Transportation Implications of Alternative Sketch Plans

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Six sketch plans prepared by the planning division for a region of 30 million population were evaluated for transportation implications. The aim was to gain insight into the form of transportation network which, according to the present means of travel, would correspond to each development sketch. The study also compares the resource commitments required for the several plans. Of the planning variables employed to construct the sketch plan alternatives, the distribution of population densities served as the measure of variation among the alternative plans. Trip generation and segregation by transportation modes were estimated on the basis of the prevailing patterns in this and other regions. Travel costs for this analysis were adapted from other studies.

Results indicate the relative growth of mass transit and auto modes of travel in terms of the 1960 volumes, and also provide an indication as to how the variation in travel might influence the resource allocation between the two modes of transportation. The value of this study lies primarily in the uniform application of travel generation criteria to a set of different population distribution schemes. The uniform evaluation was accomplished by transforming characteristics of the sketch plan communities into mathematical models.

Sketch plans represent development concepts, and the objective of this undertaking is to open vistas for speculation on the course of future urbanization trends. This analysis provides the first approximation of transportation implications for the analyzed development schemes. It also suggests the succeeding steps that could be taken to narrow the gap between sketch plan ideas and workable alternatives.

•THE six sketch plans which were analyzed in this report represent three basic patterns of regional growth: (a) decentralized—under minimum of development control; (b) new-town concept; and (c) the concentration of future population in a few large urban units. Each of the three patterns were presented in two variants differing in the number of units and in the intensity of development.

Figure 1 shows the sketch plans. The circles represent the relative size and the number of communities. The original sketch plans were composed of residential, commercial, industrial, governmental, and park land units. Each unit represented a land area of one square mile. The following factors were considered in developing the sketch plans (1):

(1) Geographic division of major socioeconomic systems (core vs remainder of region); (2) activity center locations within major urban systems; (3) population distribution by major geographic areas; (4) household composition distribution by core and remainder systems; and (5) open space pattern throughout the region.

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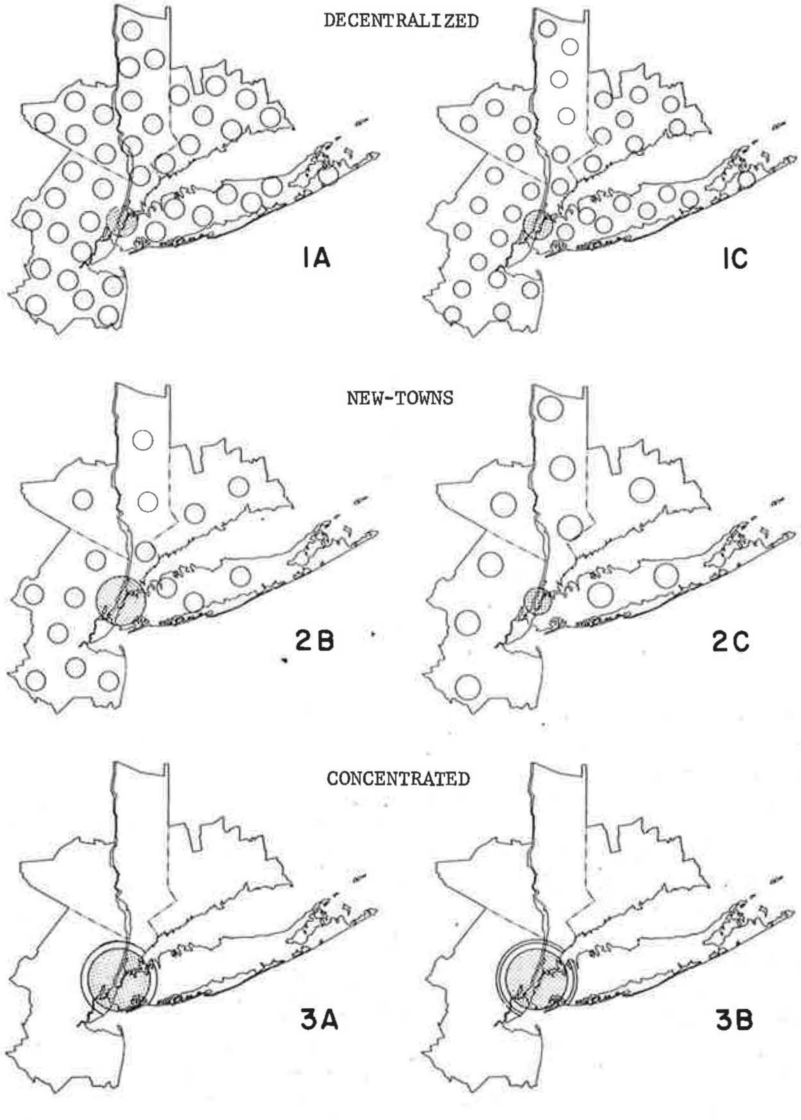


Figure 1. Sketch plans.

Table 1 summarizes the basic sketch plan quantification data which served as input for the travel implication analysis. The basic difference between the two "decentralized" sketches (Fig. 1) can be seen in the area of land allotted for residential purposes. Nearly equal populations of the two metropolitan community groups are allocated drastically different areas of residential land. The average density of metropolitan communities in sketch 1A amounts to 2,810 persons per square mile, and in sketch 1C, to 3,870.

As to the "new town" sketches, the average population density of the core area of sketch 2C is considerably higher than that of sketch 2B. Densities of the metropolitan communities for this development pattern vary only moderately.

Of the two "concentrated" schemes, the average core density of sketch 3A is somewhat higher than of sketch 3B. Density of the surrounding communities, however, differs considerably.

Certain elements are common for all the schemes. All sketches are designed to accommodate the estimated future population of 30 million. An equal amount of jobs

TABLE 1

POPULATION DISTRIBUTION

Pattern	Sketch	Part of Region	Number of Units	Population (000)	Res. Land Area (sq mi)	Avg. Resid. Density (000) Per Sq Mi
Decentralized		Core	1	10,000	533	18.75
	1A	Met. Area	40	20,000	7,120	2.81
		Total	41	30,000	7,653	3.92
		Core	1	11,000	435	25.30
	1C	Met. Area	38	19,000	4,902	3.87
		Total	39	30,000	5,337	5.63
New Towns		Core	1	14,000	1,184	11.80
	2B	Met. Area	16	16,000	3,328	4.81
		Total	17	30,000	4,512	6.65
		Core	1	10,000	410	24.40
	2C	Met. Area	10	20,000	3,190	6.28
		Total	11	30,000	3,600	8.33
Concentrated		Core	1	26,000	2,026	12.82
	3A	Met. Area	1	4,000	1,123	3.56
		Total	2	30,000	3,149	9.53
		Core	1	22,000	2,077	10.60
	3B	Met. Area	2	8,000	1,190	6.72
		Total	3	30,000	3,267	9.20

was distributed among communities in all sketches. This was done on the basis of the prevailing ratios among the several employment classes. The current composition of household sizes was projected for the region's future population.

The several sketches embody density variations in the core areas and in metropolitan communities. This was accomplished by either changing the size and the number of communities or by increasing or decreasing the area of open land. Combinations of these provided a spectrum of population distribution patterns for the region.

It is common knowledge that lower densities produce more trips and that high densities utilize mass transportation to a greater degree for routine travel. In the planning process, nonetheless, it is of interest to know the relative change in travel patterns and the degree of change associated with different population distribution patterns for a given future region's population. Further travel implications become apparent by weighing the relative cost of travel under different regional development schemes.

From the basic premises of population distribution, this analysis reveals the travel implications with respect to the intensity of trip generation and to different utilization of auto and mass transport modes. It also demonstrates these implications in terms of costs.

FINDINGS

Travel implications for the six sketch plans were determined in two steps. The first step deals with travel characteristics. The trip-making potential for the six sketches was established, and the estimated volumes were expressed in terms relative to population increase.

In the second step, communities which indicated propensity to support public means of transportation were fitted with mass transit systems. Travel costs for these systems were evaluated beforehand. Ultimately, this analysis step established the extent of resources needed for travel purposes under each development scheme.

Travel Characteristics

Two aspects of travel characteristics were evaluated: the propensity for making trips and the relative utilization of transportation modes. Subsequently, the resulting

TABLE 2

TRIP-MAKING CHARACTERISTICS—INCREASE ABOVE 1960 VOLUMES[a]

Pattern	Sketch	Part of Region	Region Total		Mass Transit		Auto	
			Trips Per Day (000)	Increase (%)	Trips Per Day (000)	Increase (%)	Trips Per Day (000)	Increase (%)
Decentralized	1A	Core	18,815		9,168		9,647	
		Met. Area	58,800		–		58,800	
		Total	77,615	122	9,168	0	68,447	163
	1C	Core	18,206		10,031		8,175	
		Met. Area	53,504		–		53,504	
		Total	71,710	105	10,031	11	61,679	137
New Towns	2B	Core	31,829		12,137		19,692	
		Met. Area	44,074		9,728		34,336	
		Total	75,903	117	21,865	143	54,028	108
	2C	Core	16,803		9,211		7,592	
		Met. Area	53,030		13,910		39,120	
		Total	69,833	100	23,121	157	46,712	80
Concentrated	3A	Core	55,923		23,178		32,745	
		Met. Area	11,442		–		11,442	
		Total	67,365	92	23,178	158	44,187	70
	3B	Core	51,915		18,613		33,302	
		Met. Area	21,029		5,778		15,251	
		Total	72,944	108	24,391	171	48,553	87

[a] 1960 volumes: mass transit, 9 million; auto, 26 million; total, 35 million.

travel characteristics of the six plans were compared to the projected population growth. (The 1960 population of 17 million was projected to reach the 30 million mark in the year 2010, an increase of 77 percent.)

As indicated by Table 2, the region's future trip-making propensity exceeds the population increase for all sketches. Sketch 3A generates the lowest trip volume and sketch 1A the highest. This could have been expected, judging from average population densities shown in Table 1; lower densities tend to produce more trips.

However, sketch 2B, with the average regional population density of 6,650, produced more trips than sketch 1C, with a population density of 5,630. This condition was brought about by the considerably lower densities in the core city of sketch 2B. Trip generation rates vary little in the high-density range, but this variation becomes significant at low densities. Thus, in comparison with sketch 1C, the lower trip generation rate of the 2B metropolitan area failed to offset the high trip production rate of the core city.

The following summary further reveals the trip generation characteristics of the six sketches:

Development Pattern	Development Variants (trips in 000)	
Decentralized	1A—77,615	1C—71,710
New towns	2B—75,703	2C—69,833
Concentrated	3B—72,944	3A—67,365

It can be seen that the trip generation potential between the two development variants of each development pattern varies more than between the comparable variants of the three development patterns. That is, the differences between sketches 1A and 1C, 2B and 2C, and 3B and 3A, are larger than between 1A, 2B and 3B, and 1C, 2C and 3A.

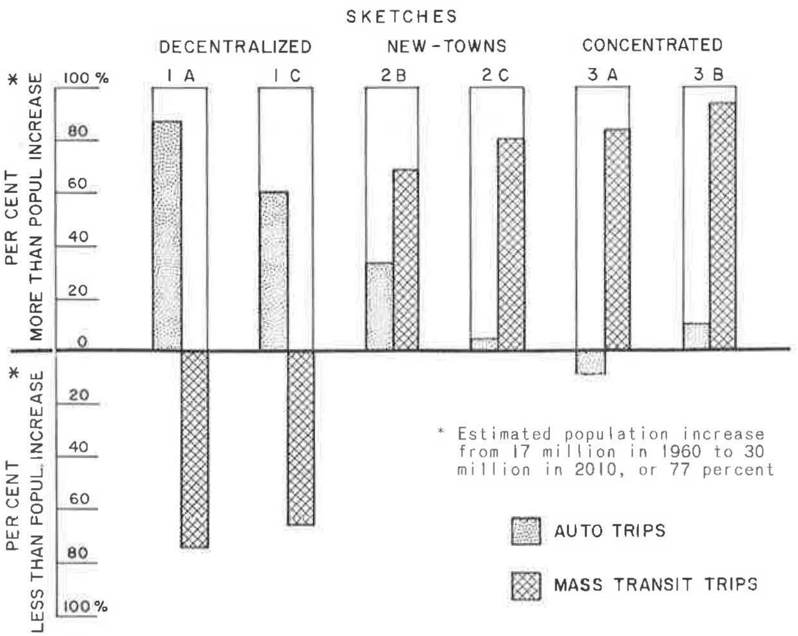


Figure 2. Travel growth by mode.

The data in Tables 1 and 2 and the above summary lead to a conclusion that the variation in trip generation potential of the six development sketches is influenced not so much by densities of the core area, but by percentages of the region's population that are expected to reside in metropolitan communities and by the average density of these urban units.

The sketches indicate a pronounced variation in the utilization of auto and mass transit modes of travel, as shown in Table 2. The increase of mass transit trips above 1960 volumes for sketch 1A equals zero, while auto trips for this scheme increase by 163 percent; for sketch 3B the mass transit trips grow 171 percent, but auto trips increase only 87 percent. The region's population for both sketches increases 77 percent.

According to the findings, mass transit facilities for sketch 1A will operate in the year 2010 at the same patronage level as at the present. Evidently the population growth under this development scheme would be accommodated in the region's outer areas where most of the travel would be done in autos. Concentrated development (sketches 3A and 3B) in this respect represents the other extreme. Here the mass transit travel would grow at more than double the rate of the region's population increase while auto usage would trail the population growth in the case of 3A and only slightly exceed it in the case of 3B.

Figure 2 shows the increase in the usage of auto and mass transit modes of travel as related to the population growth. At the extremes, in sketch 1A the population growth would expand only auto travel. In sketch 3B, the auto travel would grow in proportion to the population, but mass transit would exceed this growth by 94 percent. The radically different picture of travel habits in the extreme development schemes implies a profound variance in the two urbanization concepts. Other sketches represent the intermediate conditions.

This drastic variation in the utilization of auto and mass transit modes of travel appears to be one of the most important issues requiring reconciliation with other urbanization problems in weighing future development policies. The obviously different means of travel in the six development schemes also implies different policy orientations toward housing, parking, distribution of jobs, and other urban development programs.

Figure 2 suggests travel implications extending beyond the issues of transportation. Some of these implications are discussed in the following.

For sketches 1A and 1C the public policy would provide for the growing demands of auto travel. New developments and redevelopment projects of existing urban areas would be auto-travel oriented, providing suitable access and parking facilities. Auto travel is space demanding. Therefore, for a proper accommodation of all urban elements, either the densities of the present urbanized areas would be reduced, or advanced technology would generate development forms which are unknown at the present. Mass transit under these development sketches would gradually be giving ground to auto travel—a condition which exists at the present.

Sketch 2B should be looked upon as the product of a conscious public policy favoring a balanced transportation system. This sketch presupposes that a balanced transportation is possible and feasible. All urban development policies under this scheme would be guided by concepts designed to sustain the planned modes of travel.

Sketches 2C, 3A, and 3B indicate a strong bias favoring mass transit. Either through specific development policies or through consciously designed transportation regimes the urban development forms would be public-transport oriented. These sketches suggest a complete reversal of the present transportation policy to one in favor of mass transit. The rate of auto travel per person in the year 2010 would remain at about the same level as at the present.

These sketch groups suggest three radically different pictures of future urban forms. Presuming that the urban development forms and transportation services ultimately must attain a functional integration, the above sketch groups imply three different forms of urban travel, as well as three different forms of urban living. The individual image of these forms is left to be created in the minds of the readers.

The Cost of Travel

The last column of Table 3 shows the estimated annual travel cost for each sketch. These costs include investments in facilities as well as operating expenditures, and are given in 1963 dollars.

Since daily travel expenditures claim a sizable part of a household's disposable income, the aggregate regional expenditures for this purpose are large, ranging from $15.48 billion for sketch 3A to $17.29 billion for sketch 1A. These figures include all public and private outlays for the transportation function.

The main body of these expenditures remains relatively stable under similar conditions of development at a given time. Only a fraction of it can be altered by the rationalization of environment, i.e., optimization of choices and maximization of benefits. Consequently, the difference of $1.81 billion between the two extreme travel costs of sketches 3A and 1A does not seem to be impressive. Nonetheless, it amounts to about half of New York City's annual operating budget and more than three times the city's capital improvement budget. Should further analysis embrace all major regional functions, even under these conditions the total savings that could be arrived at through the optimization of separate functions most likely would not amount to more than two or three billion dollars annually. Proper reinvestment of these moneys, however, could have profound effects on the region's well-being. Thus the differences among the total travel costs of the six development schemes in the economic sense are significant and meaningful. The impact of the economies in travel could be considerable by freeing substantial resources for other improvements of the general urban plant.

Figures showing the daily travel expenditures for the different sketch plans in Table 3 follow, to a degree, the pattern of trip-making characteristics. The size, the arrangement of mass transit facilities, and the effect of population density on the cost of auto travel, however, influence these expenditures for each sketch plan differently. Daily travel expenditures, therefore, are not entirely proportional to the number of trips.

Viewing the daily expenditures as resources which are being withdrawn from the population's income and put into the development and operation of transportation facilities, the resource allocation picture for the different development schemes is shown in Figure 3. This analysis was concerned not with the effects of population growth, but

TABLE 3

RELATIVE COST OF TRAVEL AND EXPENDITURE INCREASE ABOVE 1960 VOLUMES[a]

Pattern	Sketch	Part of Region	Number of Units	Region Total Daily Expenditure $(000)	Region Total Increase (%)	Mass Transit Daily Expenditure $(000)	Mass Transit Increase (%)	Auto Daily Expenditure $(000)	Auto Increase (%)	Total Annual Cost $ (billions)
Decentralized		Core	1	12,446		3,367		8,779		4.54
	1A	Met. Area	40	34,986		—		34,986		12.75
		Total	41	47,432	118	3,367	0	43,765	140	17.29
		Core	1	12,596		4,012		8,584		4.60
	1C	Met. Area	38	31,835		—		31,834		11.60
		Total	39	44,431	104	4,012	11	40,419	122	16.20
New Towns		Core	1	20,018		4,355		15,163		7.30
	2B	Met. Area	16	25,037		3,405		21,632		9.11
		Total	17	45,055	107	8,260	129	36,795	102	16.41
		Core	1	11,656		3,384		7,972		4.25
	2C	Met. Area	10	32,275		6,260		26,015		11.77
		Total	11	43,931	102	9,344	176	33,987	87	16.02
Concentrated		Core	1	35,631		9,271		26,360		13.00
	3A	Met. Area	1	6,808		—		6,808		2.48
		Total	2	42,439	95	9,271	158	33,168	82	15.48
		Core	1	31,922		7,445		24,477		11.61
	3B	Met. Area	2	13,031		2,389		10,142		4.76
		Total	3	44,953	106	10,334	187	34,619	88	16.37

[a] 1960 estimated daily expenditures (in millions): mass transit, $3.6; auto, $18.2; total, $21.8.

with the travel implications of the different schemes designed to accommodate this growth. Therefore, in Figure 3, as in Figure 2, the diagram shows the relative magnitudes by which the daily expenditures for the two modes of transportation exceed the population increase, or lag behind it.

In the dispersed development (sketches 1A and 1C), mass transit would be alloted about the same amount of resources as at the present. Resource allocation for this mode would not be affected by the population growth. The investments in auto travel, instead, would exceed the present rate, reaching 140 percent above the present in the year 2010.

At another extreme, the resources put in mass transit for sketch 3B would outpace the rate of population increase by more than twice, reaching the 187 percent level in 2010. Resource allocation to auto travel in this scheme would increase at the rate of population growth, exceeding it by only 11 percent in 2010.

Figure 3 thus suggests the direction which would be followed by the decision-making process in the allocation of resources for transportation under conditions of the six development schemes. The figures presuppose the present amenity level of travel for all sketches. Depending upon which of the two factors is regarded as cause and which as effect, one can look upon Figure 3 as an indication for channeling the resources to achieve the desired development characteristics, or, from another point of view, Figure 3 indicates the corresponding travel modes for the six regional development patterns established by means other than the transportation regime.

ESTIMATION OF TRAVEL CHARACTERISTICS

Sketch plan communities were constructed from one-mile squares representing several classes of land development. Residential land uses were shown in four density ranges, the highest 72,800 persons per square mile and the lowest 350. The number of such density squares for each sketch plan was determined by planners according to a preconceived idea of the region's development trend. Each sketch consists of a core

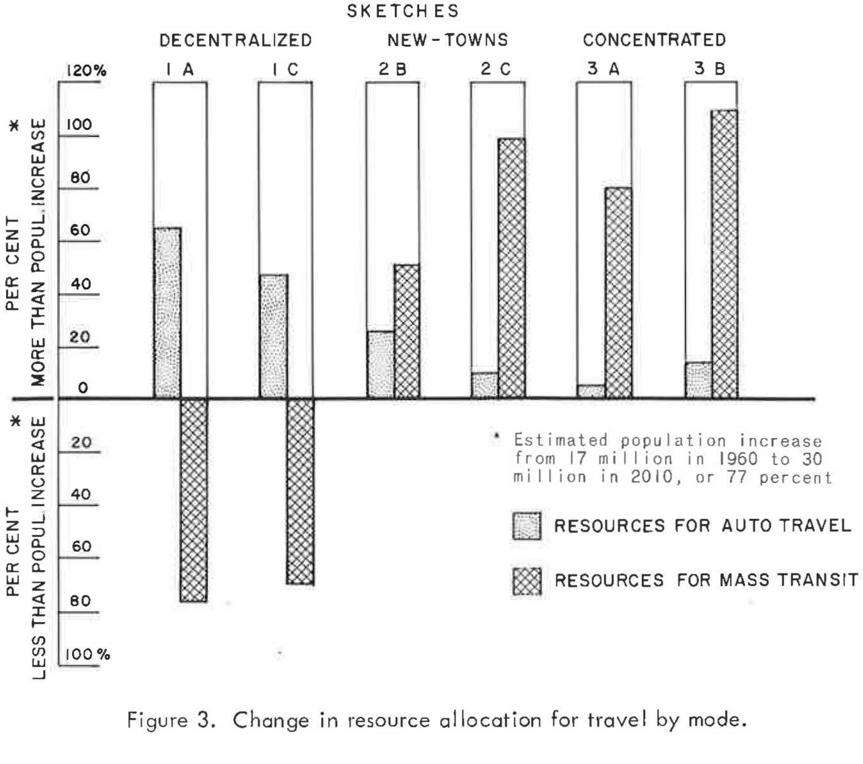


Figure 3. Change in resource allocation for travel by mode.

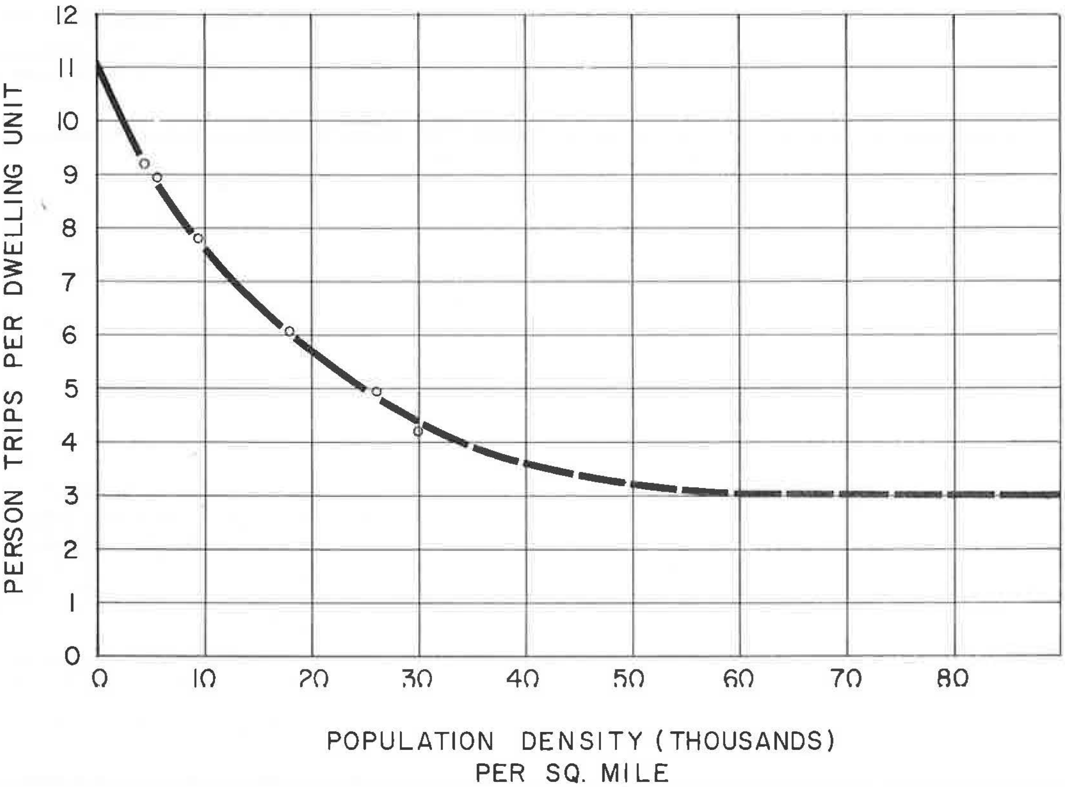


Figure 4. Trip generation rates.

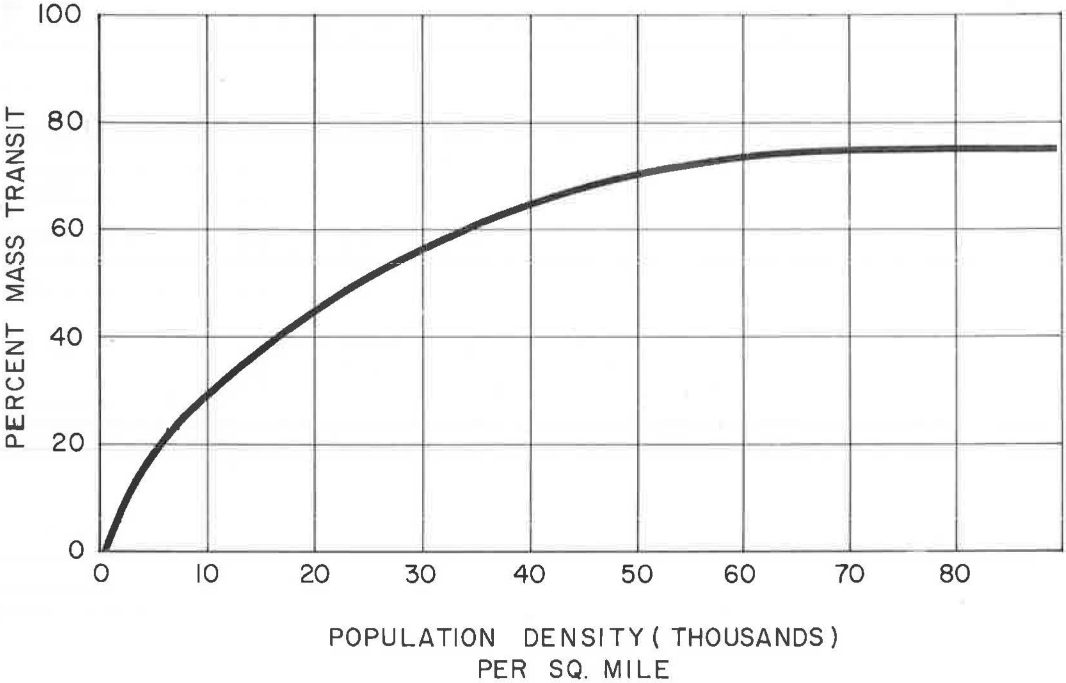


Figure 5. Travel by modes.

area and a specified number of quantitively identical metropolitan communities. The distribution of land use squares within each community, however, differs. It was mapped intuitively. Thus the sketch plans speculate on the quantitative aspect of the region's growth as well as on the geographic dispersion of these quantities.

In order to evaluate travel characteristics for the six development sketches uniformly, it was necessary to define the communities in mathematical terms. Since the quantities varied not only between sketches but also between communities of the same development sketch, this made the application of mathematical formulations problematic.

The exponential density gradient has been found to fit the density distribution in old cities (2). In arranging the sketch plans, the planners were inclined to see small community subcenters surrounding the major urban centers. In addition to commercial, manufacturing and other job-producing land uses, these subcenters also include high-density residential developments.

The net effect of clustering subcenters about a major center upon the density distribution pattern was such that the density gradient for the sketch plan urban units approached a declining straight line. These observations and the awareness that this analysis is to be the first approximation in the process of narrowing down the alternative choices led to choosing the cone-shape density distribution model.

Thus, the analysis was carried out on the assumption that the urban unit's population confined within the residential land area A is distributed in such a manner that

$$P = (1/3)\ A\ H$$

where H is the peak density and equals 3P/A. The density d at a distance r from the center equals

$$d_r = 3P/A\ (1 - r / \sqrt{A/\pi})$$

Trip generation potential and the trip segregation by modes were established for each model utilizing the graphs shown in Figures 4 and 5. These graphs were developed from preliminary Tri-State survey data and from findings in other metropolitan areas.

Figure 6 illustrates the process of applying the trip generation rates to sketch plan models. All models were divided into analysis rings. Uniform boundaries for the corresponding rings of all sketches were defined by selected density ranges on the density scale of the trip generation curve. Projecting the selected densities to the model outlines, the intersection of such horizontal density lines with the model surface delineated the analysis ring.

After determining the ring population, this quantity was multiplied by the corresponding average trip generation rate and by the appropriate coefficients segregating the trips

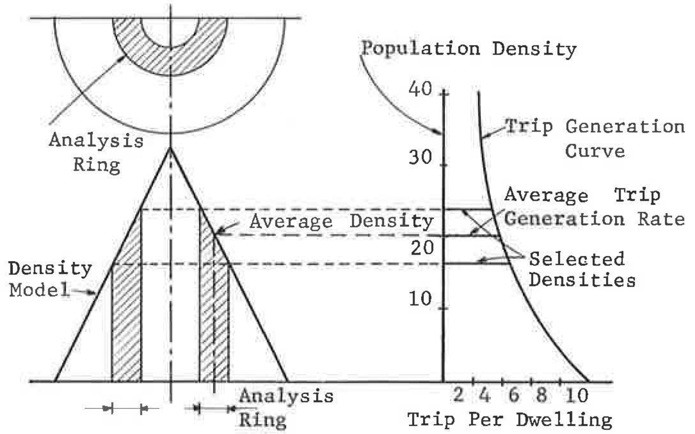
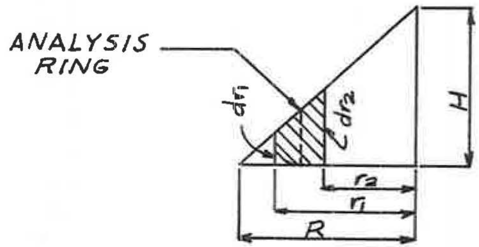


Figure 6. Uniform designations of analysis rings.



SCHEME 2B CORE

POPULATION DISTRIBUTION P = 1/3 AH

Population in (000) P = 14,000
Area A = 1184 Sq. mi.
H = 3 P/A = 35.47; $R = \sqrt{A/\pi} = 19.42$
S = H/R = 35.47/1942 = 1.826
Average density d_{av} = P/A = 11. > 4
(It was taken that urban units with average population density of 4000 and over would require mass transit)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Boundary Density d_r	$\Delta H = H - d_r$	$r = \Delta H/S$	πr^2	$\pi r^2 d_r$	$1/3 \pi r^2 \Delta H$	(5) + (6)	Ring Area	Ring Volume	d_{av} (Ring)	Trip Rates	Person Trips	% Mass Trans.	Mass Trans. Trips	Auto Trips
0	35.47	19.42	1184	0	14000	14000								
							129	120	1.0	10.6/3.4	374	-	-	374
2	33.47	18.33	1055	2110	11770	13880								
							180	618	3.5	9.6/3.3	1823	14	255	1568
5	30.47	16.69	875	4375	8887	13262								
							264	1965	7.5	8.3/3.0	5345	24	1283	4062
10	25.47	13.95	611	6110	5187	11297								
							254	3268	13.0	7.0/2.8	8170	34	2778	5392
16	19.47	10.66	357	5712	2317	8029								
							254	5095	20.5	5.6/2.6	10954	45	4929	6025
25	10.47	5.73	103	2575	359	2934								
							103	2926	30.0	4.4/2.5	5150	56	2884	2266
35	.47	.26	0	0	0	0								
							0	8	35.2	3.9/2.5	18	60	8	5
¢	.00	.00	0	0	0	0								
							1184	14000			31829		12137	19692

Figure 7. Evaluation of the model.

TABLE 4

TRAVEL CHARACTERISTICS

Pattern	Sketch	Part of Region	Number of Units	Population (000)	Res. Land (sq mi)	Total Trips (000)	Mass Transit Trips (000)	Auto Trips (000)
Decentralized		Core	1	10,000	533	18,815	9,168	9,647
	1A	Met. Area	40	20,000	7,120	58,800	–	58,800
		Total	41	30,000	7,653	77,615	9,168	68,447
		Core	1	11,000	435	18,206	10,031	8,175
	1C	Met. Area	38	19,000	4,902	53,504	–	53,504
		Total	39	30,000	5,337	71,710	10,031	61,679
New Towns		Core	1	14,000	1,184	31,829	12,137	19,692
	2B	Met. Area	16	16,000	3,328	44,074	9,728	34,336
		Total	17	30,000	4,512	75,903	21,865	54,028
		Core	1	10,000	410	16,803	9,211	7,592
	2C	Met. Area	10	20,000	3,190	53,030	13,910	39,120
		Total	11	30,000	3,600	69,833	23,121	46,712
Concentrated		Core	1	26,000	2,026	55,923	23,178	32,745
	3A	Met. Area	1	4,000	1,123	11,442	–	11,442
		Total	2	30,000	3,149	67,365	23,178	44,187
		Core	1	22,000	2,077	51,915	18,613	33,302
	3B	Met. Area	2	8,000	1.190	21,029	5,778	15,251
		Total	3	30,000	3,267	72,944	24.391	48,553

by travel modes. This analysis process was carried out numerically. A sample of the computations is shown in Figure 7.

Table 4 presents the summary of the computed travel characteristics for all sketches. Figure 8 demonstrates the relative increase in trips for auto and mass transit modes above 1960 volumes.

This analysis presents the first approximation of the travel implications. Subse-

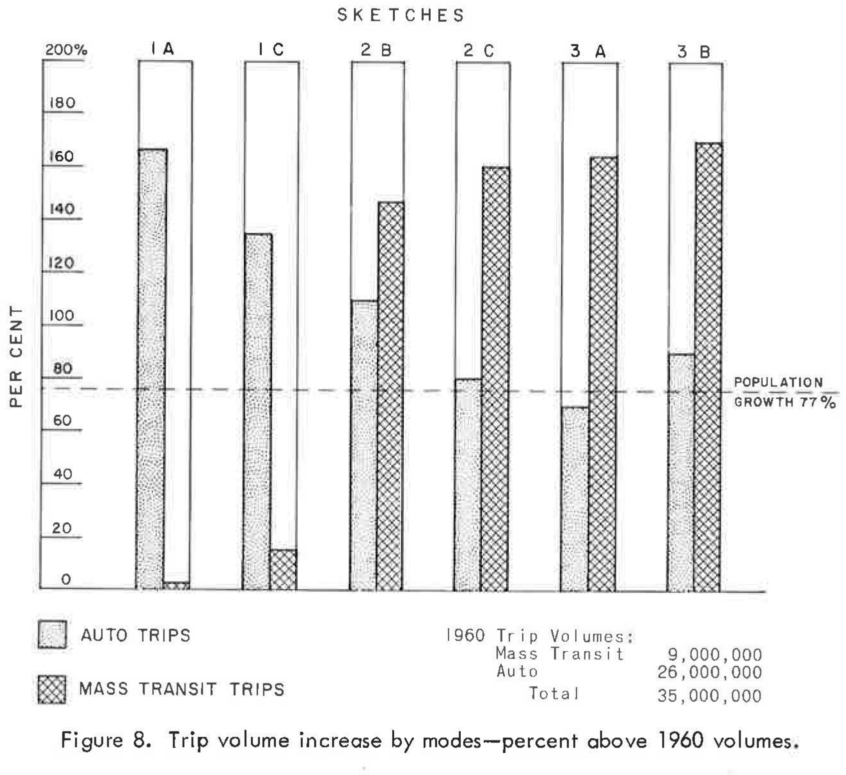


Figure 8. Trip volume increase by modes—percent above 1960 volumes.

quent analysis of selected alternatives would have to work with a more sophisticated density distribution fit for future communities. These could be developed through reasonable deductions.

EVALUATION OF RESOURCE NEEDS

The resource allocation for transportation in a metropolitan area is proportional to the mileage of trips and to the total travel cost per mile for each mode of transportation. The magnitude of resources required for this purpose can increase or decrease, depending on the average number of trips generated per person, the average trip length, and the cost per mile of travel. Resources for this purpose are being raised by means of user payments for facilities or services, individual expenditures, special taxes, general taxes, and borrowing.

Transportation costs which were used in this study include the installation and operation of facilities, improvements, and other incidental expenditures attributable to urban travel. Only two modes of transportation were considered, auto and rail mass transit. Designating the number of auto trips as T_a, mass transit as T_m, and indicating the average trip length for respective modes as l_a and l_m and the cost per mile of travel as C_1 and C_a, the total resources allocation for travel can be shown as

$$R = C_1 l_a T_a + C_2 l_m T_m$$

Trip volumes denoted as T_a and T_m were evaluated in the preceding section. Transportation costs were adopted from a study by Wohl (3). This study utilized three sizes of rapid transit systems: 6-mile, 10-mile, and 15-mile long routes. Travel costs for these systems are shown in Figure 9.

Each sketch plan community that indicated potential to support mass transit was fitted with one of the three mass transit networks. Whether or not a community could support mass transit and the extent of such systems were determined by the following criteria: (a) it was assumed that communities with an average population density of 4,000 or more persons per square mile are capable of sustaining rail or bus mass transit, and communities with less average density than this would resort primarily to auto travel; (b) it was taken that mass transit within a given metropolitan transportation system primarily accommodates the centrally oriented rush-hour travel.

For communities which indicated propensity to support mass transit, such lines were extended from the core outward to areas of about 3,000 persons per square mile density. It was assumed that buses serving lower densities would connect with the rapid transit at these points. Thus, the mass transit route length was determined by the radius extending from the center out to the density ordinate of 3,000 in a community model. This radius was rounded off to one of the three systems—6, 10, or 15 miles (Table 5).

In determining the number of service sectors in the system, the trip load on each line was kept within practical limits for convenient and economical travel. The maximum arc length between the outer ends of two lines was limited to about 6 miles.

The number of one-way passengers at the maximum load point of a line was arrived at by assuming that 50 percent of daily mass transit trips are made during the four rush-hours of the day. Ten percent of this volume was assumed to travel in the opposite direction. Allowing another 10 percent for along-the-line destinations, the volume of trips collected in a sector and accumulated at the maximum load point per one rush-hour equals

$$\frac{0.5 \times 0.9 \times 0.9}{4} = 0.1012 \times 100 = 10.12\% \text{ of 24-hour volume}$$

Thus, multiplying this factor by the 24-hour trip volumes per sector, the one-way hourly volume was obtained. On the basis of these volumes the mass transit trip costs were derived from Figure 9.

The cost variation between bus and rail mass transit is not significant enough to be taken into account at the sketch planning stage. Only rail transit was considered, but

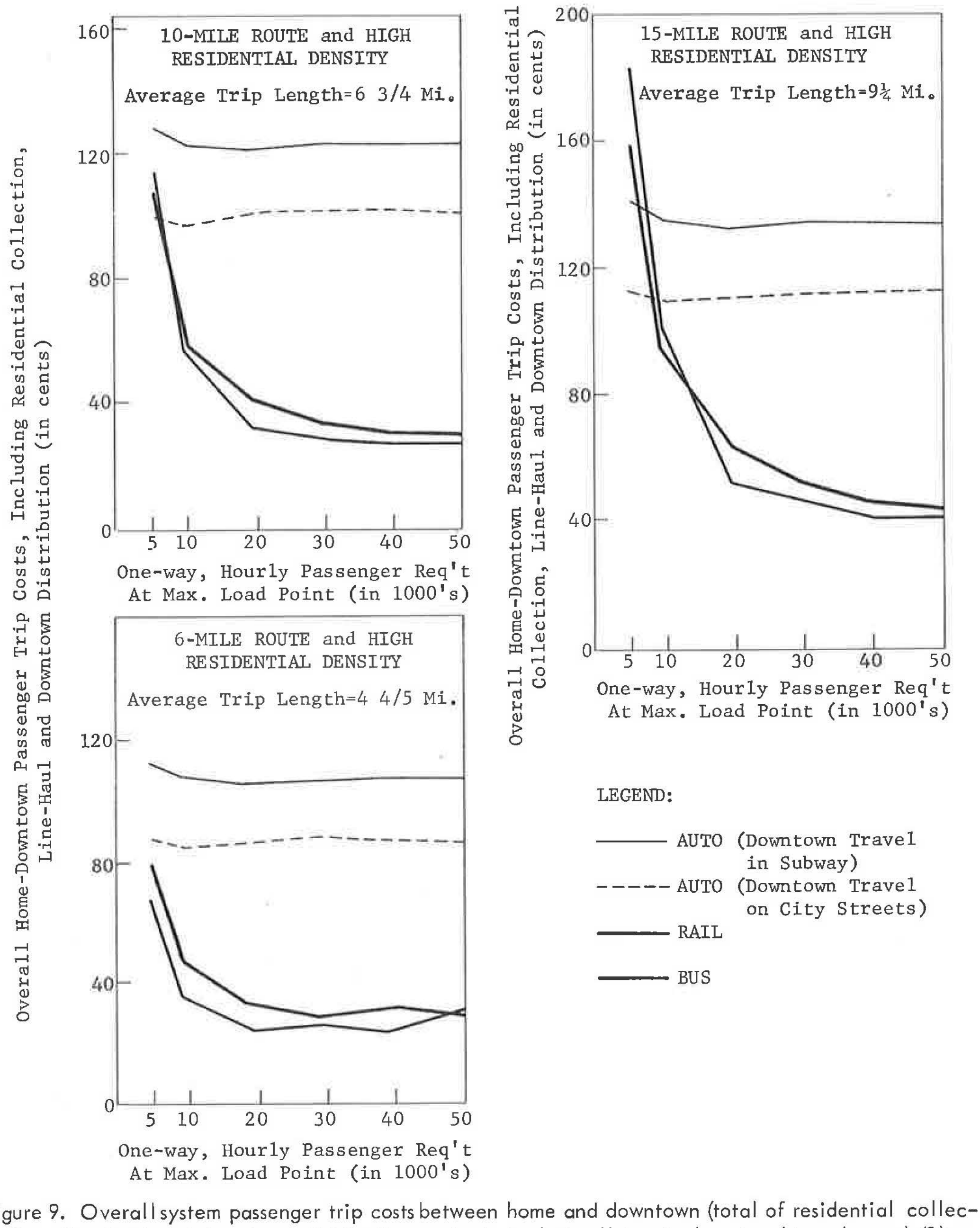


Figure 9. Overall system passenger trip costs between home and downtown (total of residential collection, line-haul and downtown distribution costs, to include all terminal and parking charges) (3).

some of these can be considered as express bus lines with the same cost characteristics as rail facilities.

Rush-hour travel greatly influences the cost of mass transit services; therefore, the average rush-hour trip cost was taken to be reasonably representative for the average daily trip. All of these costs include expenditures for roads, rolling stock, and operation.

The downtown-bound auto travel cost, as shown in Figure 9, remains nearly constant at different loads but responds to the average trip length. These graphs indicate auto travel costs in high-density areas.

TABLE 5

MASS TRANSIT TRIP COSTS

Pattern	Sketch	Part of Region	Number of Units	rd*	Selected Route Length	Number of Sectors	24 Hour Trips (000)	24 Hour Trips Per Sector (000)	Trips Per Hour at Max. Load Point (000)**	Rush-Hour Trip Cost (Fig. 8)
Decentralized	1A	Core	1	12.3	15	18	9,168	509.3	51.6	.40
		Met. Area	40	—	—	—	—	—	—	—
	1C	Core	1	11.3	10	18	10,031	557.3	56.4	.40
		Met. Area	38	—	—	—	—	—	—	—
New Towns	2B	Core	1	17.8	15	18	12,137	674.3	68.3	.40
		Met. Area	16	6.5	6	6	608	101.3	10.3	.35
	2C	Core	1	11.0	10	18	9,211	511.7	51.8	.40
		Met. Area	10	8.5	10	10	1,391	139.1	14.1	.45
Concentrated	3A	Core	1	23.4	15	30	23,178	772.6	78.2	.40
		Met. Area	1	—	—	—	—	—	—	—
	3B	Core	1	23.3	15	24	18,613	775.5	78.5	.40
		Met. Area	2	12.8	15	15	3,399	226.6	23.0	.50

*Radius extending to 3,000 persons per sq mi density.
**Conversion factor 0.1012.

This study made no distinction between the downtown-bound and the circumferential auto travel. The auto trip cost, as shown in Figure 10, reflects the population density in which the trips originate. In establishing the range of costs shown by this figure reference was made to several sources. The extreme cost values adapted from other studies were superimposed by a straight-line proportion over densities occurring in this study. The auto travel costs represent road construction, maintenance, auto ownership, operation expenditures, and parking. The average trip length for all sketches was assumed to be 6 miles.

Table 6 shows the computation results indicating travel costs for the six sketch plans. Viewing these costs as part of the population's resources, the analysis results indicate the extent of resources to be expended for travel purposes under conditions of the six development schemes. In the last column Table 6 shows these daily expenditures on a per-person basis. Figure 11 demonstrates the increase in resource allocation by modes above the 1960 level.

APPLICATION OF DENSITY MODELS FOR THE EVALUATION OF SELECTED ALTERNATIVES

The cone-shaped sketch planning models for the selected development alternatives could be transcribed into density models of the hyperbolic parabola type on the basis of existing and projected densities (Fig. 12).

The selected sketch alternatives, in all likelihood, would consider the scatter of existing urban units as the basis for the urbanization pattern of the future. These units would be projected for the population increase and, perhaps, a number of new communities would be planned to rise in the course of time. Future urban units in the metropolitan area would not be uniform in size. The regional urbanization system would reflect not only the anticipated population growth, but also the interaction of communities. Urban units could be ranked by the scope and character of planned activities.

Employing density models, such alternatives could be evaluated for the basic travel characteristics and for resource

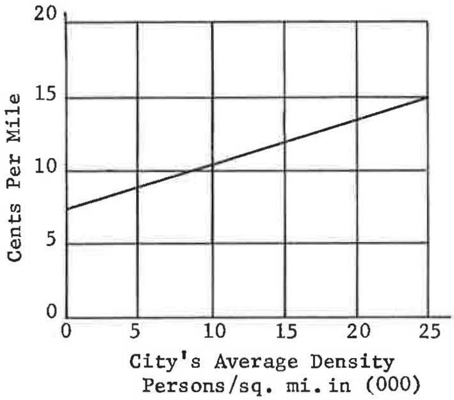


Figure 10. Auto travel cost per person trip.

allocation requirements. On the basis of these findings, alternative development schemes could also be provided with conceptual layouts of facility networks.

Utilizing the inventory data, criteria for travel generation and for the determination of travel costs could be refined to represent these factors more accurately. The analysis output of final alternatives on this basis could give a fairly realistic picture of changes that might take place in the evolution of transportation systems as well as of the resource allocation requirements for such development processes.

Should the selected alternatives be detailed by development stages, such as programs for each decade, this method of analysis could estimate the changes in travel demand, modal use, and the required resources allocation for transportation systems at each development period. Detailing long-range plans by development steps would provide the opportunity for a rational planning of transportation systems. The required land for transportation facilities

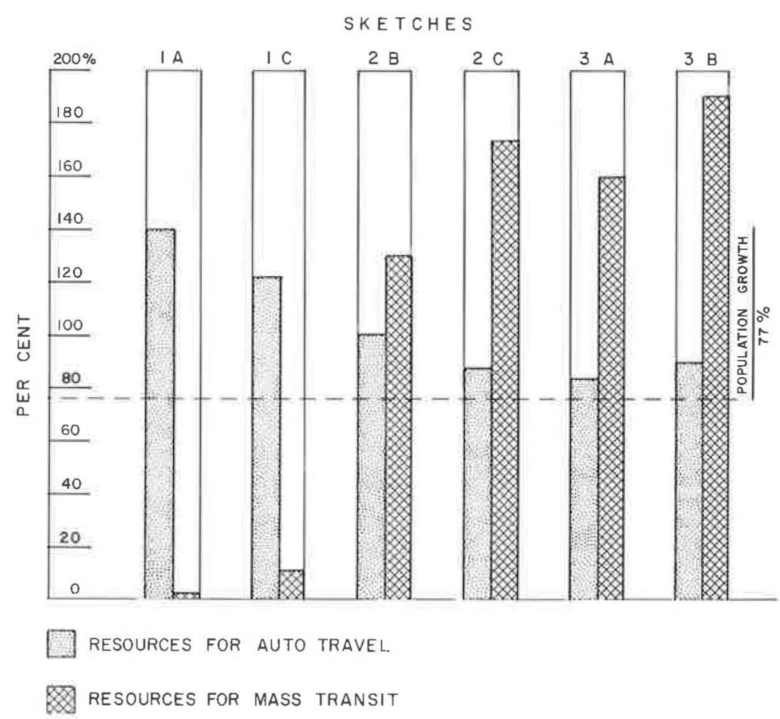


Figure 11. Resource allocation increase by modes—percent above present volume.

TABLE 6

TRAVEL COSTS PER 24 HOUR DAY

Pattern	Sketch	Part of Region	Total Trips (000)	Mass Trans. Trips (000)	Trip Cost ¢	Mass Trans. Travel Cost $(000)	Auto Trips (000)	Trip Cost ¢	Auto Travel Cost $(000)	Total $(000)	Per Person $
Decentralized		Core	18,815	9,168	40	3,667	9,647	91.0	8,779	12,446	1.24
	1A	Met. Area	58,800	—		—	58,800	59.5	34,986	34,986	1.75
		Total	77,615	9,168		3,667	68,447	69.0	43,765	47,432	1.58
		Core	18,206	10,031	40	4,012	8,175	105.0	8,584	12,596	1.15
	1C	Met. Area	53,504	—		—	53,504	59.5	31,835	31,835	1.68
		Total	71,710	10,031		4,012	61,679	65.0	40,419	44,431	1.48
New Towns		Core	31,829	12,137	40	4,855	19,692	77.0	15,163	20,018	1.43
	2B	Met. Area	44,074	9,728	35	3,405	34,336	63.0	21,632	25,037	1.56
		Total	75,903	21,865		8,260	54,028	68.0	36,795	45,055	1.50
		Core	16,803	9,211	40	3,684	7,592	105.0	7,972	11,656	1.17
	2C	Met. Area	53,030	13,910	45	6,260	39,120	66.5	26,015	32,275	1.61
		Total	69,833	23,121		9,944	46,712	69.0	33,987	43,931	1.46
Concentrated		Core	55,923	23,178	40	9,271	32,745	80.5	26,360	35,631	1.37
	3A	Met. Area	11,442	—		—	11,442	59.5	6,808	6,808	1.70
		Total	67,365	23,178		9,271	44,187	75.0	33,168	42,439	1.41
		Core	51,915	18,613	40	7,445	33,302	73.5	24,477	31,922	1.45
	3B	Met. Area	21,029	5,778	50	2,889	15,251	66.5	10,142	13,031	1.63
		Total	72,944	24,391		10,334	48,553	71.0	34,619	44,953	1.50

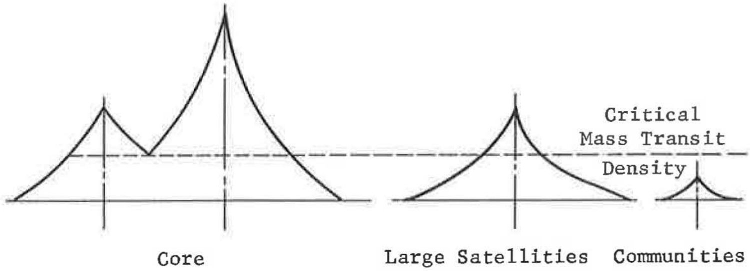


Figure 12. Illustration of density model for final planning alternatives.

could be mapped in advance and the introduction of new facilities could follow the rationale of long-range urban development. Shifts in travel modes could also be accommodated at the proper time.

Study of Mass Transit Levels for Large Cities

If some of the region's cities were to reach high density levels, and if technological advances were to be experienced in mass transportation technology, the different urban development states would have to be provided with appropriate means of mass passenger conveyance. Figure 13 illustrates four possible types of mass transportation systems.

Mass Transit I, in very high density zones, could be slow- to moderate-speed continuous passenger conveyance facilities such as pedestrian conveyors or moving sidewalks. Mass Transit II, in high density areas, would be medium-speed facilities. The network would be extensive and with only little local street transit. Mass Transit III, in medium-density areas, would be a combination of high-speed regional transit system and local bus or equivalent services. Low density areas would depend on auto travel.

The indicated levels of mass transit systems are hypothetical concepts. A separate study would be necessary to better define such services and to correlate them to densities that would demand and have the propensity to sustain such facilities.

Density models could be employed to relate the stages of urban growth with the needs of different level transportation systems. Urban development stages could also be timed to regard the life span of such systems. Major shifts in development policies could be proposed in order to prepare a logical transition from lower to higher rank of mass transit facilities. Resources allocation and methods of financing could be part of such a study.

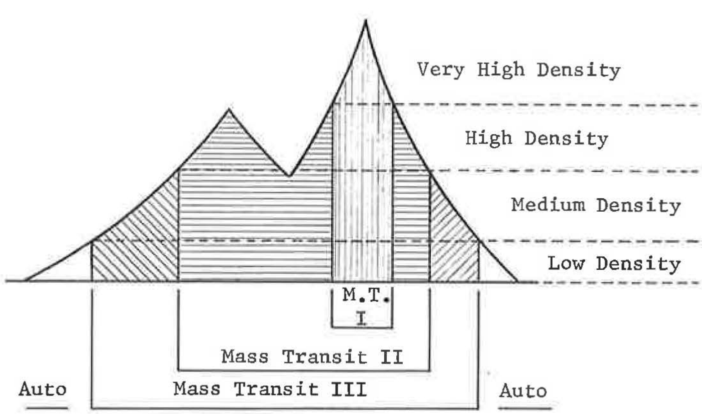


Figure 13. Levels of mass transit services.

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