Traffic Patterns and Land-Use Alternatives

ALAN M. VOORHEES, Alan M. Voorhees and Associates, Inc;
CHARLES F. BARNES, Jr., Automotive Safety Foundation; and
FRANCIS E. COLEMAN, Connecticut State Highway Department

• FOR SOME TIME it has been recognized that travel in urban areas is related to the land-use activities in these areas. It is logical to expect, then, that transportation requirements are influenced by the way the land-use activities are arrranged in the metropolitan area.

It has also been brought out in the past, particularly by studies made in the Baltimore area, that average trip length increases as transportation service improves. For example, in 1926 the average work trip length in the Baltimore area was 2.6 mi; in 1946 it had increased to about 4 mi; and today it is over 5 mi. This continued increase in trip length is attributable, in a large degree, to the improved transportation service in the Baltimore area (1).

The key point is that the average trip length directly affects the transportation requirements. Given a substantially fixed number of trips, trip length dictates the vehicle-miles of travel on the street system. If the average trip length could be halved, the vehicle-miles of travel and the traffic volume would, in effect, also be cut in half.

From a transportation point of view, to reduce trip length and therefore travel, it is essential to know what factors influence trip length and to understand how these factors work.

Some authorities feel that the reduction of transportation requirements is not the primary objective, believing that the important thing is an increase in mobility, per se. However, if increased mobility does not provide additional service, it holds no advantage. There is no benefit in traveling seven miles to work rather than five unless the job opportunities or choice of residence are increased thereby. On the other hand, if it is possible to reduce the average trip length, while providing similar opportunities, the city in fact has been made more convenient. Here certainly is a worthwhile objective.

This paper therefore attempts to describe (a) what factors influence trip length, and (b) what can be done to minimize trip length and thereby reduce urban transportation requirements.

FACTORS INFLUENCING TRIP LENGTH

Several attempts have been made recently to quantify the relationships between level of service and land-use arrangements on one hand, and average trip length on the other. Because it is practically impossible in an actual field test situation to isolate all the variables present in order to obtain a comparable analysis, most of these studies have been based on the use of mathematical models. In this approach, mathematical formulations are developed to simulate conditions under various assumptions of land use and transportation system arrangements.

The most recent of these attempts is the Hartford Area Transportation Study, conducted cooperatively by the Connecticut Highway Department, the City of Hartford, the Capitol Region Planning Agency, and the U.S. Bureau of Public Roads (2, 3). By use of the gravity model for traffic simulation and an urban growth model to simulate land-use development, projections were made of land use and traffic under several different sets of assumptions.

With additional data from similar analyses made during the Baltimore-Washington Interregional Study (4), it is now possible to state with fairly firm conclusions the interrelationship between land-use arrangements, level of transportation service, and vehicle-miles of travel.

Level of Transportation Service

In the Hartford Area Transportation Study, projections of land use and traffic were made for the years 1965, 1975, 1990, and the horizon year (5). The land-use projections were made under the assumption that the forces presently shaping the urban area (zoning, economic and political factors, etc.) would continue into the future with no substantial change. In effect, it was considered that the growth of the urban area would continue in the future much as it had in the past—the only exception being a greatly expanded freeway system, resulting in a higher level of transportation service. From the traffic analyses for these various land-use patterns it was evident that the growth of traffic was greater than the growth of population, car ownership, or any other factor.

For example, it is estimated that between 1960 and 1975 the population will increase 37 percent, car ownership 61 percent, and vehicle trips 57 percent. However, in this same period, vehicle-miles of travel will increase an estimated 99 percent. It is evident that the major part of the vehicle-mile increase is associated with average trip length, which it is estimated will increase 34 percent during this period. Because this increase is based on a continuation of the existing land-use pattern it must be the result of changes in the transportation system.

Furthermore, by relating the trip-length increase comparatively to desire line and network assignments, it is possible to determine that about 10 points of the 34 percent increase is associated with out-of-direction travel, the other 24 points being due strictly to better transportation service.

Parenthetically, engineers for many years have been adding a factor onto traffic forecasts to reflect unexplained but measurable increases. These increases, generally termed "induced" or "generated" traffic, have ranged from about 25 to 50 percent, depending on the change in level of service, with the usual figure being about 30 percent. This, of course, is very close to the increase observed in the Hartford analyses.

The conclusion that trip length and level of service are interrelated confirms the findings of other work in this field (6). However, by using a model approach it is possible to predict with considerable accuracy the extent of the change in vehicle-miles of travel as the level of service is raised.

Land Use

Various studies have pointed out that, through the proper arrangement of land uses, travel requirements could be materially reduced. For example, the high-density residential development near high-density employment centers should cut the volume of work travel. Two recent investigations, the Baltimore-Washington Interregional Study and the Hartford Area Transportation Study, have undertaken projects to measure, quantitatively, the effect of alternative land-use developments on the regional transportation system requirements.

Regional Approach.—The Baltimore-Washington Interregional Study, in an effort to determine the influence that regional land-use patterns have on urban travel, analyzed four different alternatives and made separate projections of population and employment for each alternative. The land-use projection was made on the basis of an urban growth model, developed in connection with this study; and a traffic model, similar to the one used previously in the Baltimore area was used for estimating travel desires. The alternatives considered were the following:

1. Extension of existing planning policies in the area.
2. Policy revision that would permit a doubling of suburban residential densities while holding constant the densities of existing built-up areas.
3. Establishment of a policy specially designed to encourage high-density development in the central cities and along a theoretical transit system between Baltimore and Washington.
4. Establishment of a regional policy to disperse new employment whenever possible.

The chief conclusion drawn from the traffic analysis of these alternatives is that general changes in land-use patterns in the outer areas will not have a substantial impact on peak-hour highway demands. Peak-hour traffic as projected in the first alternative (the continuation of existing trends) would be reduced only a few percentage points by following the second or fourth alternatives. But by following the third alternative, involving radical changes in density and highway capacity restrictions in the downtown area, really substantial reduction in auto travel could be brought about. However, the bulk of the reduction in auto travel that might be gained with the third alternative is attributable to greater use of transit. The length of the average work trip was about the same for all four alternatives. This means that if a rapid transit system is built in keeping with the third alternative, increases in employment and population densities along these routes will cut auto travel. The remarkable similarity of trip lengths between the various alternatives tested in Baltimore and Washington are especially significant because the plans tested were quite different in nature.

It would appear that this finding stemmed from the fact that large zones were used. Quite often the travel time between zones was in the neighborhood of 10 min. Therefore, the different patterns that were analyzed in Baltimore and Washington were related largely to land-use activities more than 10 min apart. As can be seen by the travel time factors used in the gravity model calculation (Fig. 1), the curves have a moderate slope beyond 10 min, whereas for travel time of less than 10 min the curves are very steep.

It is apparent from these curves that travel time is relatively critical for zones that are located less than 10 min apart whereas travel is comparatively independent of travel time for zones over 10 min apart. For example, a 2-min change in travel time orientation, say in, the 0- to 10-min range, will have a great effect on the number of trips between zones. On the other hand, a 2-min change in the travel time on the flatter portions of the curve, say in the 30- to 40-min range, will have a rather insignificant effect. Hence, the most important relationships in land-use patterns, as they affect travel requirements, are those within 10 min of each other.

The Hartford analysis differed from the Baltimore-Washington study in the method of developing the alternative test plans. Rather than accept the rational restraints imposed by the use of an urban growth model, alternative land-use patterns were simply

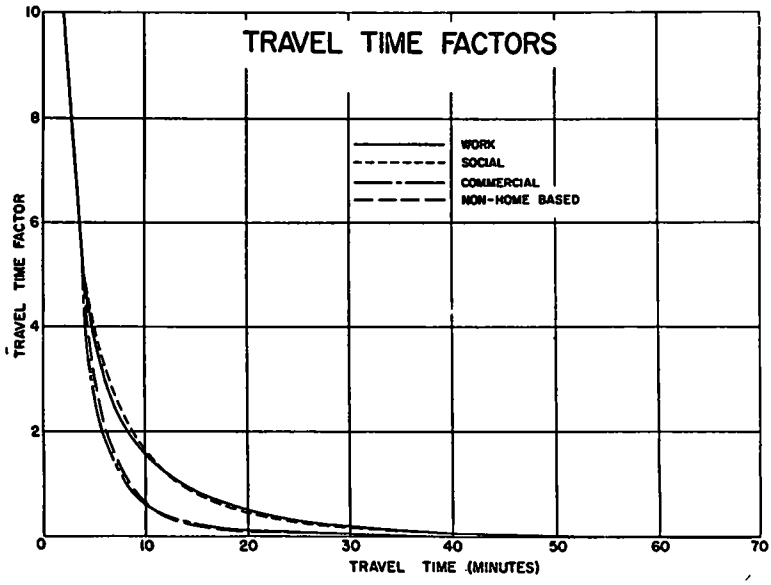
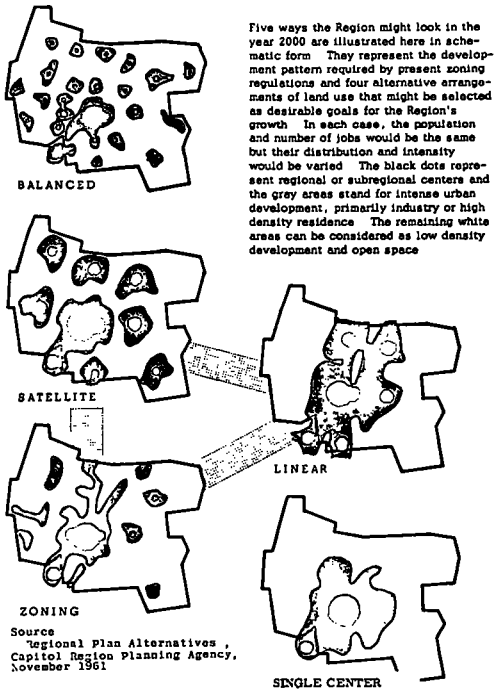


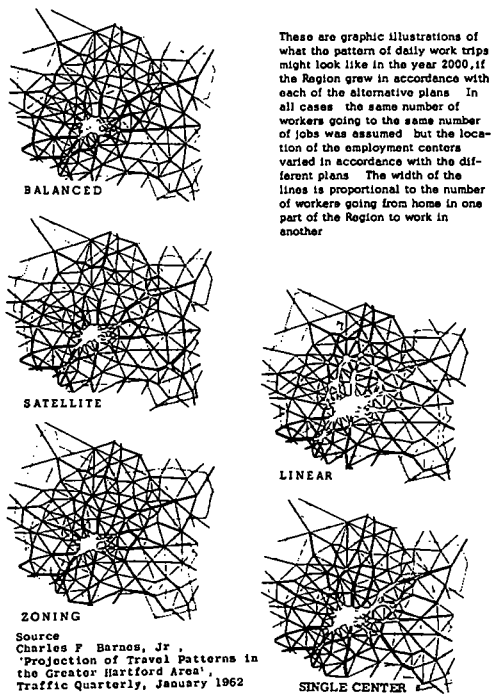
Figure 1. Travel time factors.



Five ways the Region might look in the year 2000 are illustrated here in schematic form They represent the development pattern required by present zoning regulations and four alternative arrangements of land use that might be selected as desirable goals for the Region's growth In each case, the population and number of jobs would be the same but their distribution and intensity would be varied The black dots represent regional or subregional centers and the grey areas stand for intense urban development, primarily industry or high density residence The remaining white areas can be considered as low density development and open space

Source
'Regional Plan Alternatives ,
Capitol Region Planning Agency,
November 1961

Figure 2. Alternative land-use plans.



These are graphic illustrations of what the pattern of daily work trips might look like in the year 2000, if the Region grew in accordance with each of the alternative plans In all cases the same number of workers going to the same number of jobs was assumed but the location of the employment centers varied in accordance with the different plans The width of the lines is proportional to the number of workers going from home in one part of the Region to work in another

Source
Charles F Barnes, Jr ,
'Projection of Travel Patterns in the Greater Hartford Area',
Traffic Quarterly, January 1962

Figure 3. Circulation patterns.

assumed to achieve the widest possible difference between the plans. No attempt was made to arrive at realistic plans.

For this phase (Phase I) of the study, special emphasis was placed on new employment and the work trip patterns. The new employment was distributed into five distinct land-use patterns, shown in Figure 2, but the population distribution was the same in all five plans. The plans were developed in sufficient detail to calculate the input necessary for the traffic model computations.

The travel patterns, (Fig. 3) developed by use of the traffic model and assigned to identical desire-line networks, showed a 22 percent difference between the Single Center land-use concept, the most dense plan of development, and the Balanced Community concept, the least dense plan (Table 1).

The fact that the basic difference between the Baltimore-Washington and the Hartford studies was that the former balanced employment and labor force through model techniques and the latter did not (and that the results were different) strongly indicates that the relationship between population and employment has an important impact on traffic demand. In fact, it would appear that in the development of any land-use plan a thorough attempt should be made to coordinate population and employment patterns. This can best be achieved by the use of an urban growth model or some other analytical procedure based on historical analysis.

Subregional Approach. —Because it was apparent that the greatest reduction of travel can be accomplished by the careful distribution of land uses within the subregional structure, both studies undertook careful analyses on this basis.

TABLE 1
AVERAGE TRIP LENGTH RELATIONSHIPS, PHASE I

Study Plan	Trip Length Relative to Existing Zoning
Balanced Community	0.92
Existing Zoning	1 00
Satellite	1 01
Linear	1 11
Single center	1.14

The Baltimore-Washington study explored a series of subregional land-use designs by use of the gravity model. However, instead of developing trip lengths for this series of plans, only the ΣAB's were used (7). The change in ΣAB between plans, when compared with the average trip length for the region and subregion, indicates the change in average trip length that would be brought about by the particular plan. This type of test is quite simple and easy to carry out and provides an effective means of evaluating transportation needs related to many different subregional plans.

This line of analysis revealed that there are several ways to decrease auto travel through sound local planning:

1. By arranging land use so that apartment house development and high-density employment areas are closely tied together, a reduction in auto travel of between 5 and 10 percent is possible.
2. Development of housing for a wide range of income groups within 10 min of large employment centers will further cut auto travel. The greatest impact here comes from reduction of work trip length. It is possible to achieve a 10 percent reduction in work trip lengths by this technique alone.
3. Develop the street patterns in the outlying areas that focus on potential commercial centers where heavy concentrations of employment may be located. This can reduce peak-hour travel nearly 5 percent. This approach, in effect, tends to create communities, and has the advantage of discouraging dispersion of retailing and commerical activities. It will increase the accessibility of certain centers and thereby encourage their growth.

By and large, then, it appears that by proper arrangement of land-use and street patterns into communities having a variety of housing types, it is possible to reduce peak-hour travel about 20 percent.

In light of the Baltimore experience, the Hartford study undertook a more detailed analysis of possible land use alternatives. In this phase (Phase II), further consideration was given the three most promising of the original plans—the Satellite, Linear, and Zoning concepts. The approach differed from the original in two major respects. First, the freeway and arterial street plans were developed for each of the plans. Secondly, actual subregional centers were developed for each plan, with attention given to the following factors found important in the Baltimore-Washington work: (a) the travel time relationship between high-density residential areas and the employment areas; (b) a balance of workers and employment in each subregional center; and (c) the basic arterial street plan to insure that the best possible access was supplied to each center from the surrounding residential areas.

The results of this work showed a substantial reduction in travel over the plans tested in Phase I. For the Linear and Satellite plans this change was quite significant. The trip lengths, reported on a percentage basis, are shown in Table 2.

Of even greater significance in understanding the underlying concepts are (a) the relative changes that resulted and (b) the fact that there was very little difference between the three Phase II test plans. On reflection, this is not surprising.

The small relative difference in average trip length between the Phase II plans can be explained by the fact that the same basic criteria were used in the development of the subregional centers. It could be argued that the Linear concept is actually a satellite plan with the satellites arranged linearly. Because these urban clusters or subregional centers are quite similar in design, yet distinct and more or less isolated, the traffic developed by the individual centers and therefore by the whole region should be quite comparable.

In Tables 1 and 2, the change in rela-

TABLE 2

AVERAGE TRIP LENGTH RELATIONSHIPS, PHASE II

Study Plan	Trip Length Relative to Existing Zoning
Linear	0 96
Satellite	0 97
Existing Zoning	1 00

tive position of the Phase I and Phase II plans is likewise logically explained. For Phase I, the Linear concept was based on a more or less continuous pattern of development, with spots of high-density development but no real attempt at discontinuity by the use of low-density land development. By comparison, the Phase II plan was developed as a discontinuous region and therefore it converted a great many of the longer inter-subregional trips into shorter intra-subregional trips. Discontinuous development was present in both phases of the Satellite concept, resulting in a relatively smaller change.

The change in trip length for the two phases of the Existing Zoning concept was less than that for the Satellite and Linear plans because the subregional centers were less well developed.

Analysis of the traffic related to the various alternatives indicates that certain plans create traffic problems in different sections of the region. For example, it is likely that the Existing Zoning concept would create severe traffic problems in the vicinity of the downtown area, whereas the Linear plan would create traffic problems in the area north of Hartford, and the Satellite plan would cause overloading on some sections of the circumferential routes. This merely emphasizes that in using the approaches outlined in this paper for the selection of one land-use alternative over another, the problems involved in handling the traffic related to each alternative must be given careful consideration.

MINIMIZING TRIP LENGTH

The results of the model analyses conducted in the Baltimore-Washington and Hartford regions indicate that substantial reductions in auto travel can be achieved by logical grouping of land-use and street arrangements in selected areas throughout the region. An illustration of how these areas should be planned and designed is shown in Figure 4, which depicts a plan that has been developed for an area southeast of Baltimore. This area is planned to accommodate 200,000 people and applies the criteria outlined in this paper. It has a strong center located at the junction of one freeway and several important arterial streets that focus on this center. Adjacent to this center and closely associated with some of the high density industrial areas are high-density residential areas and the whole area containing a variety of housing types.

Size of Subregions

Another question explored by these studies was how large these urban clusters should be. An analysis was made of urban travel habits to determine the travel patterns of a typical suburb. On the assumption that travel habits reveal people's preferences, this study indicated that the primary field of interest of the adult suburbanite is within 10 min of home. In today's suburban development, a 10-min radius typically includes about 100,000 people. Such an area appears to be adequate to support the stores, shops, and services that are required by most individuals. In other words, it takes at least 100,000 people to support the variety of stores and services that are demanded by the average citizen.

This pattern is revealed by an evaluation of travel patterns for several different sized areas throughout the country (see Fig. 5). For example, in a small community in San Diego containing about 7,000 people, it was found that only 12 percent of the trips made by the residents stayed within the area. This area had all the stores and activities that normally could be supported by 7,000 people. Similarly, for a community of 28,000 people, in the same region, only 27 percent of the trips made by the residents stayed within the area. This community had the full range of stores and community services usually supported by such a population.

On the other hand, in the Bethesda area, just outside the District of Columbia, an area containing about 80,000 persons, it was found that about 60 percent of all auto trips made by residents stayed within the area. Futhermore, if the boundaries of Bethesda are extended to include adjacent jurisdictions, the proportion of trips staying within the area is increased only slightly. Thus, it appears that most people demand the range of stores and services found in a region of 100,000 population. However,

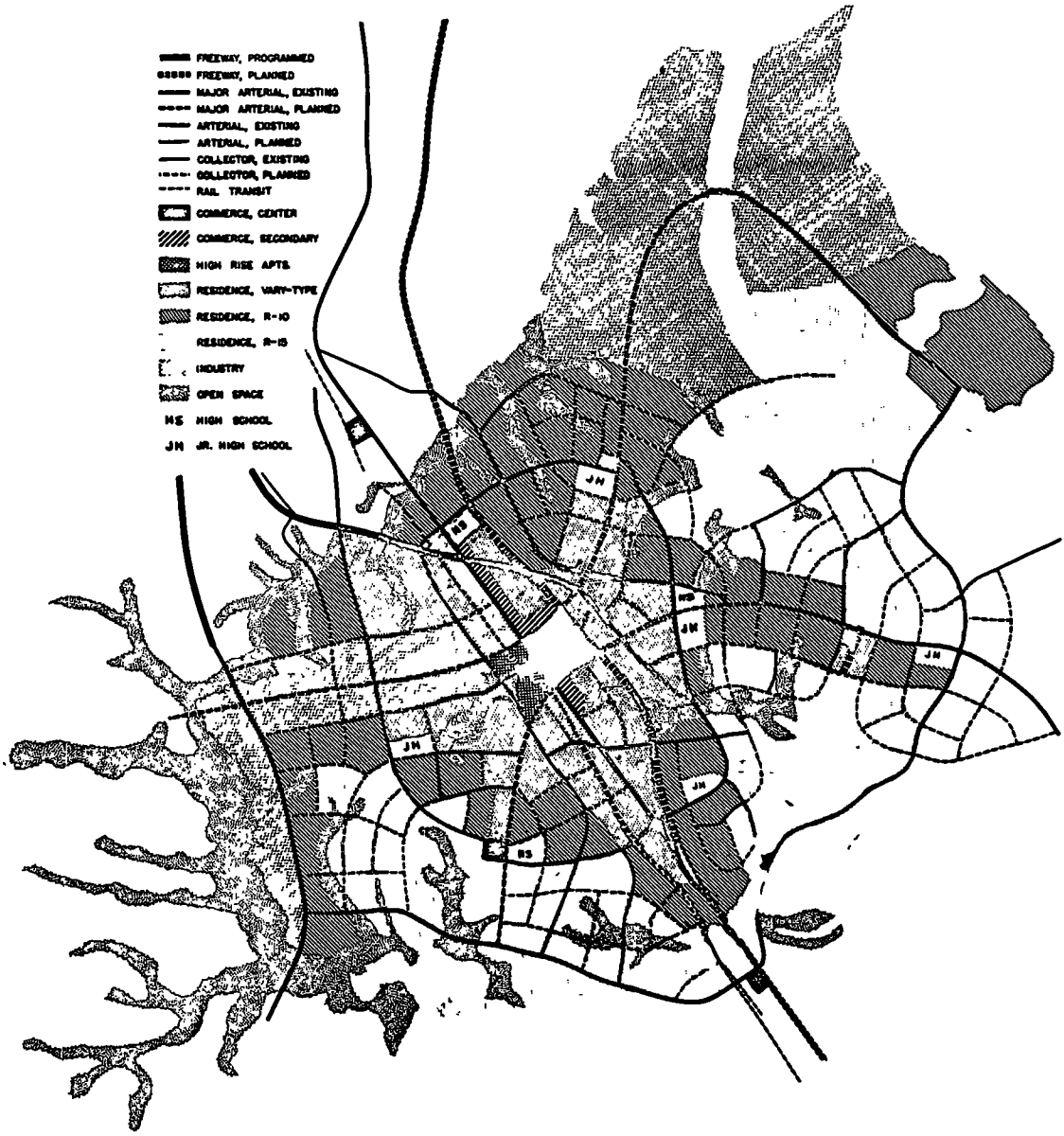


Figure 4. Typical subregional center.

they will go outside of such a region for work purposes and occasional shopping, recreational and social trips.

The curve shown in Figure 6, theorized on the basis of these facts, attempts to point up the interrelationship between community size and transportation cost. Communities below a size of 100,000 persons cannot support the shopping and job opportunities demanded by the majority of the population. This necessitates a large proportion of trips, of all types, outside of the immediate area to satisfy personal needs. As communities grow in size, they can support an increasingly higher percentage of the specialities required for daily living, and a proportionately greater percentage of trips remain within the community.

However, in communities with a single center population exceeding 150,000 or

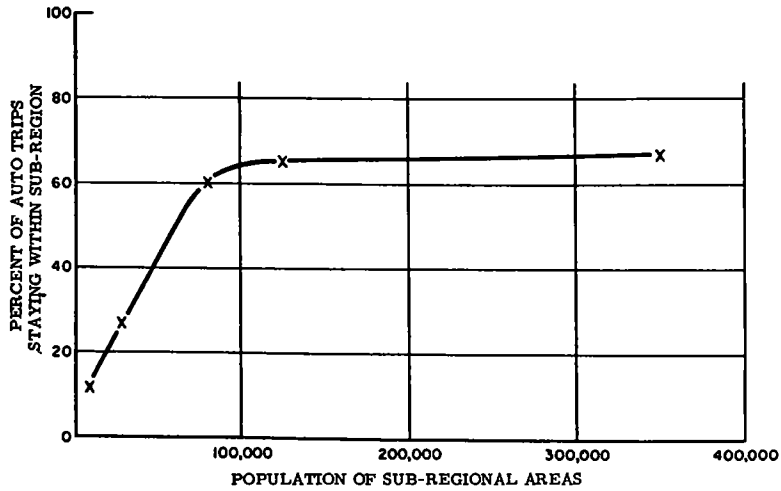


Figure 5. Effect of size of subregional areas on trip length.

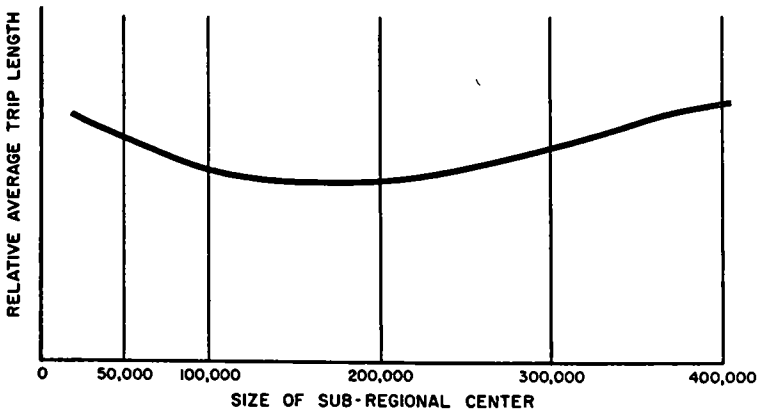


Figure 6. Theoretical relationship between size of subregional center and average trip length, Hartford Area Transportation Study.

200,000, there is a steady drop in the percentage of people who can live within reasonable proximity to their job and shopping opportunities. This forces a general increase in the average trip length, as indicated by the Single Center trip length reported in Table 1.

SUMMARY AND CONCLUSIONS

From these studies it is evident that land use, including transportation, has a marked effect on transportation requirements. This paper has highlighted several, apparently more important factors involved and has indicated the effect that each seems to have on transportation requirements.

It has been shown that vehicle-miles of travel are associated with level of service, and that as level of service rises the vehicle-miles of travel will increase in proportion.

It has also been shown that travel can be minimized by the judicious arrangment of future land use, and that the key factors are as follows: (a) high density residential

development must be located within close proximity (10 min or less in travel time) of the high-density commercial and industrial areas; (b) the housing must provide a wide range of types that will attract a diversity of social and economic groups; (c) the street and highway system should be laid out to encourage centralization on the urban center, (d) the development of subregional centers should be encouraged, with populations ranging in the order of 100,000 to 200,000; and (e) the subregional centers should be as distinct and isolated from one another as the natural topography and existing development patterns will permit.

These forces, if utilized to the ultimate, can produce a reduction in travel requirements of 20 percent or more, compared with prevailing patterns of land development. Equally important, this can be accomplished without decreasing the range of job opportunities or the selection of housing types, and hence results in a much more convenient and livable city.

In conclusion, this paper demonstrates that different patterns of land use and transportation have a profound effect on travel. These differences are of a magnitude that can "make or break" the tranportation plan, and it is therefore vital in the development of a regional plan that the interplay between land use and transportation be recognized and given due consideration. Tools are available, today, to measure the impact of various plans quantitatively. It is of the first importance that these tools be employed to aid in the recognition of these differences during the development of the regional plan.

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