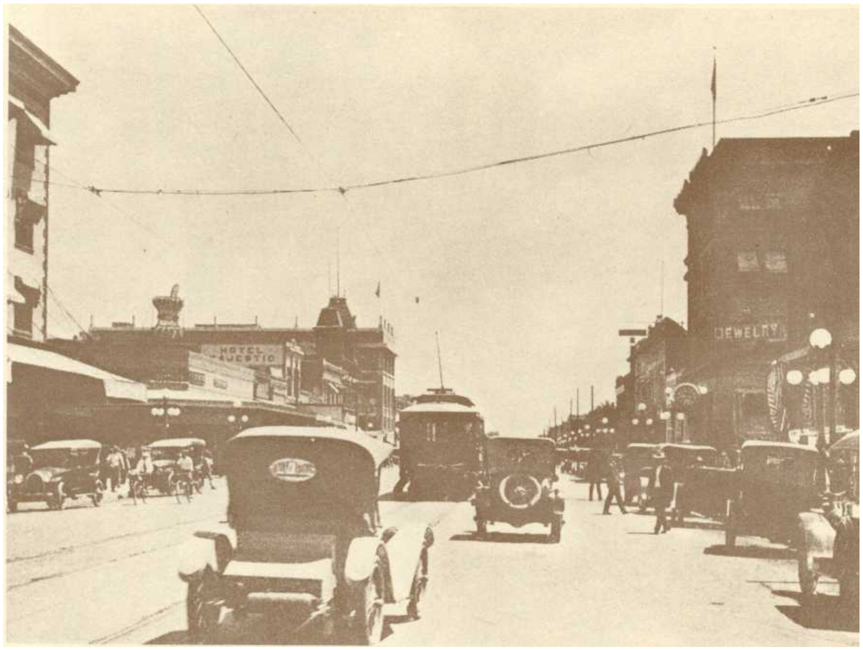
FIGURE 13

Trends in Yearly Transit Patronage

Sources: *1968 Transit Fact Book*, American Transit Association.
Future Highways and Urban Growth, Wilbur Smith and Associates, 1961.

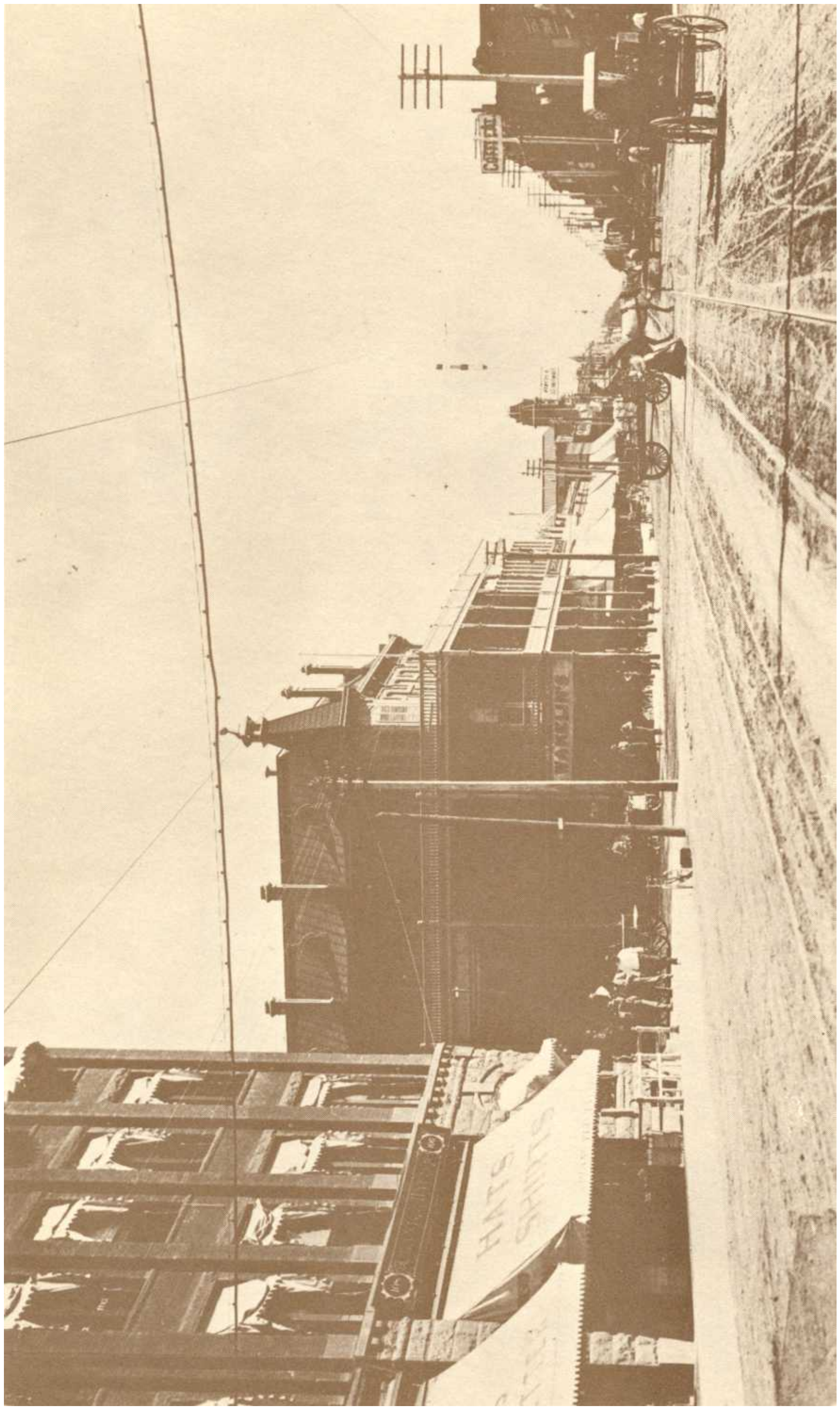
Phoenix Courthouse and Plaza – Late 1890's
Courtesy State of Arizona Department of Library and Archives

Phoenix Area Transportation Systems – Pre-Statehood
Courtesy State of Arizona Department of Library and Archives



Early-Day Washington Street
Courtesy State of Arizona Department of Library and Archives

Washington Street Looking West from First Street, About 1905
Courtesy State of Arizona Department of Library and Archives



Early Phoenix Scene
Courtesy State of Arizona Department of Library and Archives

New systems incorporating this dual mode flexibility and potential are in the planning stage and range from adaption of the automobile to a newly designed "personal" vehicle. The main common denominator of these proposals is a high capacity line haul facility adapted to individualized collection and distribution.

In 1980, based on present trends, there will be 250 million people in the U. S. traveling 800 billion urban miles.[14] The composition of urban land use in 1980, if the same as present, will have about 30 percent of the total developed land used for streets, freeways, and other transportation. The central business districts of today's large cities like Chicago, Detroit, and Minneapolis have about half of their total area devoted to the movement and storage of automobiles. In Los Angeles, it is approaching two-thirds.

A detailed examination of urban form as it has historically related to transportation technology, is presented in Chapter 6.

Phoenix's Transit

Horse-drawn cars marked the beginning of transit in Phoenix in 1887. The system grew to a five-car operation with eight miles of track in 1892. Electric railway cars replaced the horse car system by 1895. Fire, unprofitable expansion, and organized labor led to purchase by the City in 1925 for $20,000. This completed the first of three cycles of public-private ownership of Phoenix transit systems.

Rebuilding of the system was financed by a $750,000 bond issue, and in 1928, the first of 18 street cars began operation. The City system expanded to 17 street cars and 23 buses by 1941.

Private operation in 1935 provided bus service to Tempe and Mesa.

In the early 1940's, the City began converting street car lines to bus operation. A fire also curtailed the City street car operation, destroying all but six cars which remained on one line until 1948 when the line was converted to bus operation.

In the 1950's, the private line then operating within the extended limits of the City of Phoenix, changed ownership twice and, eventually, purchased the City system providing an integrated service for the entire City.

In 1966, the ownership transferred to the Phoenix Transit Corporation, a subsidiary of Chromallory American. Local service is presently provided in Phoenix, Scottsdale, and Glendale. Sun Valley Busline operates between Phoenix, Tempe, and Mesa. Greyhound Busline provides a similar service to the communities to the southwest of Phoenix. A jitney service operated on the Arizona State University campus for several years, but financial problems resulted in its closure in 1969.

The historical trend of the Phoenix Transit Corporation has been a steady decline in revenue passengers and passenger revenue. Other sources of revenue, including charter service and advertising, have been steadily increasing, but it has not been sufficient to offset the decline in passenger revenue. The history of revenue passenger use is shown on Table 3.

TABLE 3
Yearly Phoenix Bus Transit Patronage

Year	Revenue Passengers
1960	9,309,573
1961	8,785,691
1962	6,415,263☼
1963	7,813,739
1964	7,366,656
1965	6,917,424
1966	7,419,175
1967	5,180,372
1968	5,131,331
1969	4,786,130

☼ 56-day strike
Source: Phoenix Transit Corporation Semi-annual reports filed by the company with the Arizona State Corporation Commission.

The trend is similar to other transit operations. People who are essentially captive users of transit probably account for most of the current use of transit in Phoenix. The Phoenix Transit regularly scheduled bus routes have about 18,000 paid fares per weekday or about 9,000 users of the weekday service. High school students represent approximately 12 percent of the total passengers on these routes. Weekend patronage falls off sharply to about 9,000 paid fares on Saturday and 2,500 on Sunday.

In 1947, there were an average of 71,318 transit trips per day. Of this total, 17,337 were school trips. Ten years later, there were 38,042 school transit trips per day. However, the total number of trips per day had decreased 13,741 to 57,577 in 1957. Last year, there were 4.5 million less revenue passengers than in 1960. There were only 4.8 million passengers utilizing the 1969 Phoenix bus transit service which operated about 3 million total bus miles. This is less than 2 revenue passengers per revenue mile.[15]

Currently, a great deal of interest surrounds transit as a solution to the urban transportation problem. New transit systems and improvements to existing systems may result in increased passenger utilization. Some future systems are discussed in the following chapter.

CHAPTER III

Future Systems

This chapter will examine a few future transit systems according to the classification defined in Chapter I. The first two sections discuss Rapid Transit and Highway Compatible Systems. Developments in these classifications are based, primarily, on technological and operational improvements of existing transit operations. For this reason, systems in this range of the transit spectrum are, probably, most adaptable to the immediate future. A recent rapid transit demonstration project, and the only large-scale new rapid transit system, are emphasized in the first section. The section on Highway Compatible Systems stresses the importance of motor bus operations along with the wide variety of demonstration projects tested and proposed.

The Individualized Transport and "Non-Stop" Transit Systems classifications conclude the chapter. Systems in these classifications are in the preliminary stage of development. Contained within these classifications are systems which are both similar to and unlike conventional transit. Notably, some of these systems need not compete with private transportation, and, potentially, they can be integrated into a transportation system serving all trip purposes within a metropolitan area.

Rapid Transit

After more than a decade of dormancy in the U. S., new rapid transit systems are being completed in three urban areas. Cleveland's four-mile,

$18 million line connects the city center and the Hopkins Airport – the first connection of this type in any U. S. major city. In Philadelphia, a 14.5-mile, $95 million suburban line now carries 30,000 passengers a day. This automatic fare collection and automatic train-operated system began service in February, 1969.[16] In San Francisco, the Bay Area Rapid Transit (BART) has been designed for the purpose of curing the Bay Area traffic congestion problem. BART and the Westinghouse Transit Expressway, which has recently undergone a two-year feasibility and demonstration study in South Park, Pittsburgh, will be examined in this section.

The Westinghouse Transit Expressway uses rubber-tired, independently propelled vehicles operated on an elevated concrete surface. Each vehicle has a capacity of 28 seated and 26 standing passengers, and the one-way capacity of this system ranges between 5,000 and 16,000 passengers per hour. Vehicles operate at speeds as high as 50 mph and are propelled by DC axle motors which collect power from the track. A rail is used in this system for guidance; however, unlike traditional systems, the rail is centrally located and not used for vehicle support. The capital cost for the elevated double track is estimated at $4 to $6 million a mile.

The major advantage of this independently propelled vehicle design is the ability to vary the vehicle-train size. This feature is coupled with completely automatic vehicle control, thus allowing continuous operation of high-frequency service provided by trains of variable size. Systems were developed which continually check the operating equipment and indicate any malfunctions to a control room. If a malfunction exists, the appropriate action is indicated. In addition, there is a two-way communication between the passengers and central control. In this manner, the passengers of the driverless vehicle are notified of actions being taken and, in case of emergency, they are able to communicate with the controller. The system tested operates on a loop. There is a need for a workable switching method.[17]

BART, unlike the Westinghouse Transit Expressway, has been designed as a steel wheel and rail system. The initial study for Bay Area Transit occurred in 1957, and the system should be completed within this decade. An excess of 15 years will have been spent in planning, testing, and construction. This system utilizes few radical changes from past rail transit operations. Computerized, fully automatic trains will operate over 75 miles of exclusive right-of-way attaining speeds of 80 mph and averaging about 50 mph. The operation on overhead, surface, and subway routes will connect three counties. Access to the BART system will be provided by 37 stations equipped with automatic ticketing facilities. Service during the week is tentatively planned for 15-minute maximum headways except during the peak hours when a 1.5-minute minimum headway is planned. The operating capacity at this minimum headway is 30,000 seated passengers per hour per single line.

The total design of the BART system results from the concept of providing service which can compete in attractiveness with the private automobile. High-speed stability considerations have resulted in rail spacings wider than conventional railroad gage. Passengers' comfort and convenience have been provided in the design of the BART cars and stations. Each 72-passenger car will have carpeted floors, wide aisles, recessed lighting, tinted windows, and automatic air conditioning. Each station has been individually designed and integrated with the other transportation facilities in the area.

The design of this modern rapid transit facility has been an immense financial undertaking. The latest reestimated total cost is $1.38 billion. Construction delays, inflation, and improvements to the system have accounted for the increases over the initially estimated $1 billion. Funds for this system have come from a variety of sources. General obligation bonds approved by the residents of the three counties and Berkeley total $812.5 million. The U. S. Government has contributed grants for demonstration projects and capital construction. Demonstration grants for transit design, fare collection, transit hardware, and beautification have totaled $8.6 million. Fifty-two million dollars of construction grants have been approved, and additional grants totaling $53.2 million are pending approval. The Trans-Bay tube and its approaches have been financed with a State of California grant of $180 million. Motor vehicle bridge tolls are the ultimate source of this grant. The rolling stock is financed from revenue bonds totaling $73 million. A one-half cent increase in sales tax, commencing in April, 1970, will ultimately provide $150 million and eliminate the financial deficit that BART has faced for the last three years.[18]

A graduated fare structure from 25 cents to a maximum of one dollar is tentatively planned to provide for the yearly operating and maintenance costs and repayment of the rolling stock revenue bonds. At this time, only estimates exist as to the impact BART will have on the Bay Area development, and, in particular, its impact on the two existing transit systems and travel on existing streets and freeways. It is estimated that the 1975 transit riders will be divided as follows; about 57 million for BART, 208 million for the Muni System, and 60 million for the AC Transit System. The estimated net revenue for that year, including advertising revenue, is: BART, + $10 million; Muni, – $7 million; and AC Transit, – $5 million. The percentage change from 1965 for the latter two is + 13 percent and – 247 percent, respectively, despite projected patronage increases of 47 percent and 14 percent. It is estimated that about 61 percent of BART users will be diverted from the automobile and that BART will carry 40 percent of their passengers in the peak hours. If comparable to other cities now considering rapid transit, this traffic will probably account for about ten percent of total peak-hour travel.[19]

BART's success or failure will be a major determinant in the future of large-scale rapid transit systems.

Highway Compatible Systems

Innovations in Highway Compatible Systems have concentrated on improvements in motor bus operations. The motor bus, presently, dominates transit usage in the U. S. Over the past five years, buses have carried approximately 70 percent of the total passengers using transit, about 5.7 billion passengers a year. Total transit operating revenue for 1967 was $1.5 billion. Motor buses accounted for 72 percent or $1.1 billion of this total. Improvements in the bus and its operating performance have been, and will continue to be, one of the main areas of emphasis in transit operations.[20]

Delays which occur on regularly scheduled bus transit routes are a major problem and, on the average, account for about one-third of the total trip time. Delays occur from traffic conditions and passenger stops. Traffic delays can occur at stop signs, signalized intersections, and because of other traffic interference. On regular city bus routes, as much as 60 percent of the total delay can occur because of passenger stops, loading, and unloading. Paradoxically, more passengers result in more delays which reduce the quality of service and, thereby, could reduce patronage. The frequent stops along a route limit the operating speed potential. Average operating speeds range from a few miles per hour to 15 or 20 mph on regularly-scheduled routes. Exclusive bus lanes and deviations from the regularly-scheduled route have been tested and will be examined in this section.

One major problem is the decline in ridership which regularly scheduled bus routes in medium size cities (from 50 to 250 thousand population) are experiencing. Demonstration projects designed to increase patronage have experienced varying degrees of success.

In Peoria, Illinois, a demonstration project was undertaken to determine the feasibility of new bus service operating techniques. Deviating from the regular route concept, a door-to-door commuter service was established for the home-to-work peak-hour trip. The passengers contracted for the service on a monthly basis and were issued special passes which they paid for on a zone-fare basis. The passes assured the passengers of a seat and were automatically reissued each month. Passenger convenience was emphasized throughout the demonstration project. Coffee and donuts were occasionally served. Christmas cards, book matches, and pass holders were issued to the subscribers. Complaints were investigated and action taken, if possible. Taxis were substituted free of charge in the event of a major breakdown. The overall results of this 14-month demonstration project were an increase in peak ridership of 13 percent, in increase in gross revenue of 12 percent, and an increase in net revenue of 8 percent.

After the project returned the operation to the Peoria city line, the company eliminated most of the above consumer services and increased the fares. This resulted in a 21 percent loss in passengers and the elimination of the previously-established growth rate. The company has recently reestablished most of the eliminated procedures, and ridership has, once again, increased. Off-peak routes were also established in new suburban areas which previously did not have a service. Regardless of the frequency of service, which ranged from 20 to 60 minutes, no route was able to earn more than approximately 25 percent of its operating costs.[21]

A similar peak-hour study being conducted in Flint, Michigan, utilizes the same concepts of door-to-door service and the passenger conveniences provided in Peoria, Illinois. It has been unsuccessful in its attempt to compete for a portion of the 100,000 automobile commuters. A $75,000 advertisement campaign to promote the service persuaded only 500 commuters to try the service while the number of regular riders has been about 300, or 11 passengers per bus.

Twenty-six 40-seat buses provide such conveniences as air-conditioned service, stereo music, and free coffee and donuts. The typical monthly cost for this service is $18 for a one-hour commuter trip. This service is presently losing approximately $200 daily. If the vehicles were only half full during the rush hours, the service would be showing a profit. The conflicting results between Peoria and Flint perhaps can be partly explained by the affluence of the commuters in Flint, and their expressed desire for more personal freedom in transport. These services limit flexibility in start time and use of intermediate stops are not available.[22]

Several other demonstration projects involve the use of exclusive bus lanes to improve the service. An experiment is underway in Washington, D. C., to provide two-way service. This not only makes downtown jobs more accessible to the suburban resident, but also makes suburban jobs more accessible to the Inner City resident. Instead of returning empty buses to the starting point, buses are rerouted through areas of the Inner City to pick up workers for suburban jobs. In a four-mile segment of the eight-lane Shirley Freeway, the two center (reversible) lanes are being tested as exclusive bus lanes during the rush hour.

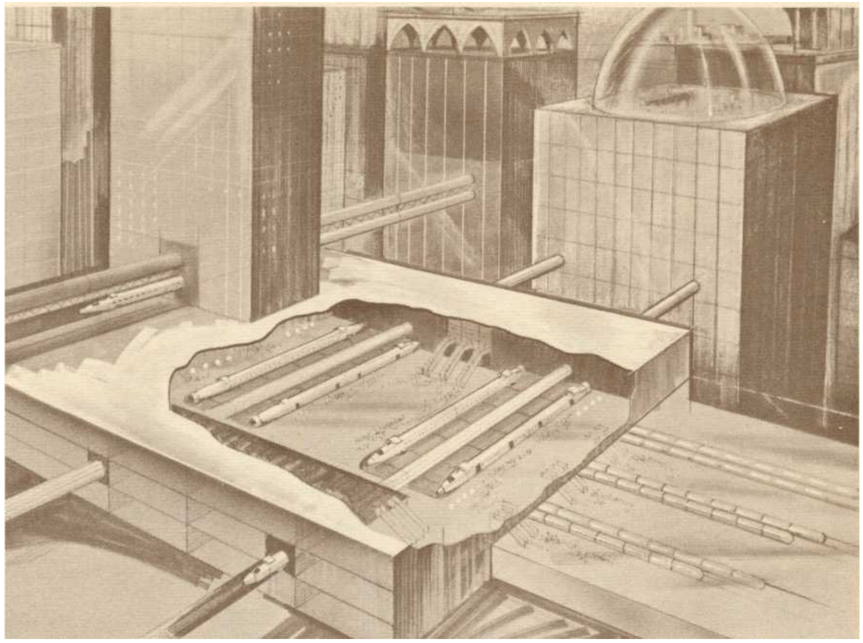
If an Atlanta plan is approved, the use of exclusive bus lanes will be coupled with the door-to-door collection of passengers. Exclusive bus lanes on arterial streets will connect suburbs with the downtown area. The proposed system consists of 750 route miles which converge with 32 miles of exclusive busway trunkline.

Another proposal is to meter cars onto freeways and allow buses to enter freely. In this manner, traffic volume and speed are regulated to improve bus operation.

Another bus innovation which is receiving considerable interest is the proposed dial-a-bus system. In this system, a driver-operated bus is routed by computer dispatch to pick up passengers after they have called for service. It is based on the recognition that low-density areas of the city are the most poorly served by public transit. Economic service on a regular basis to these low-density residential areas has been unsuccessful. The collection and distribution services in these low-density areas would be provided by computer dispatch of the nearest bus which could best serve the trip origin and destination recognizing the destination requirements of other passengers already on the bus. In this manner, flexibility of both routes and schedules can be attained. This linkage of many origins and many destinations combines the mass movement advantages of the bus and scheduling advantages similar to a taxi. The service, as conceived, consists of small buses with 10- to 15-seat capacity possibly connecting with other mass transit facilities.

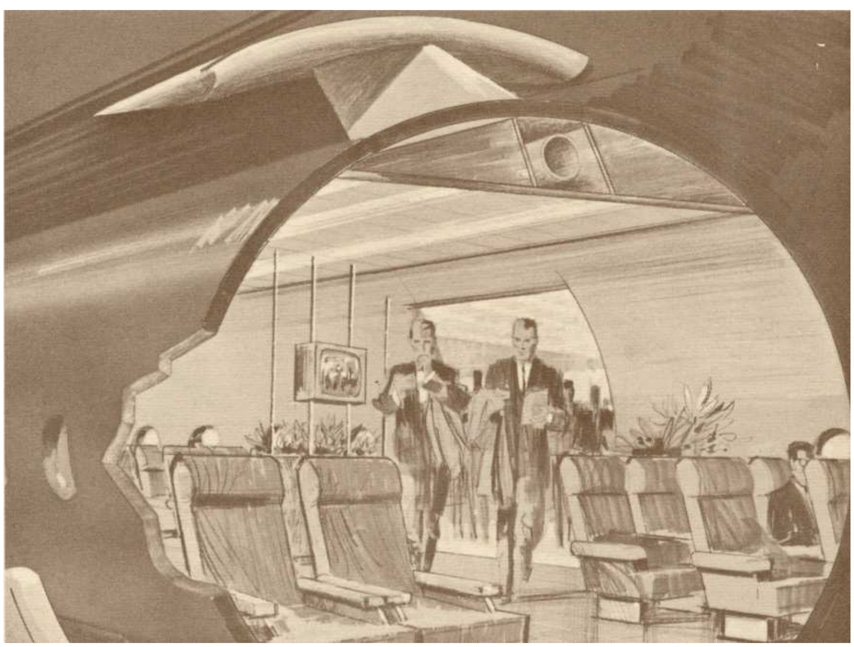
Another proposal consists of standard collection routes on existing streets with a line haul service by the same bus operating on a rail facility. This is very similar to the Atlanta Plan except that the dual mode capabilities can, potentially, lead to an all-electric vehicle requiring no driver on the line haul rail portion of the trip.

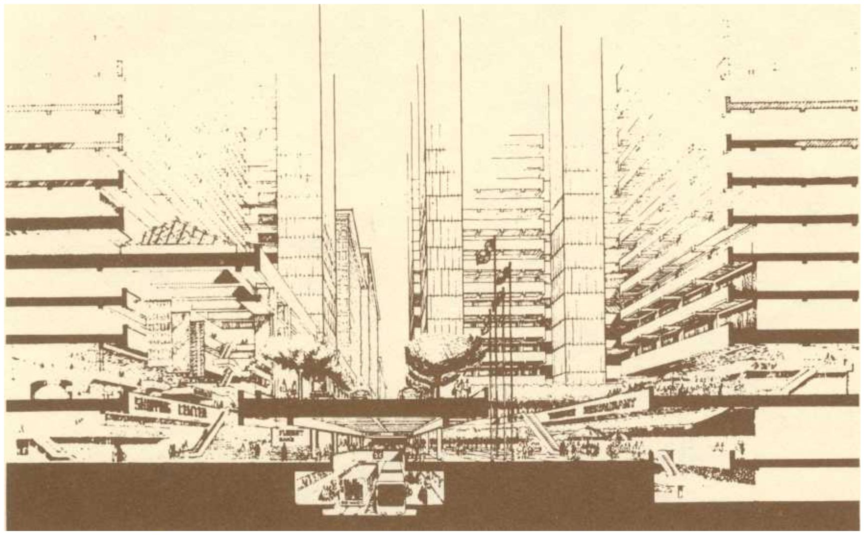
In the Los Angeles area, bus experimentation has centered around the provision of service for the urban poor. It was found that most of the existing buses to ghetto areas did not fulfill the origin and destination requirements of the residents. New lines were established through



Midtown Tubeflight Station
Courtesy Rensselaer Polytechnic Institute

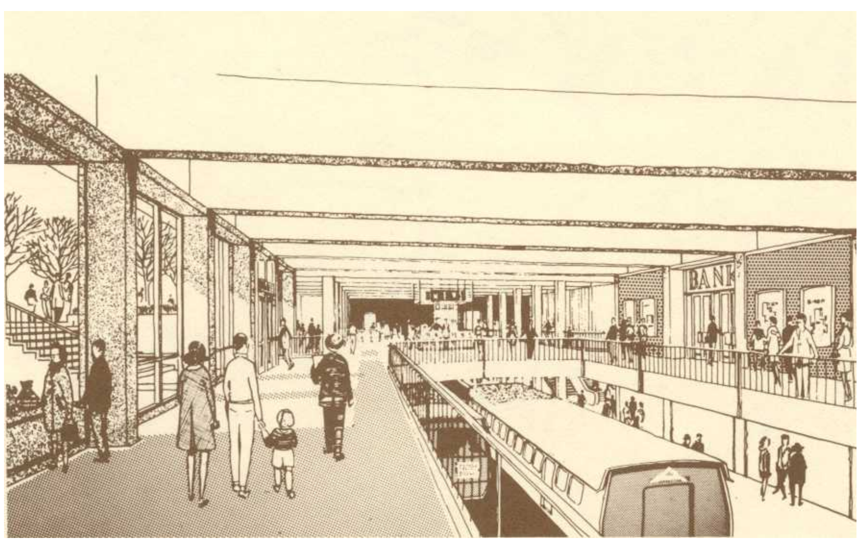
Tubeflight Vehicle Interior
Courtesy Rensselaer Polytechnic Institute

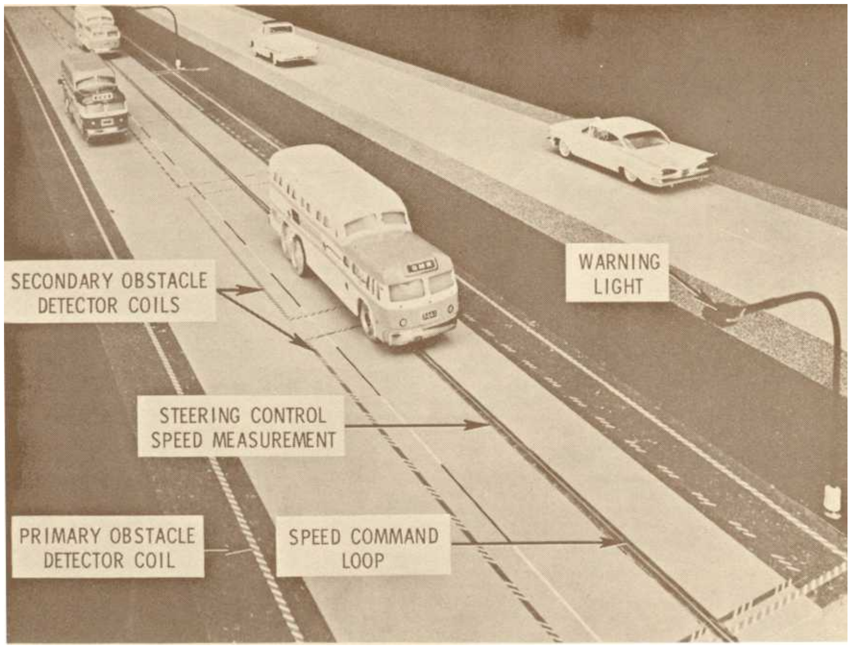




Seattle – Downtown Station Concept
Courtesy U.S. Department of Housing and Urban Development

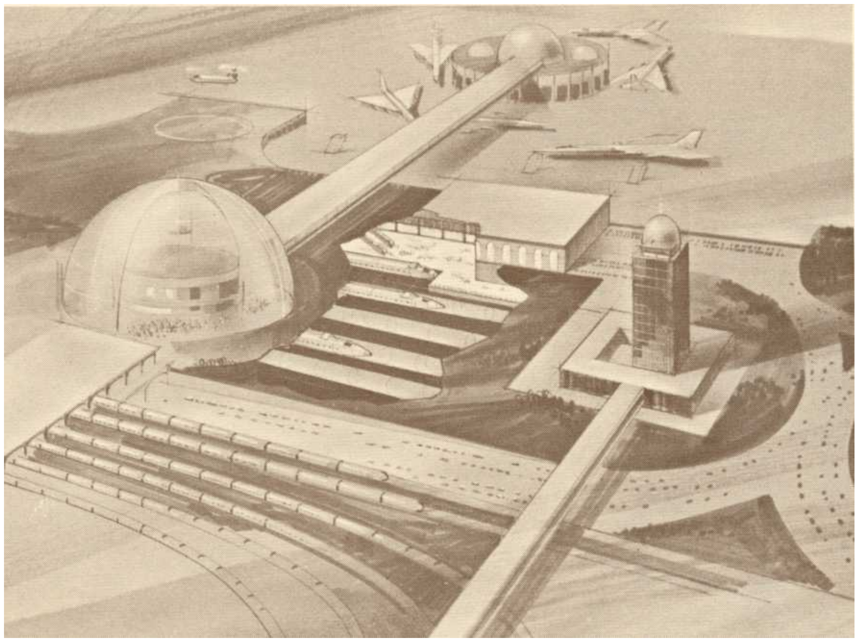
Advanced Station Design Concept
Courtesy U.S. Department of Housing and Urban Development





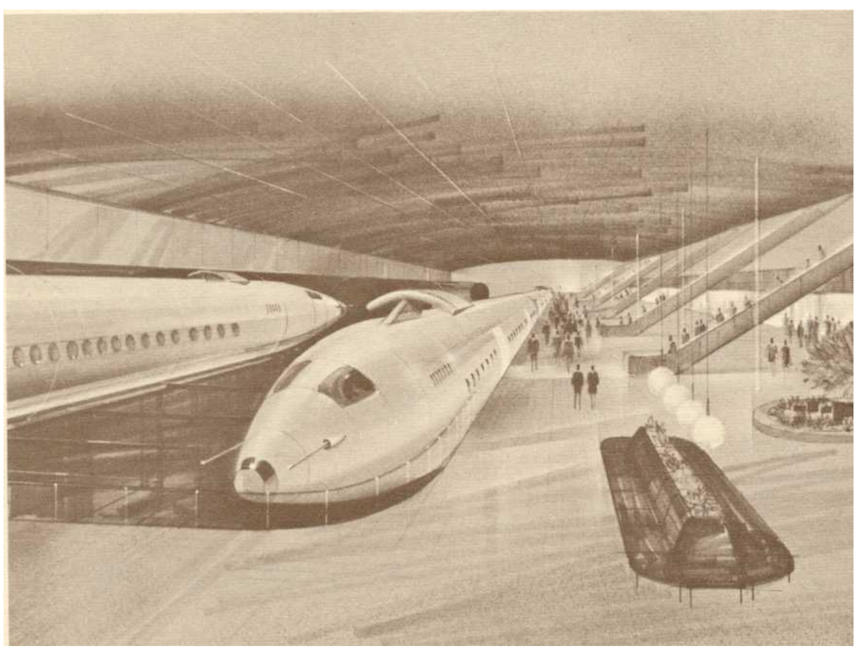
High-Speed Automated Bus Lane
Courtesy U.S. Department of Transportation, Federal Highway Administration

General Motors RTX Bus
Courtesy American Transit Association



Future Transportation Complex
Courtesy Rensselaer Polytechnic Institute

Tubeflight Vehicle Station
Courtesy Rensselaer Polytechnic Institute



Watts which were subsidized during the development stages and, later, converted to a permanent line. The results of these operational changes were that 60 percent of the trips carried on this line were work trips and 35 percent of the passengers were able to obtain new jobs. Another bus service provided direct home pickup of passengers for destinations to scattered industrial areas. A bus pool was established with the individuals working in the same plant as the passengers. This portion of the study has found that the elimination of transportation barriers does not create new job opportunities for the people in the project area and that the improved public transportation did not have a substantial effect in reducing unemployment unless there was a high demand for low-skilled labor.[23]

To summarize, the bus experimentations have found some success. There have also been significant failures. Nonetheless, this form of public transportation seems best equipped to adapt, in the immediate future, to low residential densities and diverse patterns of origin and destination.

Individualized Transport

The concepts being tested in Individualized Transport utilize many of the advantages of the personal vehicle and combine these advantages with those of conventional transit operations. The individuality and flexibility of the private automobile is most often combined with the high-carrying capacity and rapid-transporting capabilities of a rail system.

The deviation from this trend is a recently-proposed public automobile service. This concept was developed to provide short-range service within local areas of low-to-medium density. This service would be provided to regular drivers and those who are capable of driving an automobile but either do not have access to an automobile or cannot obtain a driver's license because of age restrictions. A special driving provision for the latter group would allow use of the facilities. The proposed electric vehicle seating from 2 to 4 people would be available at stations throughout an area, and rented by the hour or on a mileage basis. A disadvantage of this system is that it would not serve the non-drivers. Furthermore, many technical and legal problems such as the issuance of special driver provisions, prevention of vandalism, maintenance of vehicles, and redistributing the vehicles to meet demand, must be overcome. A prototype vehicle which would probably cost about $1,000 has been built and demonstrated successfully.[24]

Individualized Transport utilizing a fixed rail operation has been based on using rail service for the entire trip or increasing the flexibility by utilizing a vehicle which is also capable of operation on existing streets. Two proposed systems, Teltrans and the automatic taxi, provide Individualized Transport service on exclusive right-of-way only. Both systems utilize electric propulsion for the four-passenger vehicles, operating in an enclosed tubular guideway. In the Teltrans system, propulsion is provided by linear induction motors. The automatic taxi system uses AC induction motors with power pickup from overhead rails. The proposed speed of the Teltrans system is 45 mph, and operation at a practical capacity of between 5,000 and 15,000 persons per hour is anticipated. The estimated cost of this system is about $3 million per single track mile. The automatic taxi system utilizes a rubber-tire vehicle with average speeds of about 30 mph. The estimated capital cost per single track mile for this system is $2 million.[25]

The StaRRcar system utilizes a dual mode, personal vehicle seating two passengers which is manually driven on city streets and is also capable of operating automatically on special guideways. The proposed propulsion system uses batteries off the guideway and external power pickup when on the guideways. Probable guideway capacity is the same as the other systems in this classification, and speeds from 40 to 60 mph are anticipated.

The StaRRcar system combines many of the advantages of modernized rapid transit and the conventional automobile. On the guideway which may be concrete, the track would guide, control, and power the vehicle. At stations, the driver may leave the guideway and manually operate the vehicle or take another mode. If another mode is used, the vehicle becomes available for another user. Users could be charged on a rental basis.

A typical work trip from a suburban residence to the central area might utilize the system as follows. The station nearest the home provides entry onto guideway, and this facility is used to the station nearest the employment site. The vehicle, then, is available for another user and can be dispatched for use or parking elsewhere. The return journey home is made in the first available vehicle. The vehicle can be driven home for evening use on the street system or left at the local station. The high-speed line haul facility is integrated with door-to-door mobility and convenience. The estimated cost of guideway is $1 to $3 million per track mile.[26]

The automatic highway has received increasing attention for high density movements. The system proposed adapts conventional automobiles to automatic control by combining onboard sensing equipment and wire blocks or cables buried in the roadway. In this manner, the privately owned vehicles specially equipped could use not only existing streets and highways, but also, these modified highways. Operation on the automatic highways would be at higher speeds and at decreased vehicle spacing resulting in an estimated capacity increase of two to four times that of existing freeways. Other advantages would include increased convenience and safety.

Major problems include the longitudinal control of the vehicles, the provision of insurance that vehicles using the system have required equipment, and that the equipment is functioning properly. High-speed breakdowns will also be a major safety consideration with the small spacing that the system is considering. The cost for this system is unknown at this time. Other systems which utilize Individualized Transport, yet combine the operation into trains during some phase of the trip, will be discussed in the following section.

"Non-Stop" Transit Systems

The basic provision in the "Non-Stop" Transit Systems is a high-speed continuously-moving line haul train. The passenger using a conventional form of transit encounters delays and stops between his origin and destination terminals. These delays can constitute a high percentage of the total trip time but are necessary for passenger collection and distribution. The "Non-Stop" Transit Systems eliminate these intermediate delays, and the only delays encountered are those associated with the origin and destination of the trip. There are two basic methods for handling passengers. In both systems, the passenger compartments are combined to form larger units during the line haul operation. In one method, the passengers relocate after connection with the line haul train and select the car which will leave the line haul facility at the desired destination. In the other system, the individualized compartments are transferred at the desired destination, and, therefore, passengers remain in the same compartment for the entire journey.

In the former case, a series of self-propelled passenger cars might be utilized as follows. The through train could consist of a series of cars moving on a closed loop or route. At a station, or terminal, the rear car (or cars) is disconnected from the through train and decelerates to a stop at the station. While this is taking place, one or more cars are accelerated from the station and enter in front of the through train. The two couple together, and the passengers relocate to the car which corresponds to the desired destination.

In this type of system, the stations need not be located immediately adjacent to the line haul facility. The only cars that stop at a station are those which contain passengers with that destination. This feature could be utilized in developing a network of local stops linked with the line haul facility at several locations. If this were the case, several cars might exit the line haul facility and each car then proceed in different directions to stations. A major technological contribution is needed to perfect a method of switching and interlocking of trains before such a system could be implemented.

Another high-speed system utilizes a pallet in combination with conventional automobiles. A personal vehicle would be driven from existing street networks and on to a continuous moving train at selected terminals. The transfer to the line haul facility by using a pallet-type arrangement has been proposed. The automobile requires no additional special equipment, and the pallet vehicle could take the form of a flat car capable of carrying several vehicles. Switching is the major problem in this system. One method proposed utilizes parallel tracks at terminal points. The automobile driver would be driven onto a flat car which, in turn, would be accelerated to the speed of the line haul facility; then, the two trains would be coupled and a lifting mechanism would transfer the pallets onto and off of the line haul train. The capacity and speed characteristics of rail service would be integrated with the automobile preserving the automobile's characteristic comfort and enhancing the total trip by eliminating driving during the line haul. There are many forms of individualized vehicles that could be combined with trains. Some of these, such as the StaRRcar, were described in the previous section and are bi-modal in nature.

This chapter has not tried to describe all of the various systems being proposed. The main intent was to present the range of concepts currently being demonstrated or researched. These new urban transit modes attempt to combine many of the positive aspects of both private autos and conventional public transit within their systems. A brief listing of the positive attributes of private automobile service include: 1) comfort in all weather, 2) convenience, 3) dependability, 4) privacy, 5) flexibility of use, 6) speed of travel, 7) status, and 8) adaptable for the entire trip.

TABLE 4

Ranges of Characteristics in the Transit Spectrum

TRANSIT CLASSIFICATION	VEHICLE		AVERAGE SPEED	SYSTEM CAPACITY	PROBABLE CAPITAL COST
	CAPACITY (passengers)	COST/UNIT		(passengers/ hr. one way)	
RAPID TRANSIT	10 - 80	up to $120,000	15 - 75 mph.	8 - 30,000	$4-18 million/mile
HIGHWAY COMPATIBLE	12 - 75	$8-70,000	8 - 50 mph.	Variable	Variable
INDIVIDUALIZED TRANSPORT	2 - 6	$1000 and up	15 - 80 mph.	5 - 15,000	$1-7 million/ single track mile
"NON-STOP" TRANSIT	6 and up	Unknown	High Speed >60 mph.	4 - 10,000 6 pass. vehs./hr	Unknown

Sources: "Public Transit and the Quality of Urban Living." *High Speed Ground Transportation Journal*, January 1969.
Modes of Transportation, August 1968.
Transportation is the World of the Future, 1968.
The Technology of Urban Transportation, 1963.

The positive attributes associated with public transit are: 1) compact movement of passengers, 2) high capacity capabilities, 3) low space requirements, 4) high safety rating, and 5) provision for non-car users. No system proposed to date approaches fulfilling both sets of characteristics, but they present an improvement in transit over that which exists today.

CHAPTER IV

The Individual Decides

The preceding chapters have described the urban transportation problem and have given some history of transit development and set forth examples of new technology and concepts which might be implemented. A general index of the costs of such transportation was also presented. This chapter will attempt to present transportation alternatives as viewed by the urban transportation user.

Since the costs of transportation to the degree they are known were identified in the preceding material, they will not be discussed here except as they may be viewed by the individual. It will be seen that various other characteristics involving speed, comfort, privacy, etc., are also important and may be very difficult to evaluate in monetary terms. Thus, the analysis of transport alternatives from the user's viewpoint becomes most difficult. Only during the past few years has research. much of it borrowing from the social and psychological sciences, been productive and substantiated by basic data collection.

The fundamental assumption behind all of the discussions which follow is that the individual transportation user is rational in his decisions regarding his use (both mode and routing) of the transport alternatives available. The problem is to identify his rationale. This requires not only the inclusion of non-quantifiable items such as comfort, privacy, and others, but also the realization that the user is not equally sensitive to the expenditure of the quantifiable items including time and money. The discussions which follow will touch briefly on a number of these in order to indicate the type of knowledge currently available and to indicate those characteristics of transportation systems which have the most negative effect on the users. It is obvious that any new or improved system should try to avoid, deemphasize, or compensate for such characteristics in order to increase its attractiveness to the user.

Although most people agree that there are a number of non-measurable transport effects, most feel that there are at least two which can be measured and that their values should be relatively constant. These are the dollar costs of transportation and the time it takes to make the trip.

Although most economic analyses rightfully indicate and compare the total cost of transportation alternates, it should be realized that the individual when making decisions regarding transportation alternates, generally does not decide on a total cost basis. Economists have long contended that the effect on the public is modified by the timing and the method used in charging those costs to the individual. The withholding feature of the income tax is an example.

When alternates are compared, there is the question of whether previous investments should be included or whether such decisions having already been made, should be neglected. When previous investment is brought to the individual level, it has an equally profound effect. It is this factor which probably has the over-riding influence on the individual's view of the direct costs of alternate forms of urban transportation.

Specifically, once an automobile or any other unit of privately-owned transportation has been purchased, the user very seldom includes the depreciation of such in his decision regarding its use for a particular trip. This is especially true when the trip is relatively short and, maybe, is somewhat less the case if an extensive trip of several hundred miles is involved. This is not to say that the individual never considers this cost. There is, probably, very serious consideration given prior to the purchase, and the availability, cost, and convenience of alternate modes of transport may be balanced against the individual's investment.

There is a possibility that, because of the high rate of style obsolescence (as opposed to obsolescence due to use) that there may be a reverse factor at work. This would be the case when the individual user having once purchased a vehicle feels that in order to "get his money out" of the investment, he would use this mode of transportation at a time when a consideration of cost would indicate it an unlikely alternative.

It has been established that the expenditures which have the greatest impact on the user are those which are removed or collected from him on a hard-cash basis each time be performs a trip. Typical of these costs are parking fees, tolls, and transit fares. Many users, when faced by a short urban trip, do not (even when asked) make their evaluation in terms of the gas consumed. They feel that the gasoline purchase has already been made and, although they realize that a certain amount of fuel will be burned on each trip, they think more in terms of filling the tank every so often. They do not consider one short trip as having much of an effect. It would seem that the methods of cost collection are prone to favor those types of transportation which are individually owned. Thus, any form of private or public ownership which is faced with the problem of collecting the costs of transport from the user as each individual trip is accomplished, is at a disadvantage.

The second quantifiable characteristic of urban travel is that of travel time. The transport user evaluates his time in terms of the total trip, that is, from the time he leaves his origin (possibly his house) to the time he gets to his destination (the inside of his office or the inside of a shopping center, etc.). This would appear rational although some studies do analyze time savings on certain portions of the trip, specifically, the line haul portion. Transportation, almost by definition, causes an expenditure of time. During this period, the user is prevented from doing something more productive or something more to his liking. Thus, it seems reasonable to look at time in transportation as something that has a disutility, or in other words, as a negative factor which should be minimized.

In measuring the amount of time saved by making a trip by one mode as compared to another, at least two major items are of interest. The first is the view of the user as to whether the actual time saved is really an advantage, and, secondly, the value in terms of dollars, that might be placed on this savings.

In the first case, it seems reasonable that an individual's view of time expended must certainly take into account the pleasantness or unpleasantness experienced. Most are well aware of the phenomenon of time seeming to "fly" when engaged in something very interesting or very appealing. On the other hand, a very short period of time may seem quite long when exposed to unpleasant conditions. Although this seems a very real and simple concept, its application to the development of urban transit systems and to an understanding of the user's decision has not been quantified until recently. There are current studies which indicate that time spent waiting during a trip is weighted as two and a half times that spent in motion.[27] Thus, any waiting – waiting for a vehicle, waiting at a transfer, or waiting at an intersection – is viewed with a much more negative attitude. It would seem that any mode of transportation which requires a transfer and, normally, a time delay at transfer, would immediately be at a disadvantage. An extension of these findings might indicate that the conditions under which waiting is accomplished is of importance. For example, being delayed within a vehicle which is protected from the elements may be less offensive than being delayed by standing on a street corner or station where one is exposed to the elements. It is not known whether a few longer waits are more or less offensive than a large number of shorter delays (with the same total delay and under the same conditions). It would not seem unreasonable, however, that the numerous short delays might be, in fact, more aggravating.

The important fact is that the expenditure of time for urban transportation is viewed differently depending on how that time is expended. Anything which can be done to improve the psychological effects of this "wasted time," the more attractive will be that mode of transportation. Where a relatively long trip is involved and where the individual is not needed to control the transport unit, the individual may be free to pursue some personally productive or pleasurable activities which might have a positive effect. The typical example of this is the businessman in eastern cities who uses the time on commuter railroads to work, catch up on his casual reading, or play cards with a group of friends.

Further characteristics of the expenediture of time become clear by investigating the user's view of the value, in dollar terms, of the time expended. Since many, if not most, improvements in urban transportation are justified not because of a reduction in operating costs, but because of a reduction in travel time, transportation economists have been interested in the appropriate value of time for a number of years. An extensive discussion of an appropriate time value in such an analysis is not of particular use here and is not included.

It is the use to which the time saved is put that is important in determining the value of that time. Thus, one should be careful of an analysis which indicates one alternative better than another based on the accumulation of very small time savings (of a minute or two) for an individual trip even though this might be applied to thousands of people each day of the year. The point is, such a small amount of time probably could not be put to much productive use as far as the economy is concerned.

A second major point is that the value of the time saved is certainly a function of the purpose of the travel. For example, special consideration is given to fire, ambulance, and police vehicles because it is realized that a very small saving in time can be very important and valuable. On the other hand, the "Sunday driver" on a recreational or social trip probably places very little value on time savings.

The third and, again, obvious point is that everything else constant, the value of the time saved is probably related to the income (productiveness) of the individual making the trip.

Although previous comments concerning the total cost of transportation might indicate that the user is not very sensitive or sophisticated in his view of transportation, recent research would indicate otherwise with regard to the expenditure of time. This might be expected if one remembers that the user is very sensitive to any expenditure which he is forced to make directly when the trip is actually performed. This, almost by definition, includes the entire time expenditure. As the previous paragraphs indicated, be is sensitive to the qualitative features of time. He may also be quite sensitive to the quantitative features. There is now evidence available which indicates that the user does view the time-saving differently depending both on his income level and on the amount of time saved. The value of one minute saved is much less both in total value *and* in value per unit of time than the savings of 5, 10, or 15 minutes in an urban trip. The value of time saved in dollars per minute when the total savings is 20 minutes may be almost three times that of a one-minute saving. In simple terms, this means that the savings as viewed by the user of one minute on each of ten trips is not valued anywhere near as much as the savings of ten minutes on one trip.

Furthermore, research indicates that the user is also sensitive to the fact that the time saved on many urban trips cannot be put to the most productive uses. Thus, one study of urban travel indicates that the value placed on time savings by the user is somewhere between 25 to 40 percent his rate of pay at this occupation.[28]

This knowledge of the value of time to the user is of extreme importance in evaluating his view with regard to alternate transportation technologies. To repeat, the user and his view of the value of time must first be determined on the total trip, must take into account the user's income level, and the total amount of time saved on the trip. This means that the planners must now be concerned with not only the time savings or the relative travel time, but also, the total trip length in terms of time.

The preceding has discussed two factors which are quantitative in nature. It must be emphasized that there are numerous other factors, most of which cannot be quantified, which have a direct effect on the individual when he makes his modal decision. These include frequency of service, need to change vehicles, reliability of service, the expected delays in changing modes, overall speed, personal comfort or the sense of freedom, safety, the control of his immediate environment both with regard to the proximity of other passengers and with regard to the temperature, ventilation, etc.

One primary concern seems to be the reliability of achieving the destination at the proper or expected time. The time factor becomes quite important when the work trip is considered. This probably reflects the individual's desire for a minimum travel time with adequate safety. It should be noted that the uncertainty of total trip duration is usually much greater at transfer points and, especially, when a mode change is required.

Another general characteristic which includes many of the factors listed above is, normally, referred to as comfort and convenience. These include the lack of waiting lines, the availability and comfort of seats, privacy, the ability to listen or not listen to the radio, the ability to smoke or the ability to be removed from those who do, the ability to control the temperature and ventilation, etc. These are, normally, more important to the individual on the work trip than for other purposes. This, probably, reflects both its length and, possibly, the individual's desire to be free from the impact of others, especially after having been subjected to such stress during the day at his work place. People on shopping, social, or recreational trips are, generally, less sensitive to this.

The preceding discussions concerning travel time may be further expanded or explained by consideration of comfort and convenience. For example, some studies have indicated that bus users place greater importance on getting to their destination in the shortest time and by the shortest distances than does the automobile user.[29] This may be due to the fact that the effects of time and distance are less acute on the automobile user because of the increased reliability, comfort, convenience, and feeling of personal freedom. Part of this is also the feeling of the ability to control, to some extent, the route, speed, and other characteristics of the vehicle during the trip. Thus, the feeling that, if a delay is encountered, the individual is free to seek another route rather than to be delayed by the decision of another or the rigidity of the system, may be important.

This chapter has presented some of the rationales used by the individual as he makes his decision regarding his use of urban transportation. In review, it is, probably, a rational decision based on economics, time, comfort, and convenience criteria. The user is quite sensitive to, and also, quite sophisticated in, his individual analysis or reaction to many of these. It points out the important fact that equal time or equal costs for different alternatives are not viewed as being equal by the user. Some costs and some expenditure of time are much more offensive than others. The more that is learned about urban transportation, the more it is necessary to analyze the entire trip and analyze it both in its relative and absolute terms. In the decisions concerning future transport investment, these facts must be incorporated, and the system should be designed so as to minimize the distasteful factors. Typical of the guidelines which might be established would be the following:

1. Minimize time and distance.

2. Keep delays and waiting periods at a minimum.

3. Decrease the uncertainty either by established schedules or by frequent service.

4. Provide a small, basic compartment or unit for privacy.

5. Provide the individual with the greatest amount of control over his environment including ventilation, temperature, smoking, etc.

6. Minimize small recurring delays.

7. Minimize the number of transfers.

8. Minimize the requirements for the user to move from one unit to another.

9. Maximize safety and freedom from breakdown.

10. Avoid repeated direct charges for service.

CHAPTER V

Financing

The preceding chapters have included presentations of transport costs and, also, the individual's attitudes toward the collection of certain fares and other costs. This section will look, briefly, at some of the questions regarding the financing of urban transportation from the standpoint of the city or governmental agency. With regard to urban transportation financing, it seems that there are two fundamental questions of concern at this time. The first of these is ownership, and the second is governmental support.

An investigation of the forms of urban transportation would indicate that there are, basically, three types of ownership currently used. The first might be called private corporate ownership. This would include those systems which are owned and operated by private corporations and supply transportation as the private sector would supply any service or commodity. These corporations are, normally, controlled by local or state regulations, and numerous conditions are imposed in their franchises which require them to perform certain functions which they would not otherwise perform. These include the inflexibility of route, the retention of routes operating at a deficit, and the retention of service during those days or times of the day when usage does not justify the service. These are typical of only a few of current restrictions. They indicate, however, that there has been historically, and still is, a strong feeling that part of a privately-owned mass transportation function is to provide services at times and for those individuals where it is not economically justified. These are, essentially, social welfare considerations. These have been provided by private corporations when they were required and as long as other, more profitable, segments were able to provide net revenue for the economic deficiencies of these functions. The problem with most of today's privately owned urban transportation facilities is that their history has been such that it tended to reduce the number of profitable lines, the number of days per week that any line was profitable, and the number of hours during the day that a profit could be sustained. Therefore, a greater and greater proportion of the activities required justification which was outside of the economics of the fare box.

Because of this, there has been a marked movement toward the second type of transit ownership. This is public ownership normally embodied in some type of public transit authority. These authorities have suffered many of the ills of the private transit companies. This would be expected. In most cases when the transit authorities were formed, they purchased, or assumed in some other fashion, the fixed facilities, rolling stock, routes, and maintenance facilities of private corporation. In many cases, they also inherited the management personnel. This does not mean, however, that public ownership was entirely an extension of the problems of private ownership. In most instances, the publicly owned corporations ad available to them relief which was not available to others. This included elimination of local property or other taxes; reduced maintenance responsibility in those cases where streets and other thoroughfares were used; release from state and/or local fuel, registration, and other operating taxes; and, finally, the availability of other governmental support. In addition, many could call upon a larger financial base from which they might issue bonds for capital improvement. It must be remembered that most of these provided only short-range relief and were not able to stem or reverse the continued reduction of transit use in the overall urban transport picture. Most of the existing systems still suffer from conventional low fares and from the attitudes concerning fares previously described.

Recently, more emphasis has been put on using conventional transit to provide mobility for the poor, the handicapped, the aged, the young, etc. Under these conditions, and remembering the demands of peak-hour loads described in the initial chapter, it is no wonder that most of them feel that under the best conditions, they will be fortunate to have revenues which cover their direct operating costs. This still leaves the depreciation of the investment in the fixed facility and vehicles. This makes more difficult, if not impossible, any attempt at implementing new technology, new management concepts, etc.

The third common type of ownership is that which is represented by the rubber tire transport industry in general. This is individual private ownership of the rolling stock and public ownership of the fixed facility. This is further tied to a philosophy which says that the individual who owns the transport unit bears full responsibility for the financing of the improvement of the fixed system. Plainly, this describes the individual and his privately-owned automobile operating on a public system of highways, freeways, and streets for which he provides the financing. This has been accomplished through the development of a concept of user charges which are specifically earmarked, both at State and Federal levels, for the improvement and maintenance of highway systems. This earmarking, in most cases, is justified by the fact that these user charges represent virtually the entire financing capabilities for major highway facilities both within and outside of urban areas.

There are many reasons for the success of this system. First, there is the flexibility of the vehicle itself, allowing it to operate on virtually any type of surface. Second, there is the freedom of the individual to decide when and what type of vehicle he should purchase. An often-overlooked factor is the system's ability to finance itself by an efficient and inoffensive tax mechanism. The highway user pays his taxes in a number of ways, the most important of which is the tax on the fuel he consumes. This tax is collected each time he purchases a gallon of gas, and yet the marketing phenomenon is such that it is not called directly to his attention. The advertised retail price of gasoline and other motor fuels include both the Federal and State user taxes. It is true that some companies are now placing signs in their stations and on their pumps which indicate the amount of the price which is tax, but this, probably, does not have the same psychological effect as the imposition of a tax after the retail price has been established. The sales tax is an example of the latter case.

This is not to infer that the taxes are not substantial. They would, probably, be much more offensive if handled as a sales tax or if the user had to be billed once a year for an equivalent amount of money. Fuel costs vary in Arizona from somewhere between 28 cents in the central part of the state during a gas war, to 45 or more cents per gallon in other parts of the state. In Arizona, there is a 7-cent State and 4-cent Federal tax on each gallon of gasoline. Taking the two extremes, one might say that the price of gasoline is from 17 to 34 cents a gallon plus an 11-cent tax. If calculated in the same fashion as a sales tax, this represents a tax of 65 and 32 percent, respectively.

The second advantageous tax characteristic is its efficiency of collection. Because of the shipping and distribution mechanism for motor fuel, it is relatively inexpensive to collect these taxes. Virtually all of the fuel will be used by those who are subject to the highway use tax. For those activities which are not subject to such a tax (boating, farm equipment, heavy construction equipment, etc.), a local separate system or a system of rebates may be established. It must be remembered that when any new taxes are established, either for the primary purpose of revenue production or, as some would suggest in urban areas today, for the purpose of controlling the transportation decisions of the individual, the efficiency of the collection system is important. Even where control is the primary purpose, it would seem unjustified to introduce a tax which would cost more to collect and enforce than the revenue produced.

The other major concern of financing today is governmental support. These are discussions of subsidy and it should be realized that, in a broader sense, governmental support is always a shift of responsibility or financial burdens from one group to another. Although the term "subsidy" has some unpleasant connotations, it is a term familiar to many and, therefore, will be used here but not necessarily in a negative sense.

Whether a subsidy exists usually depends on the scope of the system under discussion. There are few, if any, transportation systems in which each part at all times pays for itself. In the highway system of this country, the lack of subsidy generally means that the highway user pays for the improvement of the major traffic arteries. However, this considers the entire national system. It can be shown that many states pay more to the Federal government in highway users charges than they receive in Federal Aid. Arizona has received more than it has paid, and, thus, it is receiving revenues generated by others. Within the State, the urban areas (this is typical of most states) pay more in user taxes than they receive in highway improvements. Thus, the urbanites generally subsidize rural transportation. This is not necessarily bad since they directly or indirectly depend on rural transportation in many ways. The justification of such subsidies must be based on an analysis of the needs of the recipients. Historically, the need for national and regional transport (the majority of which is rural transport) has taken precedence. This may no longer be the case (for reasons not within the scope of this report). Even within the urban areas, it is probably true that the off-peak users, be they users of private or publicly-owned transit or the highway system, probably subsidized the peak-hour users.

Similarly with transit, the consideration of subsidy has to be well defined. In most cases, subsidy now means that operations can no longer produce revenues equal to expenditures. Some relief of this, as previously indicated, can be accomplished by relief from existing tax responsibilities. This might be considered a relatively soft subsidy. In fact, it might be considered a justifiable redistribution of responsibility in that, historically, the operations may have, in fact, subsidized some other form of transportation or other programs.

However, more recently the discussion of subsidy revolves around the more difficult questions of a hard money transfer. Currently, this usually concerns capital funds for the construction or improvement of the fixed facilities. There is a growing concern that this is necessary in order to accomplish any improvement in transit service since the current revenue would cover operating costs only. This might be called the second level of subsidy where tax release is considered the first. The third level of subsidy is the provision of funds on a continuing basis to cover direct operating costs. At this point, it probably would be advisable to think not in terms of a transportation service, but in terms of a welfare function.

It is necessary to look at any transfer of financial responsibility or subsidy in its proper context and with respect to its proper function. If a particular mode of transportation is to provide a social welfare function over and above what it can economically support, then it probably should be given aid from those sources which normally provide for that type of function. If it is to be used to help produce a particular type of urban area, then it might rightfully expect support from those who benefit from that particular type of urban area rather than from a form freely chosen by the individual urbanite. If it is to be encouraged in order to support an existing extensively-developed central business district, or to retard the relative decline of such an area, then its financial needs should be met by those who benefit from such action. If a particular mode of transport requires any financial support and it improves the operation or decreases the cost of an alternate form of transport, then the latter could justifiably provide financing for the former. However, it must be emphasized that this assumes that the shift occurs because of the choice of the individual. The mere fact that one form of transportation needs financial support is no justification for obtaining that support from another mode of transportation on the sole basis that they perform the same function.

Justification for subsidy for existing transit has often been based on the argument that the poor would suffer if fares were raised. This may not be the case. Transit subsidies are often financed from regressive local taxes (such as a retail sales tax) which have a greater proportional effect on the very people which it claims to help. More importantly, this may lead to a subsidy of the rich by the poor. This results from the fact that the subsidy is required for the lightly used segments of the system and not the heavily traveled central city portion of the system. Those heavily used segments usually extend from low income areas to the central area and pay their own way. The lightly traveled segments serve the suburban and outlying higher income communities.

It would seem that the advisability of subsidy would rest on numerous evaluations. Some of these have already been indicated. Although there may be sufficient justification for subsidy for capital investment or tax release to support existing systems where those systems have proved to be no longer technologically advanced or acceptable to the user, these types of decisions must be investigated thoroughly. The decision to take over or support a system which had a recent history of decline must realize that it may continue to decline to the point where operating costs may no longer be recoverable from revenues. The urban areas must be sensitive to the fact that existing physical transit facilities may not be the best solution and that continued support of such systems may become harder and harder to justify. On the other hand, most urban areas are faced with the fact that they cannot, by themselves or with the current level of Federal Aid, do much in the way of extensive innovation. It is fully recognized that local officials do not want to be saddled with a failure in their own community. They are, therefore, reluctant to pursue investments such as transit innovation which may have a significant probability of economic failure. This, when combined with the total shortage of funds to meet urban problems, reenforces the elected officials' reluctance for such programs. When this is further reenforced by the failure of such modifications as described for the Flint bus program, the situation becomes serious.

The preceding sections have indicated that minor modifications probably will not cause a major shift in the current attitudes and decisions of users regarding modes. This means that substantial changes in the alternates available are necessary. To meet today's needs, this means that substantial systems or subsystems would have to be built to provide these alternatives. They will be very expensive to construct. There is no assurance that any particular concept will prove to be more efficient or attractive to the user than some of the existing alternatives. Thus, there is no assurance that they will be financially successful. Because of this, it is understandable that the individual communities are not in a position to do very much to provide these large programs. At the most, they could attempt one, and its failure could have long-range financial repercussions for the community.

Therefore, it would seem that the higher levels of governments must be looked toward for the financing of new transport concepts in urban areas. The individual urban areas should analyze the range of concepts available and try to obtain State and Federal financing for a concept which it considers might best meet its particular needs. The concept which satisfies New York or San Francisco will not necessarily satisfy Oklahoma City or Phoenix. Any urban area that unduly burdens one group of users or one mode of transportation to completely subsidize an alternate mode, will effectively increase its total cost of transportation and, therefore, become that much less attractive than other urban areas. This would, normally, restrain the rate of growth, which has both positive and negative aspects, but it is generally considered to be an unwanted situation by most community leaders.

In conclusion, it seems important that the community identify its problems, realize the magnitude of financing transport alternatives, and realize that this problem, like that of air pollution, is one that cannot be solved by a small geographic area. The communities may be called upon to give some tax relief or subsidy to existing systems, and this is often justified. However, they should remember that the subsidy will have to be provided by some other sector. If this sector cannot be found, or cannot stand the financial responsibility, then it will probably be up to the taxing powers of the general urban base to provide the funds – the funds which are most critically needed, however, and those which are almost non-existent: the funds which can be used to try new systems, new techniques, and new management concepts.

CHAPTER VI

Urban Form and Transportation Considerations

Previous chapters have been concerned with both the technical and non-technical aspects of transportation. This chapter will attempt to relate urban form to both the transport technology available at any point in time and relate this to the probable growth characteristics of the Phoenix urban area during the next 20 to 25 years. Urban form refers to land use characteristics. The concern here is related, specifically, to the distribution and the intensity of land use. It will be illustrated that both must be considered in order to understand the requirements placed on a transportation system.

Initially, it is necessary to establish the relationship between urban form and transportation technology. To develop and illustrate this relationship, it is useful to look at the historical development of urban areas as related to the transportation technology available at the time when such development occurred.

Pre-Industrial Towns

The ancient cities in Mesopotamia, Greece, and the Roman Empire provide a number of very important architectural and archeological remnants; these civilizations supplied much of the birthright of western Europe, and, therefore, attract a great deal of interest. Most of the towns were quite small by today's standards. It is doubtful whether any ever achieved the population of Phoenix today. Many were no larger than 50 to 100 thousand people. They covered limited areas and were compact, tending toward a circular shape. In many cases, this was modified by local topographic characteristics. The transportation technology available was very limited and consisted only of the use of human feet or beasts of burden and what they could carry or pull. Most personal travel was slow, and most freight movement was not only slow but conducted in very small units.

Many of the towns were laid out on a rectangular grid pattern. This was true even in Greece where the topography would normally have led to other systems.[30]

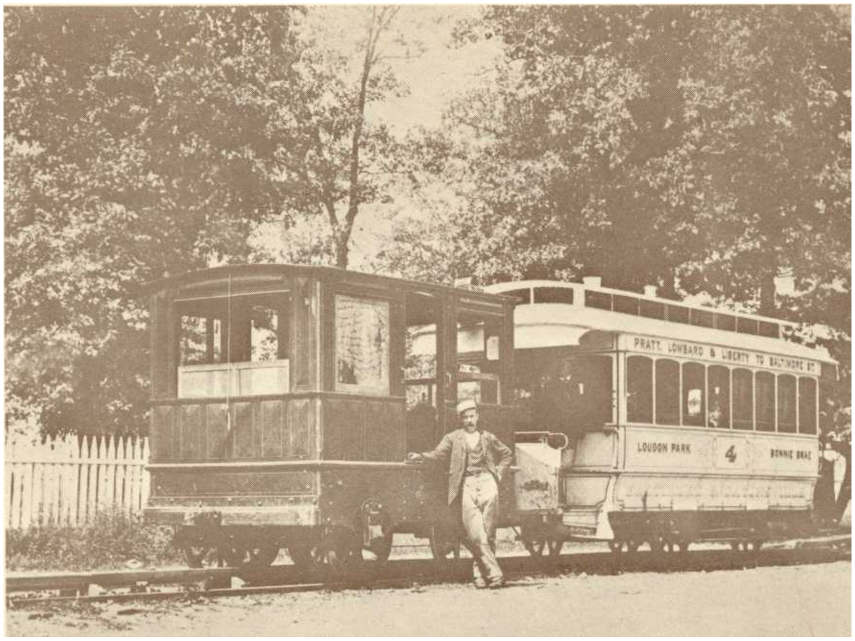
These systems consisted of passways and not of roads or streets as conceived today. Most were very narrow and provided little or no access to wheeled vehicles of any size.

A number of the cities did develop broad, magnificent avenues or boulevards within their center. These were normally provided for triumphful parades and the exhibition of surrounding palaces, temples, or public buildings. Traces of some of these remain today. It is important to remember that these boulevards were the exception and that the vast majority of the transport system has long since disappeared.

As one considers the medieval towns of Europe, many of the same characteristics are found. Again, the towns were quite small compared to present-day standards and even more compact. This resulted from the need to build walls or ramparts for protection. Many of these towns sought sites on hilltops for similar reasons. The entire urban form of the medieval city was oriented toward military protection. The rectangular pattern of pathways and streets disappeared to be replaced by narrow and curving streets and paths. In many towns, the adjacent buildings were extended over the streets to virtually create a tunnel. It is not clear whether this was purposeful, but such pathways and overhangs could provide added defense if the walls were breached. There was very little open space. It was not necessary because of the proximity of the countryside. Also, it must be remembered that there was no great ebb and flow of transportation demand such as is evident in modern cities because a substantial number of people worked in shops within their homes.

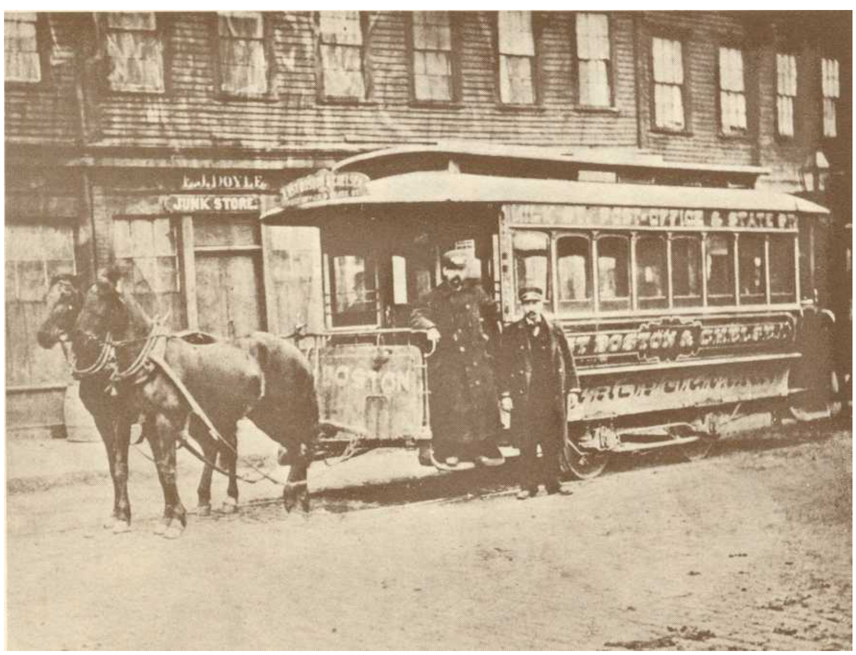
If there was a major influence of transportation on the ancient and medieval cities, it probably was related to their overall size. These towns depended upon the surrounding hinterlands for their food and supplies. Thus, regional transportation capabilities as well as political and agricultural considerations governed the total non-rural community which could be supported.

First Cable Car - San Francisco, 1873
Courtesy American Transit Association



America's First Electric Line – Baltimore, 1885
Courtesy American Transit Association

Horsedrawn Streetcar, Boston
Courtesy American Transit Association

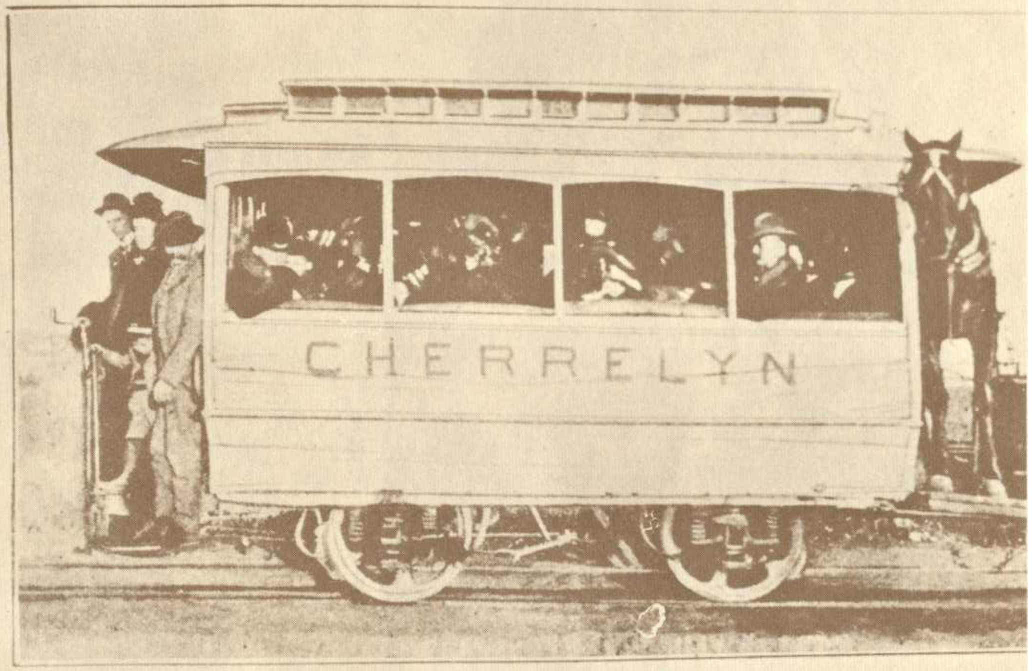


Portland, Oregon, Electric Power Company, 1905
Courtesy American Transit Association

One-Man Streetcars, Norfolk, Virginia, 1927
Courtesy American Transit Association

Fifty-Fifty

On this archaic line, in the outskirts of Denver, a horse pulled the car up hill and then rode down on the rear platform. He was on the job so long that his shoes wore grooves in the flooring.



Courtesy American Transit Association

The Industrial City

The development of modern urbanized communities is marked by the initiation of the Industrial Revolution. Most of the modern metropolitan areas of today reflect the impact of the 19th and first part of the 20th Century. It was industrialization that first led to the existence of large and populous urbanized areas. The Industrial Revolution caused very rapid urban expansion. It was a time of rail expansion. The parallel growth of industrialization and rail transport was no accident. The historical fact that one of the first applications of steam power was to transportation, illustrates the lack of capability to transport large quantities over great distances overland prior to that time.

Industrialization of urban areas during the initial part of the era was built upon the development of basic industry. Those industries were often extractive in nature and required large inputs of ore or other raw materials. In many cases, the assembly of two or three different materials that did not occur naturally together was required. This could not be accomplished without some efficient form of overland bulk transport.

Three forces were acting which together would create an urban form which is still reflected in many American cities. The first of these forces was the very rapid increase in population. The second, was the development of the factory concept. The Industrial Revolution and its factory was based on the idea that it was more efficient 1) for the people to specialize in one part of a manufacturing process rather than in the complete process, and 2) for the people to assemble into a common area to work. This was the first time there was such complete separation of the home location and the work location, and it developed the need for people to travel between these two urban land uses. In other words, the work trip was born and, as has been discussed in a previous chapter, this requirement that people not only assemble in a particular place, but also at a particular time, has caused the major urban transportation problem of today. The third factor was the existence of at least one rail line in the community. This resulted in the existence of a form of transportation that was far superior to the previous or existing alternate technology, both in its speed, capacity, and reliability.

As these three forces worked together, it became obvious that the new technology (rail) should be used to transport people to and from their work as well as to transport industrial materials. This led to the development of street railways, rapid rail transit, and commuter railways. All of these were rail facilities which could serve a large number of people.

There was one characteristic which was to prove to have a very important impact on the urban area. This was the fact that to initiate this form of transportation, it was necessary to invest considerable funds in the fixed facilities. In other words, it was necessary to place ties, rails, junctions, and all the other appurtenances of rail transport. All of this investment was necessary prior to the existence of any transport product. Simply, you had to build the railroad before you could move the train or streetcar. Because of this expense, it was not economically possible to construct rail facilities down every existing street or pathway. It was only possible to build a relatively few facilities. Since most of the communities grew from an existing town, from a joining of water and rail transport or the crossing of rail transport facilities, there was an obvious initial growth point. Since limited facilities could be built, it was obvious that these would be built from this point. Thus, as growth occurred, it was typical that the rail facilities radiated from what was to become known as the Central Business District (which was often adjacent to a central industrial district) .

As these lines were constructed, a second phenomenon occurred. New development occurred adjacent to these rail facilities. In addition, development often occurred at very high densities. The reason for this can also be related to transport technology. Travel along the rail facilities was quite efficient as compared to the alternate forms of land transportation available. Basically, people had to rely on walking to a rail facility. Thus, very high densities were developed in residential areas in order to accommodate the population and minimize the walking distance. In the mid-19th Century, it was not uncommon that 24 to 25 dwelling units would be constructed on a piece of ground about 100 feet in depth with about 25 or 50 feet of street frontage.

The radial shape of the transport system also created another phenomenon, and that was the development of the dominant central business district. As already described, the transport focused on this point and this became the most accessible area within the entire urbanized community. Because of its great accessibility, it became very valuable from a real estate standpoint and became a point that was common to the vast majority of residents. Everybody went downtown, if not to work, then to shop or to conduct other business. The value of the land, because of its accessibility, was later reflected in a tremendous investment in buildings and other improvements.

As industrial growth continued, the above-described characteristics intensified. Ultimately, the city that developed could be described as having a star-shaped development with the arms of the star radiating out from the center as illustrated in Figure 14. Farther out there was development around the immediate area of a station. In general, the cities were characterized by very high densities, both residential and in the central area. Further, they reflected a centralization of activity both industrial and commercial because of the pattern of the transportation system and the difficulty of movement on alternate systems. Thirdly, although the land in the immediate area of the rail facilities was intensely developed and although it might be a considerable distance from one edge of urban development on one side of town to the other, there were extensive undeveloped areas between the arms of urbanization. And, thus, the countryside was never too far away. This fact has numerous implications, one of which was the lack of necessity, at that time, to be concerned with open spaces in residential areas, a problem that now faces these same old high density developments.

Enter The Automobile

The city described in the previous section existed at least until the first-third of the 20th Century. By then, the technology existed which has caused another major change in urban transportation and has been reflected in urban form. This was the existence of the private automobile. Its impact was delayed throughout the 1930's because of the Depression and through much of the 1940's because of World War II and the recovery therefrom. However, when its impact came, it was probably all the more intensive because of these restrictions. The automobile provided a new transport technology which was relatively cheap, was attractive in many of its non-economic characteristics, and provided as fast an origin-to-destination service as the rail modes.

The automobile and truck had one technological characteristic which was to have major impact on the urban area. That was the ability to traverse virtually any kind of surface from a dirt path to a paved road. In truth, probably the unsung invention which has had more than its proportionate impact of the development of modern urbanization is the pneumatic tire. The fact that the automobile could traverse these different surfaces meant that it did not need investment in fixed facilities (normally provided by governmental agencies) to operate. Investment by the private individual in an automobile provided him with mobility within the urban area whether or not improved roads were provided. Although paved streets and, later the development of freeways, decreased the costs of travel, they were not necessary preconditions for mobility. It is probably true that if the automobile had required pave-

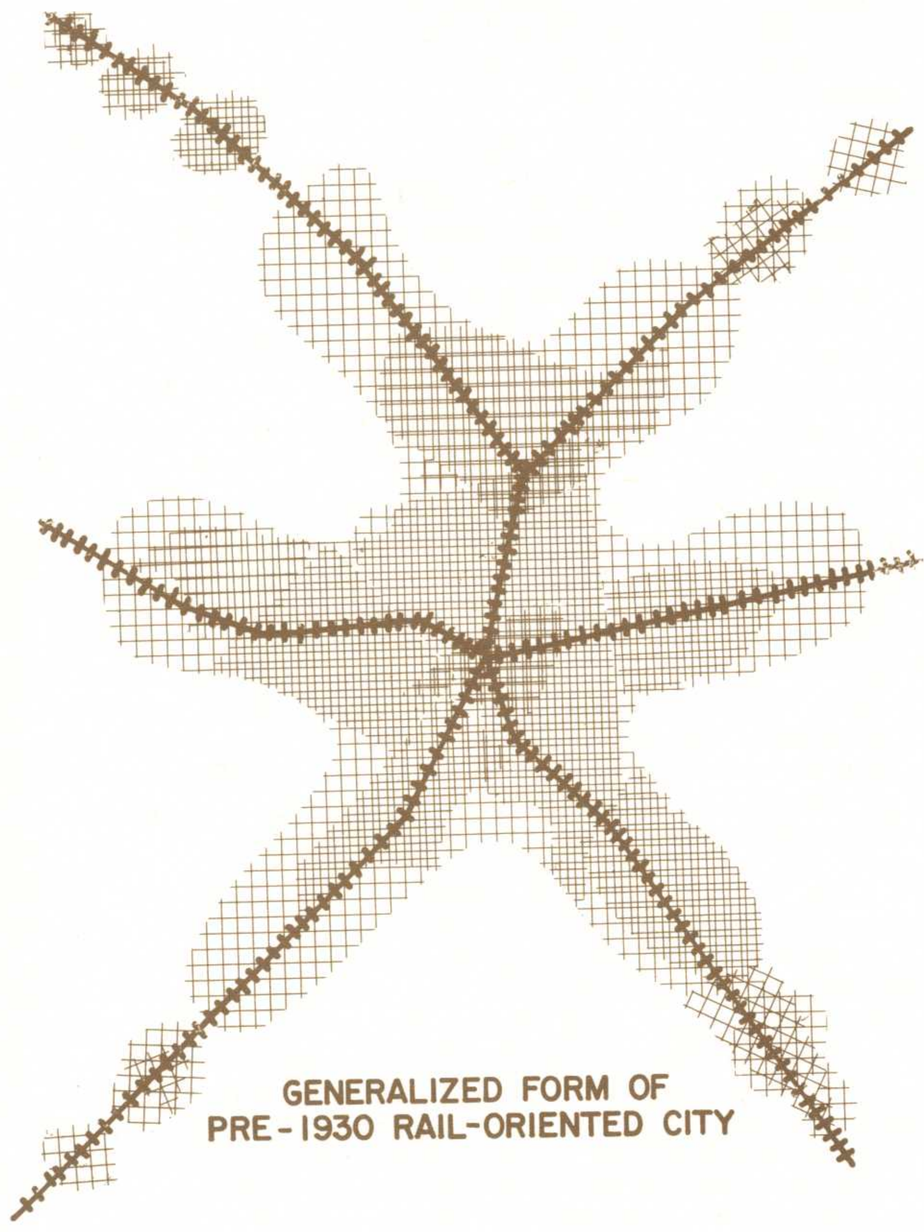


FIGURE 14

ment or freeways for its operation, the automobile would never have become as popular as it is today. Even in this latter half of the 20th Century, it is not uncommon for one urban trip to use multi-lane freeways and during the same trip traverse a dirt or gravel driveway or street.

The other characteristic of the automobile was that it resulted in congestion when demand brought large numbers together in one area at one time. Admittedly, modern freeways do provide high capacity facilities, but before the freeway era, it has to be admitted that the accumulation of large amounts of vehicular traffic or parking demands probably presented a negative factor with regard to the use of the automobile.

With the rapid increase of car ownership after World War II, and with the characteristic of the automobile being able to traverse any type of surface, this then freed the urbanite from living in close proximity to a rail line; in fact, it opened large areas between the arms of urbanization. The automobile ad no directional preference and could travel almost anywhere there was a dry surface. Therefore, in a very short period of time, vast areas of land were now accessible for development.

At the same time, very substantial increases in real income were realized in the United States. Many of the urban dwellers moved into these newly-accessible areas and built single family dwelling units at relatively low densities. There was, then, an equalization of the accessibility of all points within the urbanized area, and this, combined with their congestion problems, reduced the relative attractiveness of the central business districts and central industrial districts. Further, parallel improvements in communication, management science, and freight movement led to the decentralization of those industrial activities that, themselves, were in a period of rapid growth. This meant that many of the new industrial developments could and did occur outside of the central areas.

There is a very important point to be learned from the preceding discussion: that is, the relationship between urban form and transportation technology which constrained the early industrial city resulting in its star-shaped growth. It was the introduction of a more flexible transport technology which released these constraints. This made available great areas of land for urban development, but it did not require that this land was to be developed or that it would necessarily develop in a low-density fashion. Obviously, there were other forces at work including increasing affluence and our cultural heritage which determined the desirability of single-family, low-density developments. Thus, there is no reason to believe that the automobile caused such development; more correctly, it allowed it to happen. This philosophy not only describes the present, but also has considerable pertinence to the planning of future urban development.

The Phoenix Form

The Phoenix metropolitan area and others in the Southwest and West are unique in a number of ways. Phoenix must be one of the very few urbanized areas of its size which is not located on the seacoast, a navigable waterway, or even a main transcontinental rail line. Virtually the entire growth of the Phoenix metropolitan area has occurred since World War II and, thus, in the era of automotive transportation. The Phoenix metropolitan area does not have a central business district in the same sense as the traditional eastern city. If Phoenix ever had a dominant central area, it was one that served only a few thousand people.

The previous description of the development of an industrial city may apply to the majority of metropolitan areas in the United States but not to the Phoenix metropolitan area. A logical extension of that description would indicate that these older cities are currently caught in a period of major transition with regard to urban form and transportation demand. Their central business districts are becoming less dominant and, in many cases, only holding their own with regard to absolute size. Their retail activities are becoming dispersed, and yet, there are good political and economic reasons for trying to protect the previous investments in central areas. If the previous history is at all rational, it would indicate that this is probably, at best, a holding action, and that future metropolitan complexes will not have one single dominant center. No one area will have urban commonality for the entire urban population. In other words, there will be no one area which will bear common accessibility and experience for all urban dwellers or to which all urban dwellers will travel on a regular basis. The larger and older metropolitan areas of the United States are suffering substantial transportation problems and shifts in urban population and real estate values. The fact that it is transitional may be fortunate. As discussed in a previous chapter, the type of trip which has concentrated demand at one end and dispersion at the other is not efficiently handled by any existing form of transportation. Of all the future concepts available, it might adequately be served by only one group, that about which the least is known, the individualized, bi-modal form of transportation.

Thus, Phoenix's transportation problem and demand are uniquely different from most metropolitan areas. While their transportation problems became acute at a unique point (very early congestion problems in the central business district) and spread from that point, Phoenix's have not been of this nature and probably will not be. Phoenix's specific transport problems probably will occur in many places throughout the Valley. The problem of transportation system inadequacy, when it does develop, may develop not at one point in the system but in an area of much larger geographic extent. Thus, the occurrence and nature of Phoenix's serious transportation problem may be less likely compared to the growth of a piece of rock candy which starts at one point and progresses from there outward and more like a gelatin which remains fluid and then in a very short period of time the entire bowl gels.

There is a difference in the Phoenix metropolitan area, and it does not need to be documented here. The dispersion of retail activity, the low density of residential developments, and the dispersion of industrial employment is well known to any who have lived here for any period of time. It is indicated in Figures 2, 3, and 4. This is further substantiated by comparing Phoenix's travel pattern to those of other cities. Figures 15, 16, and 17 are an attempt to illustrate this point. These figures are constructed so that a particular area (zone) is selected and its travel characteristics are mapped. The numbers indicate the density of trip ends (in terms of number of trips per square mile in the destination zone with origin in the specific zone). Needless to say, there would be a very large number of illustrations if this were done for each and every zone in the urban area. These zones were selected more or less at random for illustrative purposes. A comparison of the illustrations will indicate that the density of trip ends decreases relatively uniformly from a zone in the Phoenix metropolitan area as one proceeds away from that zone. Although there is some indication of increased density near the central corridor of Phoenix, it is not acute. The other urban area selected for this analysis was Detroit, Michigan. This represents an area in the older industrial region of this country, and yet, one that may be more automobile-oriented (because of its own industrial history) than cities like Chicago, St. Louis, Cleveland, and others. Nonetheless, a very brief inspection of Figures 18 and 19 will lead one to the identification of the location of the central business district and illustrate its high attraction rate for peripheral areas.

There is every indication that at least for the next 20 to 25 years, the Phoenix metropolitan area will continue to grow in a dispersed pattern. Figures 20, 21, and 22 indicate the expected residential, employment, and retail sales pattern as forecasted for 1980. Barring a national disaster, there are probably no basic factors on the foreseeable horizon which would lead one to predict a major shift in lifestyle in this area. The

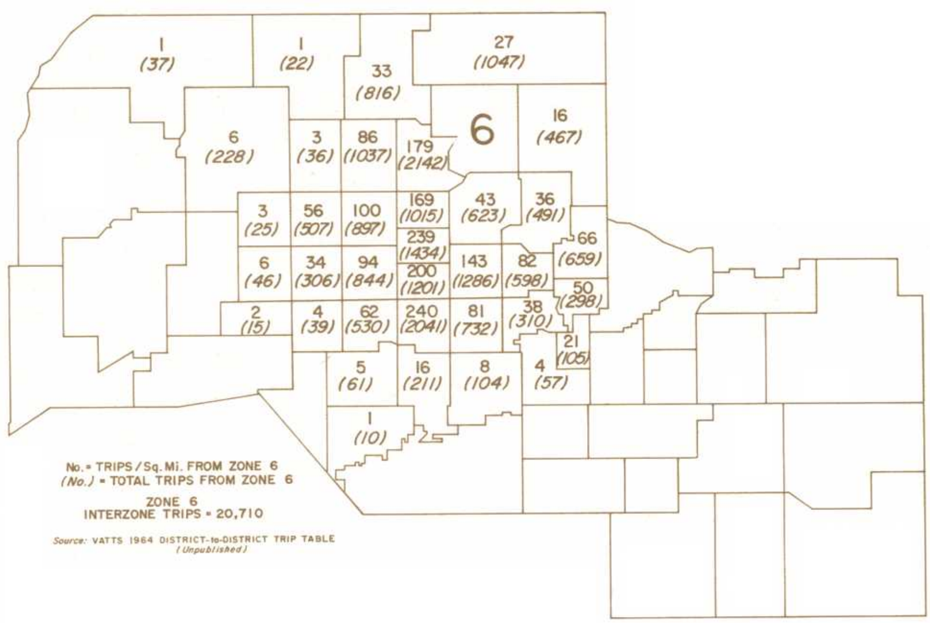


FIGURE 15

Distribution of Trips To and From Zone 6 – Phoenix

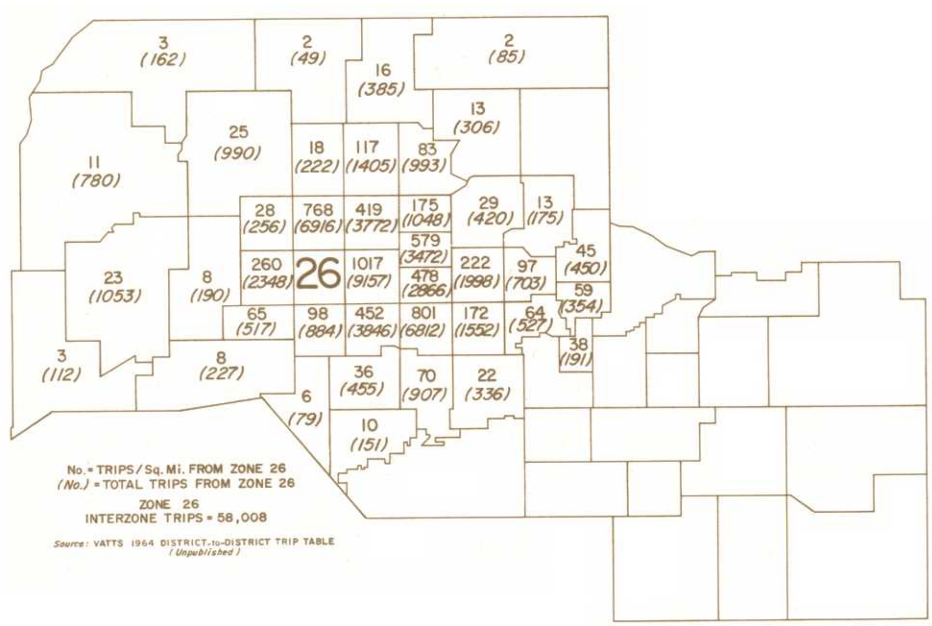


FIGURE 16

Distribution of Trips To and From Zone 26 – Phoenix

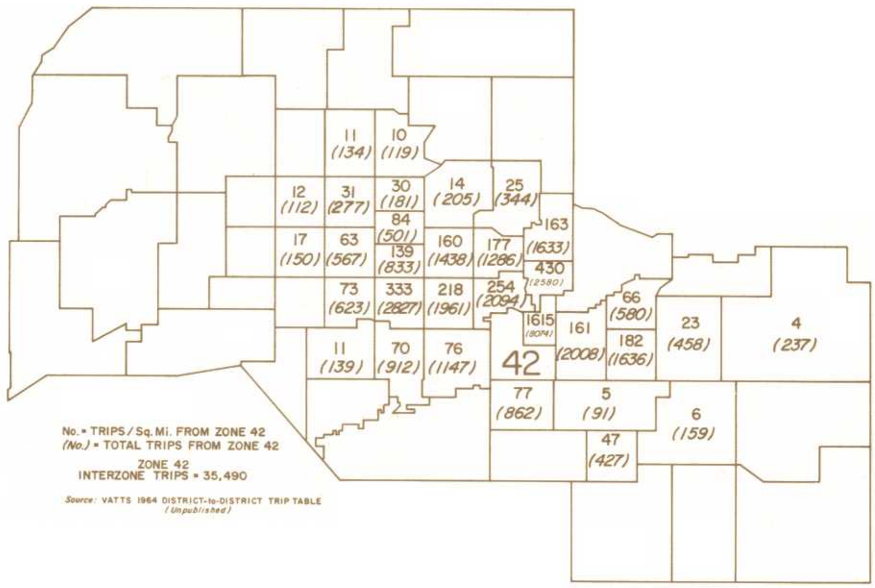


FIGURE 17

Distribution of Trips To and From Zone 42 – Phoenix

problem of the disappearance of land for urban development which may occur in the northeastern part of the United States when metropolitan areas impinge, would not affect this area within the next 25 to 30 years, and, probably, for a considerable period thereafter.

The growth reflected in Figures 20, 21, and 22 will produce an increase of several fold in the transportation demand within the Valley. Although the facilities in the central portion of the metropolitan area will still have the highest demand and will continue to carry increased transportation, no matter what the mode, the major increases, both numerically and proportionally, will occur in the more outlying areas. This is illustrated in Figures 23, 24, and 25 which indicate the growth in forecasted transportation demand between 1964, 1980, and 1995.

In looking at any particular portion or in analyzing any particular corridor of the system, one must be careful not to be misled concerning the type of transportation demand that has been illustrated. Although specific corridors and specific facilities have substantial flows of traffic, these flows are uniquely different than those that one is historically used to seeing in the industrial star-shaped city or the transitional city of the East. The trips represented at any given point within the corridor are not trips with a common origin or destination, or are not trips which even have a common set of origins along a corridor, They are trips which come from a wide hinterland on one side of the point and are destined to a wide area on the other side. They cannot be considered a homogeneous transportation flow. This is illustrated in Figure 26. This identifies the traffic which shares a specific link within the system. This might be a stretch of freeway between two interchanges. It considers all the traffic that passes through that road section. As seen in Figure 26, traffic can be

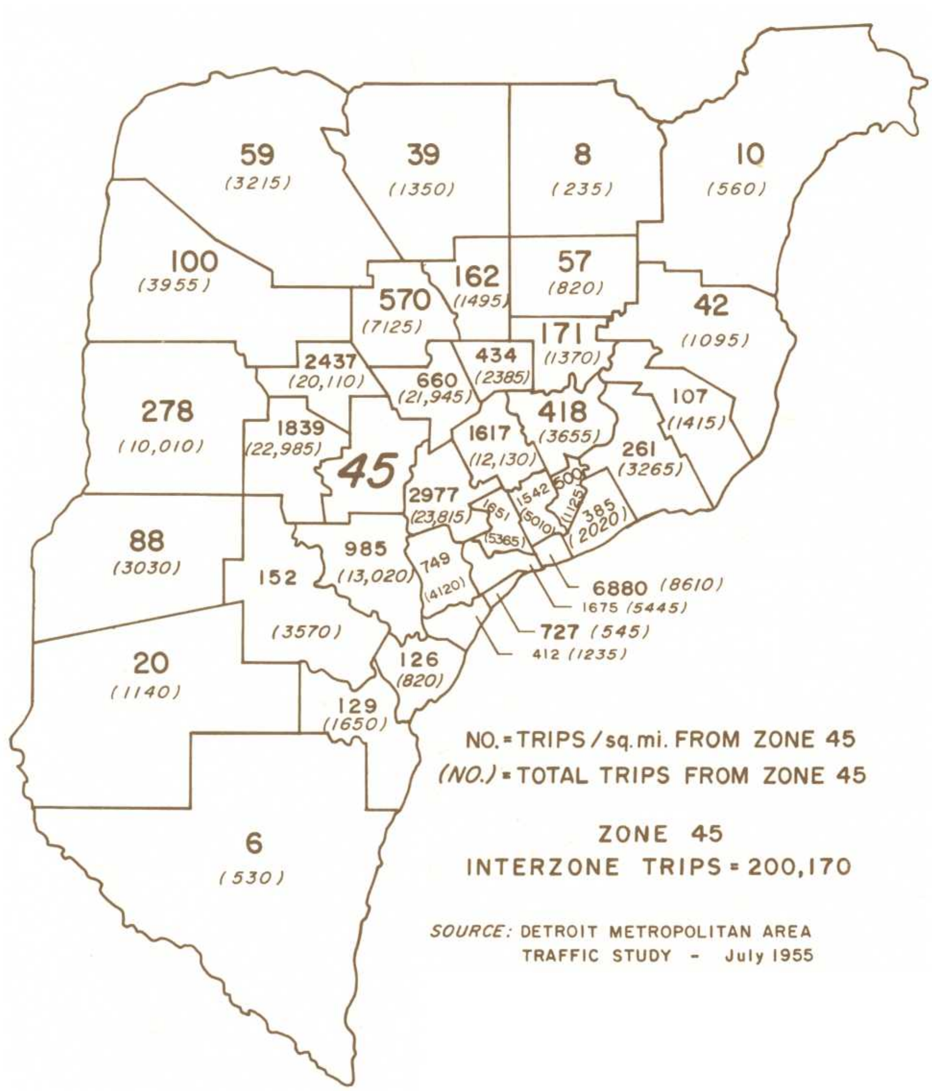


FIGURE 18

Distribution of Trips To and From Zone 45 — Detroit

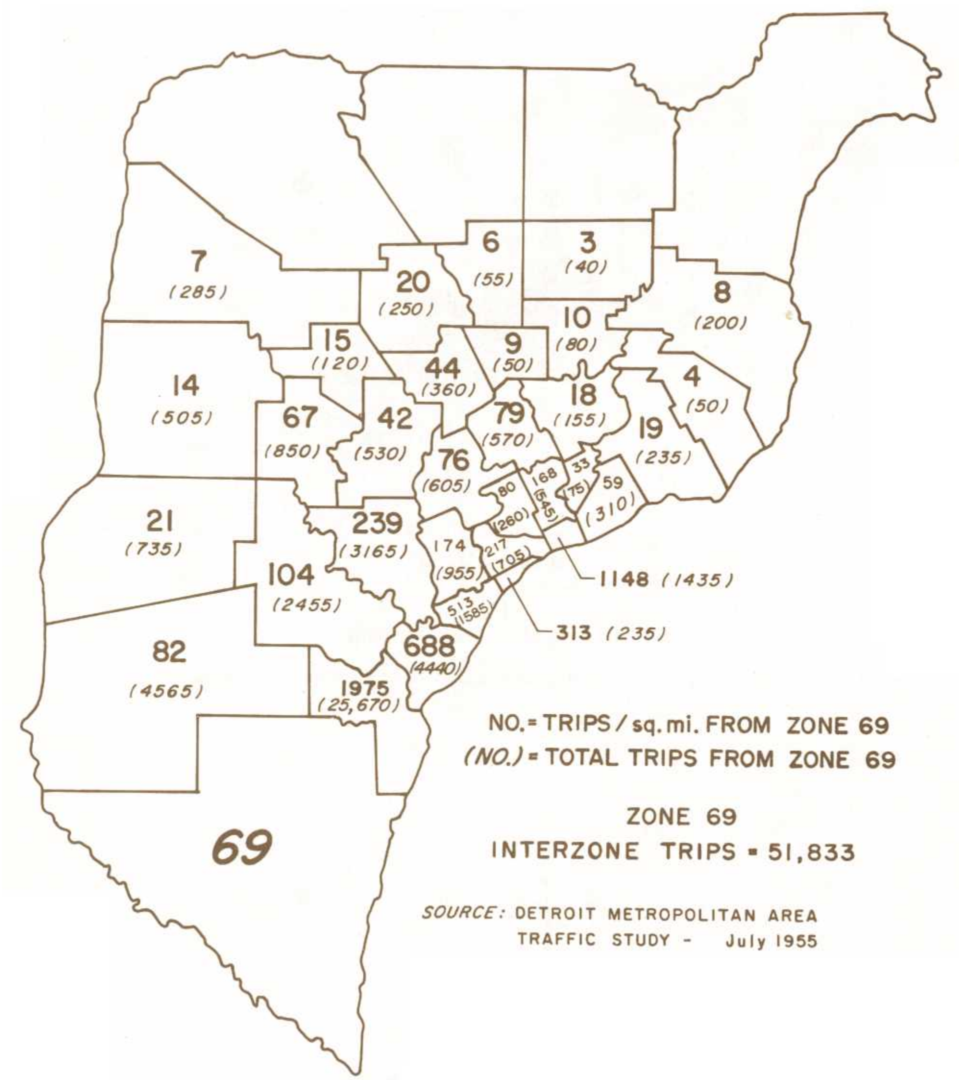


FIGURE 19

Distribution of Trips To and From Zone 69 — Detroit

made up of individual trips from a very large number of origins to a very large number of destinations. This is the type of trip described in Chapter I as having an extensive collection and distribution function.

If all the present forecasts are even close to being true, then it is evident that the Phoenix metropolitan area will have transportation demands which are dispersed. This would indicate that research and in-

FIGURE 20

1980
Living Unit Distribution

Source: Valley Area Traffic and Transportation Study (unpublished data).

FIGURE 21

1980
Employment Distribution

Source: Valley Area Traffic and Transportation Study (unpublished data).

FIGURE 22

1980
Retail Sales Distribution

Source: Valley Area Traffic and Transportation Study (unpublished data).

vestigation and pilot projects should probably be aimed at forms of individualized transport and bi-modal systems. That such systems have their problems is without argument. But, if it can be established such systems would best meet the needs of the Phoenix metropolitan area, then the proper emphasis and investment can be placed on solving the specific problems. A good illustration of this is the recently-completed analysis of transportation in the Phoenix Inner City area. Certainly, the economically disadvantaged are restricted by lack of mobility with the existing system of individually owned vehicles. Studies similar to those in the Phoenix Inner City are being conducted in other cities, and at least one would indicate that the overall advantages of an individually owned vehicle are such that such a vehicle will be purchased almost as soon as the individual reaches even the fringe of economic viability.

After extensive analysis of a number of alternatives, some quite sophisticated in their operations, the Phoenix Inner City Study recommended: 1) the provision of transportation service to assist individuals in searching for employment, 2) the improvement, where possible, of existing bus service, and 3) the continuation of a successful pilot program which helps individuals purchase their own vehicle once they've found employment.

There is one over-riding problem with urban dispersion: it is very

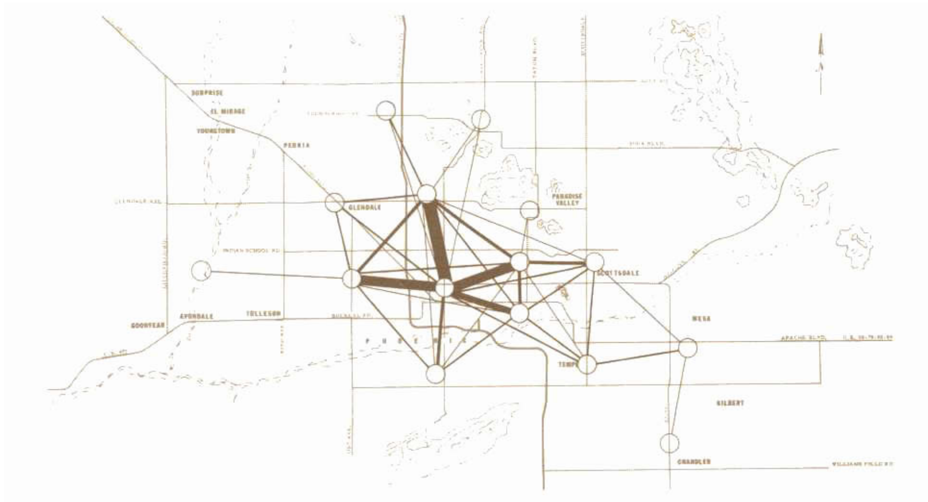


FIGURE 23

1964
District -To-District
Desire Line

Source: Valley Area Traffic and Transportation Study, *1969 Annual Report,* Page 11 – September 1970.

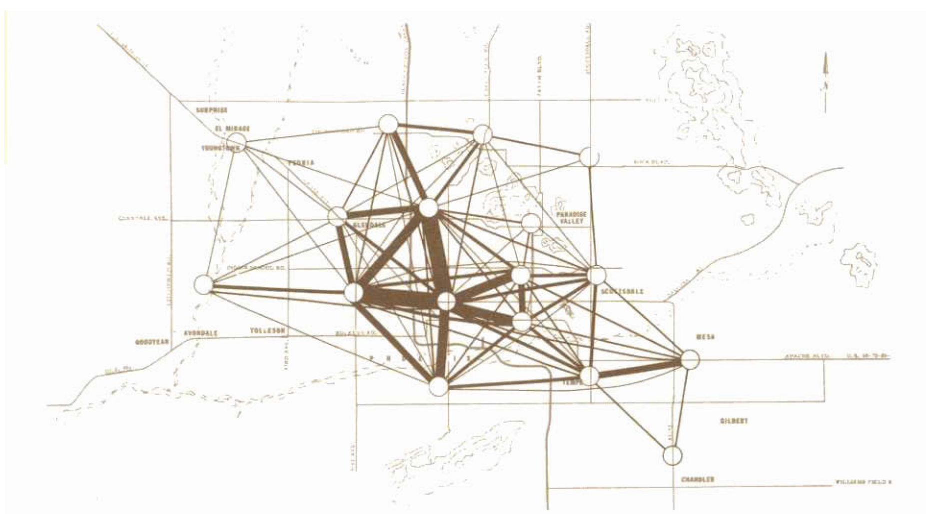


FIGURE 24

1980
District -To-District
Desire Line

Source: Valley Area Traffic and Transportation Study, *1969 Annual Report*, Page 11 – September 1970.

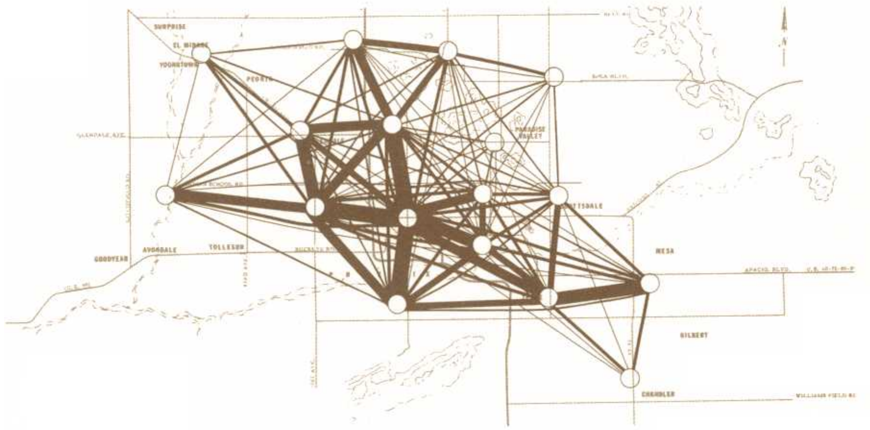


FIGURE 25

1995
District-To-District
Desire Line

Source: Valley Area Traffic and Transportation Study, *1969 Annual Report*, Page 11 – September 1970.

easy to allow it to happen, but, possibly, quite difficult to arrange for it to develop in an acceptable fashion. The following section will indicate the problems which can be identified now.

The Future: The Basic Community

If dispersion is to occur, it is important to identify what dispersion is and what it is not and to try to identify some of the future pitfalls which will have an impact on transportation but may be avoidable by action of local government. First, dispersion is not necessarily related to density. The opposite of dispersion is concentration, but in the context used here, it means concentration and commonality. Concentration means concentration of all activities of one kind in one area. It means placing all of retail in one area, or all libraries in one area, or all governmental activities in one area. Certainly, a large regional shopping center is a concentration of retail activity, but not retail activity which is common to the entire metropolitan area. Therefore, dispersion is an area-wide phenomenon, and the entire urbanized area has to be considered in making evaluation as to whether substantial dispersion of concentration is taking place or not.

Dispersion is usually directly connected in people's minds with low density since in most areas of this country the two have occurred to-

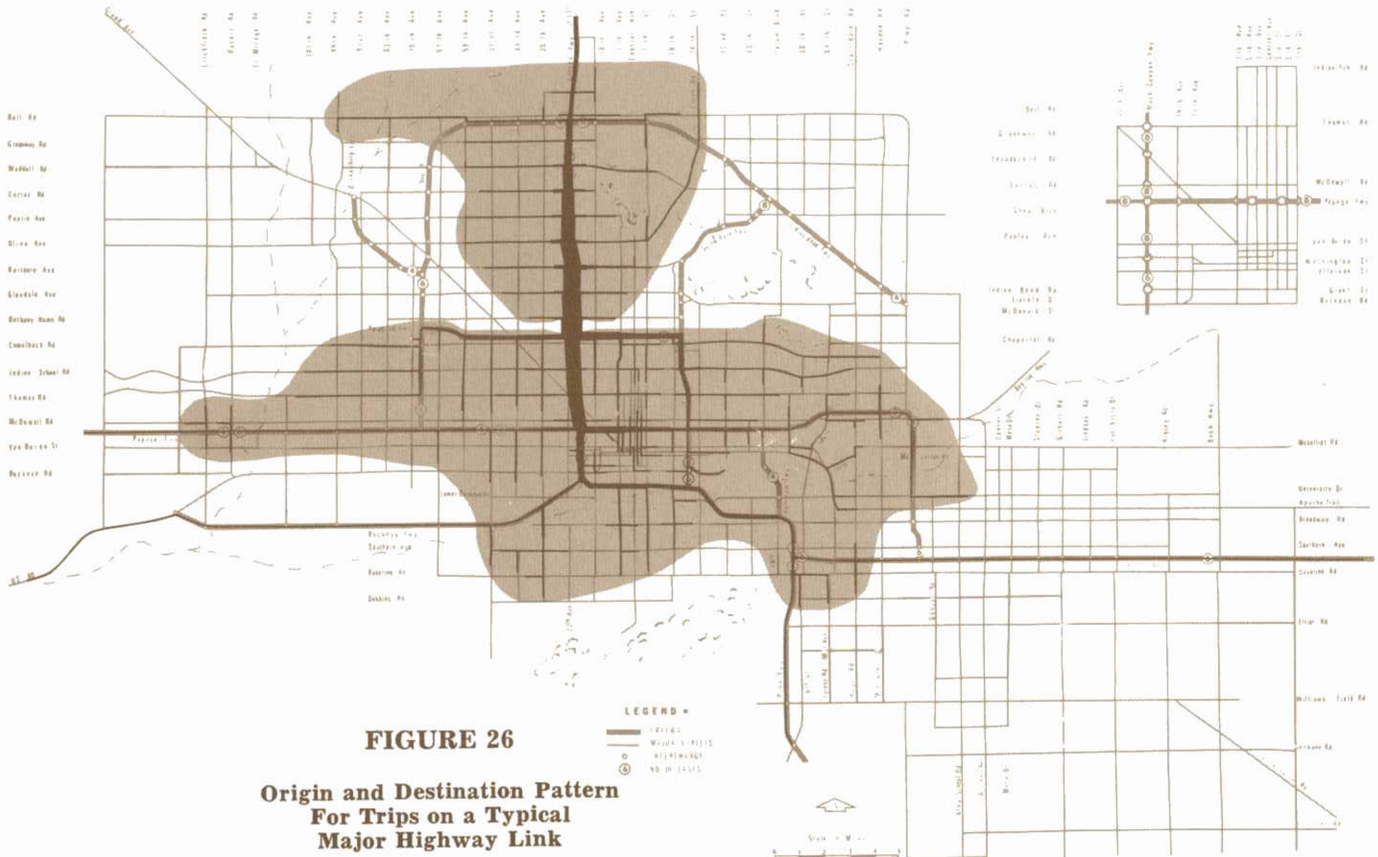


FIGURE 26

Origin and Destination Pattern For Trips on a Typical Major Highway Link

Source: Valley Area Traffic and Transportation Study (unpublished data).

gether. They do not necessarily have to occur together. It is possible to have a very high-density activity, residential or other, in a dispersed pattern. These might be surrounded with park area or low-density development. The previously mentioned large regional shopping centers are an example of a highly intensive activity, and yet, the centers are dispersed throughout the urban area. Conversely, relatively low density concentrations might be possible if one could conceive of an urban area with modern, one-story industrial plants with their surrounding parking and open space all collected into one section of the metropolitan area. Here, the density might be no higher than in dispersed patterns, but, certainly, there would be concentration and the formation of one area which would be common on a regular basis to the majority of the urban workers.

To take an extreme case to illustrate the point of dispersion and density, a community could be designed so that all business and industry is located on one side of the town and all residences on the other. This would have a major impact on the transport system demand and the selection of the best mode whether or not the development was low density or high density.

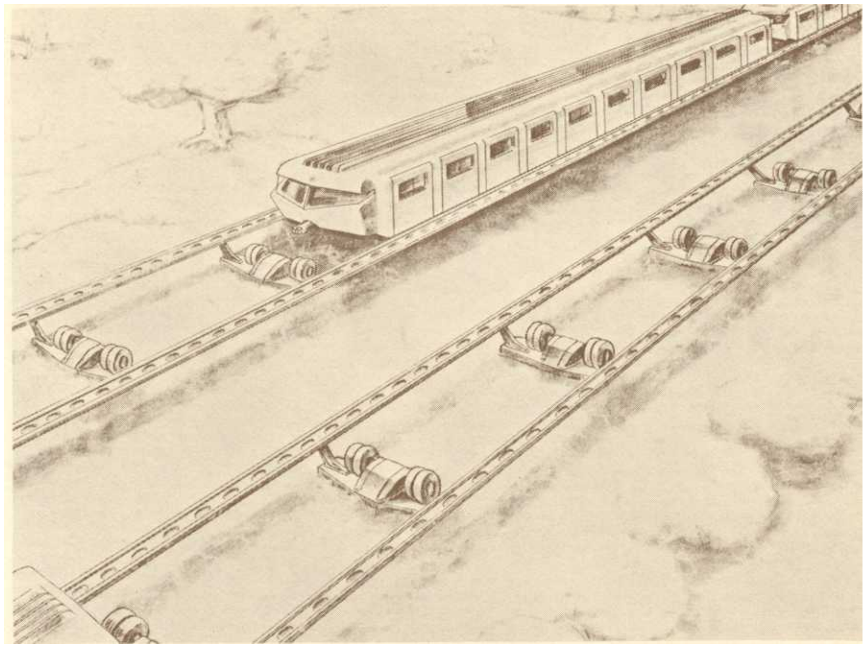
This difference between dispersion and density results in different types of transportation problems. A tendency toward concentration and development of a point of commonality has a system-wide effect. Theoretically, trip lengths will have to increase since a large proportion of trips are to common point. The demand function around that area will warp the entire system so that extensive facilities will be required in the immediate area and for some distance from the concentration. This will be true whether the concentration is high density or low density, although it may be somewhat more acute for high-density concentration. On the other hand, the introduction of a high-density use within a dispersed pattern will generally have very little effect on the overall transport system, or demand picture. Needless to say, it could cause very acute problems on transportation facilities in the immediate area, but effects would probably be felt for no more than a mile or so. Thus, the exact location of one high-rise office building or one high-density residential complex or a regional shopping center will not significantly change the overall requirements of the transportation system, although their local effect could be considerable.

Based on all preceding chapters and the immediately-preceding discussion, it would seem that if the urban area is to be dispersed, then individual occurrences of high-density development do not have a significant transport system impact. However, concentration would lead a city into a form similar to that described for the eastern cities which are now in transition and could distort the transportation demand into a form that would have severe system implications.

It is often argued that there are still functions which need to be concentrated. In the sense that the term has been used here, this is to be questioned. Certainly, industry and retail activity have illustrated the advantages of dispersion. Currently, it is in vogue to have office functions concentrated in a specific area. It is probably true that such functions, unlike industry, benefit from being concentrated in a high-rise, high-density, high-intensity structure. Commonly, at this time, these structures are being grouped together to form concentrations. It is not clear, however, that this should be the case, and it may be true that when the impact of modern communication and techniques have their ultimate impact on the business community, the current desire for concentration may disappear.

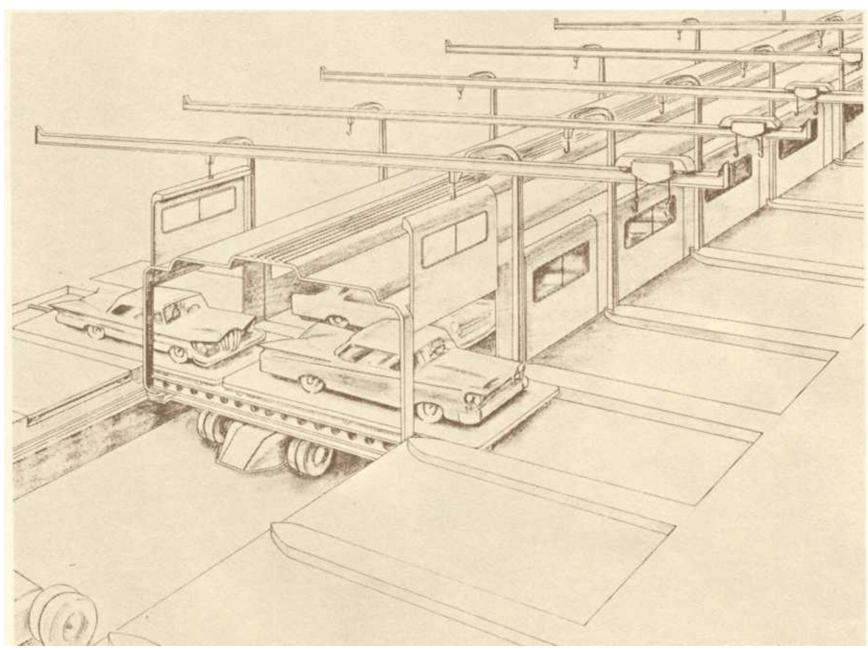
Currently, there are also attempts to concentrate cultural and governmental activities. Concentration should not be confused by the case where only one facility is required. The argument has often been made, regarding retail activities, that there are certain stores which require the population base of the entire community in order to exist; therefore, these would be located in the central part of the community in order to be equally accessible to all. This can be a fallacy. Although a very large population base may be very necessary to support a unique retail establishment because of residential patterns, the people that support this store may not be dispersed throughout the community. Thus, the exclusive shop is much better located in the part of the city which houses the type of people who patronize it. A local illustration is the location of Scottsdale's Fifth Avenue specialty shops. There may be just one of a kind for the metropolitan area, but it is much better located in the center of its particular customer area than in the center of the Phoenix area. This then weakens the argument that an art gallery or theater or other unique activity needs to be centrally located. In addition, there should be questions raised about the uniqueness of some of these activities. Although a large, central library may be desirable, if the desire or function is to encourage use by all of the residents of the urban area, it might be much more desirable to provide a number of smaller libraries. Instead of providing an elegant concert hall, it might be better to develop techniques by which the city's symphony orchestra could perform in smaller auditoriums using facilities throughout an urban area.

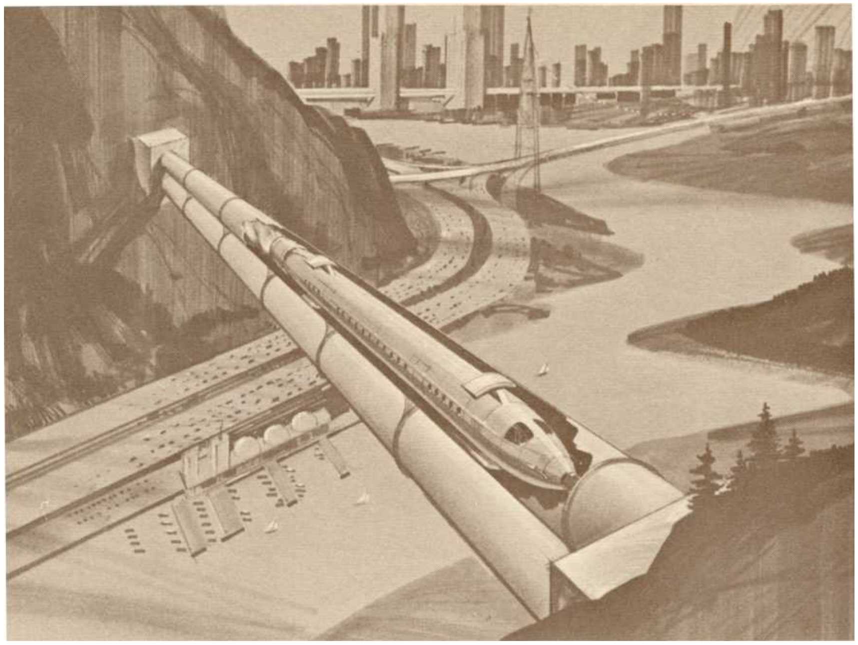
This brings one to the final bastion of centralization, the govern-



The Rolling Road – Westinghouse Electric Corporation
Courtesy U.S. Department of Transportation, Federal Highway Administration

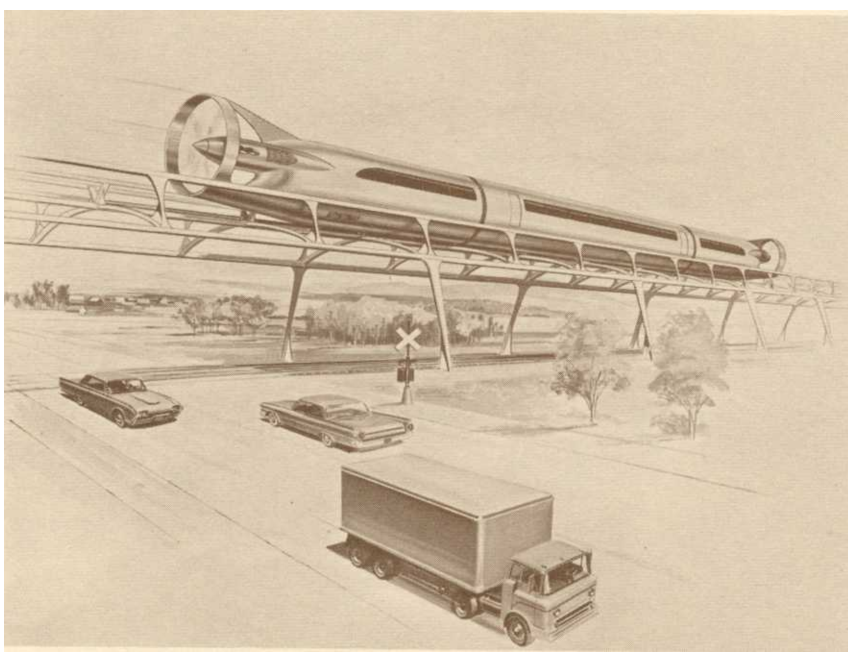
The Rolling Road Terminal – Westinghouse Electric Corporation
Courtesy U.S. Department of Transportation, Federal Highway Administration





Tubeflight Vehicle
Courtesy Rensselaer Polytechnic Institute

Levacar
Courtesy Ford Motor Company



mental complex. Since the end of the 19th Century and Daniel Burnham, the concept of the centralized elegant government complex has been with us. Serious consideration should be given to their appropriateness for the future. They are often aloof, cold, and have difficult access. They may lead people to think of local goevrnment in the same terms. It would seem that recent problems in cities would be enough to indicate that local government might develop more decentralization of function and greater accessibility to not only the elected officials, but also, the bureaucratic functions.

The advice for the Phoenix area (in the context of transportation demand) would be to avoid concentration and, thus, avoid backing into the situation faced by many large metropolitan areas today. Plans for tomorrow often reflect today's problems and are based on yesterday's traditions. It seems that every generation or era looks back on that preceding and identifies it as good and secure when, in reality, memory has dulled or history forgotten the troubles and tribulations which caused the people of that preceding era to move in different directions. Decision-makers must ask themselves whether concentration and dominant districts are really, functionally, what will be needed in the future or if they are carry-overs of the historic desire for monuments. More critically, are they an admission of the ability to provide only a small, limited area which can be a pride for the community and the inability to develop the community as a whole?

Currently, for most urban areas, including Phoenix, the one type of concentration which is increasing in importance and which at this time seems to be defying dispersion, is the airport. It may well be that the airport in Phoenix, more than any other single location within the Valley, represents a point of common experience for the population. Thus, it is not inconceivable that in the future, the airport may develop some of the transport problems which are normally expected of a central business district. These problems should have considerable attention. The possible solution to this particular problem is beyond the scope of this report, but it should be noted that the Los Angeles metropolitan area is considering what, in essence, might be called "decentralization of airport activity."

What develops from dispersion might be called "accumulation of communities." These communities would contain such urban activities that they could be substantially self-supporting. This idea of a community might be related to the new town development in Great Britain and in Europe. This same concept is reflected, locally, in the development of Litchfield Park. These new towns, although normally near the major metropolitan area, were planned to be essentially self-contained and surrounded by open area. They, therefore, contain not only governmental, cultural, recreational, and retail activity, but also, very importantly, employment opportunities for the residents. In the new towns surrounding London, one virtually has to be employed in the town in order to obtain a residence there.

The size of these communities varies considerably, and there has been much academic argument over the ideal size for an urban development. However, British experience would indicate that the originally-planned towns were too small, in the neighborhood of 40,000 or 50,000, and current towns being planned and developed are often 150,000 to 250,000 people. The importance is that they are planned as a unit.

In the United States, many references identify the neighborhood as the basic unit. It seems that this may be too small a unit from which to build a viable urban area. One weakness throughout the country has been the lack of emphasis given to industrial base. The basic "reason to be" for an urban complex is to collect people in such a way that they can enjoy a better life and earn a better livelihood. In addition, because of the specific and often quantitative requirements of industry, its future location is often much easier to forecast than the location of other urban developments. The following quotation should illustrate that this problem is current and not confined to any one area:

> "It should not diminish admiration for the work of the Douglas Commission; for example, to note that its report, 'Building the American City,' is building a city without industry."[31]

It is one thing to design and build isolated new towns such as those in Britain; it is quite another to consider the community as a basic building block of a large, continuous urban area. It is conceivable that communities could be built adjacent to one another with no intervening area. Furthermore, such communities might not necessarily have to have such rigid boundaries – the boundaries could become somewhat hazy. At this point, each resident would envision his own community as that in which he operates. The actual boundary might be somewhat ill-defined. It might change with time and might be different for different functions. One's social community might be defined by one boundary, his retail community another, and so on. In addition, his community boundaries would be somewhat different than his neighbor's, but there would probably not be a great deal of difference.

Specifically, this type of community concept can apply to the dispersed urban area and, probably, applies to the Phoenix area today. The concepts reflect no point of commonality for everyone. It reflects a dispersion of activities. It uses a dispersion in space rather than a staggering of hours to gain some respite from the peak-hour transportation problem.

A basic question for Phoenix might be the application of such a concept and its implementation in the day-to-day decisions regarding urban development. It means greater attention paid to the quality of each community throughout the urban area. It means serving these communities with the proper transport technology.

In conclusion, the basic issues of tomorrow's transportation problems in urban areas resolve themselves into questions of dispersion versus centralization and of density – in other words, questions of land use. This chapter has tried to identify some of the questions regarding the Phoenix metropolitan area. Once these questions are answered, many of the decisions regarding specific mode will also be answered. One thing seems certain, and that is for the planning period under consideration, 25 to 35 years, ground transportation will retain its dominance as far as urban transport is concerned and that all ground transportation requires right-of-way. Therefore, the reservation of corridors of land for transportation facilities must rank high on the list of transportation priorities.

Footnotes

FOOTNOTE

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[5] *Traffic Engineering*, Vol. 39, No. 7, April, 1969, p. 51.

[6] U. S. Department of Housing and Urban Development, *Tomorrow's Transportation*, (Office of Metropolitan Development, Urban Transportation Administration, Washington, 1968), p. 52.

[7] *Product Engineering*, Vol. 39, No. 25, December 2, 1968, pp. 46, 48.

[8] Edward L. Trom (ed.), *Popular Mechanics' Picture History of American Transportation*, (New York: Simon and Schuster, 1952), pp. 103-109.

[9] Wilbur Smith and Associates, *Transportation and Parking for Tomorrow's Cities*, (New Haven: 1966), pp. 125-128.

[10] A. Q. Mowbray, *Road to Ruin*, (New York: J. B. Lippincott Co., 1969), p. 208.

[11] Bay Area Rapid Transit District, *Official Statement Relating to: $70,000,000 San Francisco Bay Area Rapid Transit District – General Obligation Bonds Series J,* 1968, p. 24.

[12] Mowbray, *op. cit*., pp. 208, 213.

[13] Wilbur Smith and Associates, *Future Highways and Urban Growth*, (New Haven: February, 1961), p. 125.

[14] Mowbray, *op. cit*., p. 77.

[15] City of Phoenix, *Personalized Transit Study – History of Mass Transit and Travel Time Studies for Automobile and Transit*, June, 1969, pp. 18-20; Wilbur Smith and Associates*, A Major Street and Highway Plan – Phoenix Urban Area – Maricopa County*, May, 1960, p. 43.

[16] *Civil Engineering*, Vol. 40, No. 1, January, 1970, p. 55.

[17] Hal Hellman, *Transportation in the World of the Future*, (New York: M. Evans and Co., 1968), pp. 28-29; U. S. Department of Housing and Urban Development, *op. cit*., p. 40.

[18] B. R. Stokes, "Bay Area Rapid Transit," *Highway Research Board Special Report 111*, (Washington: 1970), p. 4; *Annual Report San Francisco Bay Area Rapid Transit District 1967-1968*, pp. 10-12.

[19] John F. Curtin, "Effect of Fares on Transit Riding," *Highway Research Record No. 213*, (Washington: Highway Research Board, 1968), p. 18; *1968 Highway Needs Report*, (Washington: U S. Government Printing Office), p. 27.

[20] American Transit Association, *1968 Transit Fact Book*, p. 6-10.

[21] Michael A. S. Blurton, "Special Bus Service," *Traffic Engineering*, Vol. 37, No. 5, February, 1967, pp. 17-21.

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[24] Neal A. Irwin, "Public Transit and the Quality of Urban Living," *High Speed Ground Transportation Journal*, Vol. 3, No. 1, January, 1969, pp. 117-118.

[25] *Ibid*., pp. 121-126.

[26] *Ibid*., pp. 137-138; Hellman, *op. cit*., pp. 122-127.

[27] Gordon A. Shunk and Richard J. Bouchard, "An Application of Marginal Utility in Travel Mode Choice," presented at 49th Annual Meeting of Highway Research Board, Washington, D.C., January, 1970.

[28] Thomas C. Thoma and Gordon I. Thompson, "The Value of Time for Commuting Motorists as a Function of their Income Level and the Amount of Time Saved," presented at 49th Annual Meeting of Highway Research Board, Washington, D.C., January, 1970.

[29] Stanley J. Hille and Theodore K. Martin, "Consumer Preference in Transportation," *Highway Research Record 197*, Highway Research Board, Washington, D.C., 1967, p. 39.

[30] Arthur B. Gallion and Simon Eisner, *The Urban Pattern*, (New Jersey: D. Van Norstraud, 1963), Chapter 2.

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