26

HIGHWAY RESEARCH BOARD

Bulletin 326

Urban Transportation

Demand and Coordination

National Academy of Sciences—

National Research Council

publication 1006

NRC, HIGHWAY RESEARCH BOARD

Bulletin 326

Urban Transportation

Demand and Coordination

Presented at the
41st ANNUAL MEETING
January 8-12, 1962

National Academy of Sciences—
National Research Council
Washington, D.C.
1962

$2.00

Committee on Urban Transportation Research

Pyke Johnson, Chairman
1707 H Street, N.W.
Washington, D.C.

M. Earl Campbell, Chairman
Engineer of Economics, Finance and Administration
Highway Research Board, Washington, D.C.

Robert J. Anderson, Assistant Surgeon General, Deputy Chief, Bureau of State Services, Public Health Service, Washington, D.C.
Donald J. Bogue, Associate Director, Population Research and Training Center, The University of Chicago, Chicago, Illinois
J. Douglas Carroll, Jr., Study Director, Chicago Area Transportation Study, Chicago, Illinois
Harmer E. Davis, Director, Institute of Transportation and Traffic Engineering, University of California, Richmond
Henry Fagin, Executive Director, Penn-Jersey Transportation Study, Philadelphia, Pennsylvania
Luther H. Gulick, President, Institute of Public Administration, New York, N.Y.
Edward H. Holmes, Director of Planning, Bureau of Public Roads, Washington, D.C.
J.B. McMorran, Superintendent of Public Works, New York State Department of Public Works, Albany
Burton W. Marsh, Director, Traffic Engineering and Safety Department, American Automobile Association, Washington, D.C.
D. Grant Mickle, Deputy Federal Highway Administrator, Bureau of Public Roads, Washington, D.C.
Robert B. Mitchell, Chairman, Department of Land and City Planning, University of Pennsylvania, Philadelphia
Gordan M. Murray, U.S. Bureau of the Budget, Washington, D.C.
Wilfred Owen, Senior Staff Member, The Brookings Institution, Washington, D.C.
Clifford F. Rassweiler, Vice President for Research and Development, Johns-Manville Corporation, New York, N.Y.
Morten J. Schussheim, Assistant Administrator for Program Policy, Housing and Home Finance Agency, Washington, D.C.
Donald C. Wagner, Managing Director, Philadelphia, Pennsylvania
Coleman Woodbury, Director of Urban Research, University of Wisconsin, Madison

Contents

SOME ASPECTS OF FUTURE TRANSPORTATION IN URBAN AREAS

Herbert S. Levinson and F. Houston Wynn 1

METROPOLITAN AREA APPROACH TO COMPREHENSIVE AND COORDINATED TRANSPORTATION PLANNING

Paul Oppermann 32

A METHOD FOR ATTAINING REALISTIC LOCAL HIGHWAY SYSTEM PLANS

K.W. Bauer 37

CONTRIBUTIONS FROM GEOGRAPHY TO URBAN TRANSPORTATION RESEARCH

Roy I. Wolfe 46

Appendix 67

PREDICTING FUTURE DEMAND FOR URBAN AREA TRANSPORTATION

Frederick W. Memmott, III, Brian V. Martin and Alexander J. Bone. . . . 69

Appendix 78

Some Aspects of Future Transportation In Urban Areas

HERBERT S. LEVINSON and F. HOUSTON WYNN, Wilbur Smith and Associates, New Haven, Conn.

This paper summarizes some of the basic interrelationships between cities, people, and their transportation requirements and shows how present trends in travel and urban development affect demands and potentials for public and private transportation. It sets forth rationale for predicting travel modes in urban areas both on a daily and peak-hour basis and shows how the characteristics of public and private transportation relate to various predictors. These predictors, in turn, provide a basis for generalizations regarding the role and balance of each form of future urban transportation.

The paper shows some of the fundamental interrelationships between land use, socio-economic status, and transportation mode. Because these elements are interdependent, it suggests that future land use and transportation must be conceived and planned as an integral unit.

• MOBILITY and industrialization have become major factors in the national culture and economy. The growth of transportation and the rise of cities has been parallel. Despite significant technological advances, the continuing expansion of urban areas has made the daily movement of people and goods increasingly complex. There is urgent need for greater efficiency and a better "balance" among the several modes of urban transportation.

This paper sets forth some of the basic problems of future urban transportation. Analyses have been based on information obtained from a series of urban areas varying widely in size, location, and economy. These areas include Chicago, Detroit, Washington, Pittsburgh, St. Louis, Houston, Kansas City, Phoenix, Nashville, Chattanooga, Charlotte, Reno, Tacoma, and Nashville. Questions investigated include:

1. How do present trends in urban development and travel affect demands for public and private transportation?
2. What bases can be developed for predicting the modal distribution of travel within urban areas in terms of today's technology and capability?
3. What are the respective roles of modern public and private transportation?
4. What land use implications are inherent in efforts to achieve a "balanced system" of urban transportation?

TRANSPORTATION AND CITY GROWTH

The history of man's civilization is often told in terms of city development. Early urban settlements developed at the crossroads of caravan commerce or at the edge of the sea, where land transport shifted to water carriers. For centuries, waterways were the principal highways of the trading world, affording the fastest and cheapest transport of people and goods. Land travel, in contrast, was slow and expensive, and cargoes relatively small.

The limited means of transportation restricted development of cities and kept them to a size that could be served by the surrounding agricultural "hinterland" within a few days wagon journey. However, despite these limitations, a few cities grew up to very large size; London, England, reached more than a million persons while still dependent on water travel and horse-drawn land traffic.

The Rise of Cities

The harnessing of steam power, brought on by the industrial revolution, provided urbanization its greatest impetus and quickly influenced transportation. New mechanical power increased agricultural productivity, and the resulting migration of persons to cities created a continuing period of city building that shows no sign of diminishing.

City growth, structure, and function are intimately related to the movement of people and goods; the railroad, horsecar, electric street railway, subway and elevated, motor bus, and private automobile have all served to extend the radius of the urban region. Within the city, the invention of the mechanical elevator has permitted a vertical growth that matches its horizontal expansion.

The central business district is the natural focus of the urban area. Until the early 20th Century, each new form of transportation encouraged concentration at this central point. The greatest concentrations developed in the large American cities where rail rapid transit systems were built—New York, Chicago, Philadelphia, and Boston. The impact of rapid transit on the growth of these centers has been unparalleled—and was accompanied by concentrations of people along the principal routes.

In the history of city development, the automobile is the only personal transport vehicle that has the potential to serve all parts of the city with equal efficiency. Consequently, it has tended to equalize the attractiveness of many different sites within an urban region.

The Individuality of Cities

Transportation plans must be objectively developed and carefully related to other

TABLE 1

DISTRIBUTION OF 1950 AND 1960 POPULATION[1]

Population Range	1950			1960		
	No of Cities or Areas	Percent of Total	Mean Density (persons per sq mi)	No of Cities or Areas	Percent of Total	Mean Density (persons per sq mi)
	(a) Central Cities					
0- 50,000	8	4.6	3,000	25	9.8	2,500
50,000- 100,000	67	38.9	4,500	111	43.7	4,500
100,000- 200,000	45	26.2	6,400	57	22.4	5,100
200,000- 300,000	16	9 2	7,600	19	7.5	5,700
300,000- 400,000	11	6 4	7,500	12	4.7	5,800
400,000- 500,000	7	4.1	7,600	9	3 6	6,300
500,000- 750,000	7	4 1	9,000	11	4 3	8,100
750,000-1,000,000	6	3 5	13,250	5	2.0	10,300
1,000,000-2,000,000	2	1.2		1	0 4	
2,000,000-3,000,000	1	0.6	17,000	2	0 8	11,700
3,000,000-5,000,000	1	0.6		1	0.4	
Over 5,000,000	1	0 6	25,000	1	0.4	25,000
Total	172	100.0	7,788	254	100.0	5,349
	(b) Urbanized Areas					
0- 50,000	-	-	-	-	-	-
50,000- 100,000	38	24.2	4,400	62	29 1	3,100
100,000- 200,000	59	37 6	4,300	66	31 0	3,100
200,000- 300,000	18	11.5	3,700	28	13.1	3,200
300,000- 400,000	8	5.1	4,500	14	6.6	3,100
400,000- 500,000	9	5.7	4,600	7	3 3	3,400
500,000- 750,000	9	5 7		12	5 7	
750,000-1,000,000	4	2 5	6,500	8	3 8	4,000
1,000,000-2,000,000	5	3 2		9	4.2	
2,000,000-3,000,000	4	2.6	7,400	2	0 9	
3,000,000-5,000,000	2	1 3		2	0.9	5,500
Over 5,000,000	1	0 6		3	1.4	
Total	157	100.0	5,438	213	100 0	3,752

[1]Source: U.S. Department of Commerce, Bureau of the Census.

urban values and goals. They must recognize the individuality of cities and the desires of people. No single, stereotyped transportation plan can be superimposed on all cities; there is no "one solution" regarding the relative roles of public and private transportation—each urban area is unique in its history, culture, economy, future mission, and transportation requirements.

The interrelationships between population and density within the nation's urban areas (given in Table 1) clearly indicate the individuality of the American city. In 1950, there were 172 central cities in the nation's 157 urbanized areas; the urbanized area population aggregated 69,300,000; central city densities averaged 7,788 persons per sq mi; and urbanized area densities, 5,438 persons per sq mi. In 1960, there were 254 central cities in 213 urbanized areas; the urbanized area population totaled 95,800,000; central city densities averaged 5,349 persons per sq mi; and urbanized area densities, 3,752 persons per sq mi. Thus, within the last decade there has been a lowering of urban densities; at the same time urbanization has sharply increased.

As shown in Table 1, densities tend to increase as cities get larger. Densities increase from about 5,000 to 6,000 persons per sq mi in central cities under 200,000 population, to over 8,000 persons per sq mi in central cities over 500,000, and over 10,000 persons per sq mi in central cities over 1,000,000. (Table 1 also shows that the increases in density in large cities were more rapid in 1950 than in 1960.) Variations in urbanized area densities were less, particularly in 1960. In 1950, urbanized area densities increased from about 4,500 persons per sq mi in areas under 750,000 population, to about 7,400 persons per sq mi in areas over 2,000,000 population. In 1960, urbanized area densities ranged from about 3,000 persons per sq mi in areas under 750,000 to 5,500 persons per sq mi in areas over 2,000,000.

Although large cities are generally more dense than smaller ones, there are many exceptions. These exceptions become more numerous as new major centers emerge.

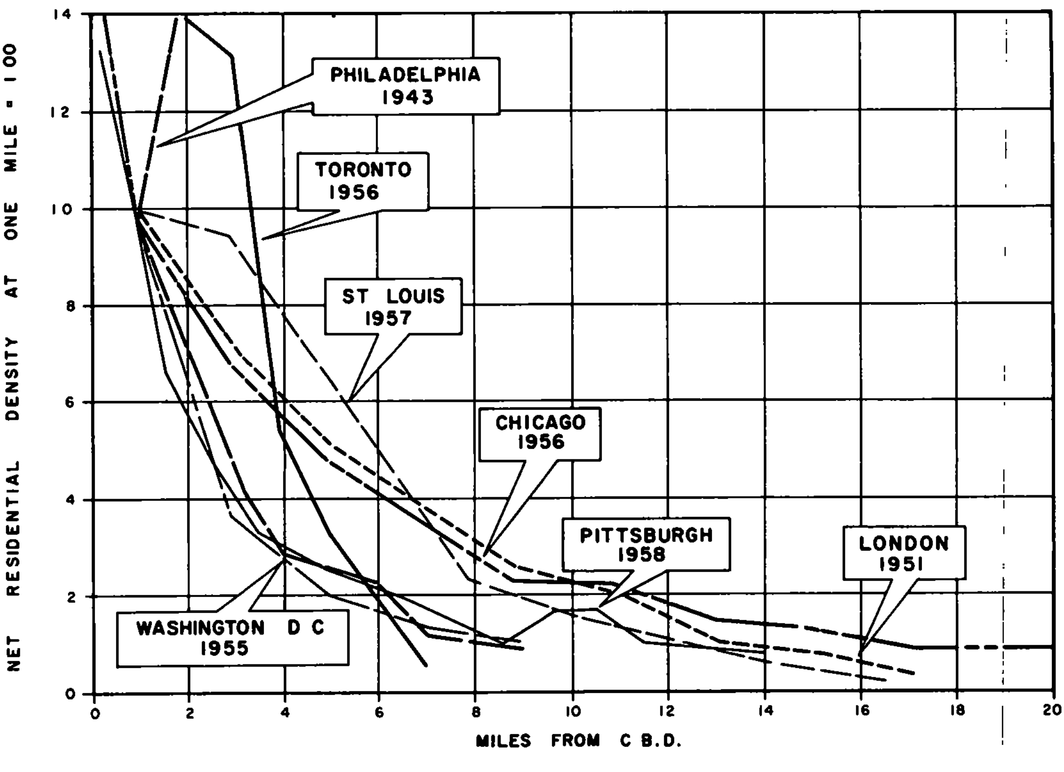


Figure 1. Population densities related to distance from central business district.

Los Angeles, for example, had a 1960 population of nearly 2,500,000, with a density of about 5,500 persons per sq mi.

The greatest concentrations of people are found in the old established cities where rapid transit systems have been operating for years. Of the large central cities in the country with 1960 densities exceeding 14,000 persons per sq mi (New York—Northeastern New Jersey, 23,321; Chicago, 15,836; San Francisco, 15,553; Boston, 14,586; and Philadelphia, 15,743), only San Francisco does not have a rapid transit system. By way of comparison, in both Montreal and Toronto, where rapid transit exists or is being developed, central city densities are about 20,000 persons per sq mi.

GROWTH IMPLICATIONS

Motivated by strong social and economic forces, the modern metropolis is spreading in every direction, in terms of both area and population. Previously remote real estate is now being occupied by people who work, shop, or visit in the neighboring urban center and its environs.

Today, the nation's population is nearly 180,000,000 people—an increase of about 18.5 percent since 1950. Within the last decade, the West grew 38.9 percent, the South 16.5 percent, the North Central area, 16.1 percent, and the Northeast 13.1 percent. The greatest metropolitan area and central city growths, in terms of percentage, were also in the South and Southwest. On the other hand, most of the old-established transit-oriented cities experienced some population decreases.

Density gradient patterns clearly depict the changing aspect of city growth and explain the "low-density" character of suburbia. As shown in Figure 1, density decreases consistently over concentric zones (3, 8, 13). In Chicago, for example, population density 4 mi from downtown is about 60 percent of that at 1 mi; at 10 mi, it is about 20 percent. The pattern in London, England, is strikingly similar to the patterns found in St. Louis and Chicago. Each subsequent zone tends to level off at a somewhat lower over-all density.

Land Use and Travel

As urban areas grow, new patterns of land use and travel emerge. The growing suburbs have precipitated new shopping centers and a dispersal of commercial services and industrial plants, creating new work opportunities in these areas. Dispersal of manufacturing activity from the inner zones of the central city was dominant throughout the nation. Downtown there has been a relative drop in sales and employment, with the central business district becoming more specialized as the center of government, management, and finance. Central business district sales in 55 metropolitan areas decreased 0.1 percent between 1954 and 1958, whereas total metropolitan area sales increased 17.4 percent (4).

All of these developments have created new travel patterns and fostered increased dependence on motor vehicle transportation, both individually and nationally. Today, approximately three of every four families in the United States own cars. Nearly 74 million registered vehicles travel more than 720 billion vehicle-miles annually. Acceptance and use of the motor vehicle have outpaced the building of adequate roads and parking facilities.

Automobile registrations have increased approximately 128 percent, and vehicle-miles 138 percent since 1940. In this same period, public transportation had declined over 30 percent (from 14.1 to 9.3 billion riders annually) and commuter railroads about 3 percent despite the increases in urbanization. Annual transit rides per capita have decreased from over 300 in 1940 to less than 100 in 1960. Within the past few years, rapid transit riding has stabilized and has even shown slight increases. Generally, rapid transit serves high-density and relatively stable service areas that were built along its lines.

Losses in transit patronage have resulted from the increased ownership and use of the private automobile, and from increasing scatteration throughout the urban area. Other causative factors include a shorter working week, changing recreational habits, increased fares, and a lack of transit modernization commensurate with highway improvements.

Within the next two decades, the nation's population is expected to reach 245 million, of which 180 million will live in urban areas—as much as the country's entire population today. Most of the new urban growth will be at population densities of approximately 2,500 persons per sq mi; the amount of land located within expanded urban limits by 1980 will be about double that of today. By 1980, the ratio of private cars to persons will likely increase about 20 percent, with one passenger car registered for every 2.4 persons. Car registration will approximate 120 million; motor vehicle travel, over 1,200 billion vehicle-miles annually.

These trends imply continued dispersion of cities and lower population densities. There will probably be more "second dwellings" at the beach, lake, or forest, resulting in longer commuting distances.

URBAN TRIP GENERATION

Knowledge of the basic characteristics of urban travel is prerequisite for the determination of future transportation requirements. Since 1944, about 150 "metropolitan area" transportation studies of urban travel have been undertaken; most were developed by state highway departments in conjunction with the U.S. Bureau of Public Roads. The current trend is toward increasingly thorough analyses that fully recognize the need to augment inventories of travel facilities and patterns with appraisals of land use, population density, and composition, as well as quality and character of housing.

Summary Patterns

The travel characteristics of residents within a cross-section of the nation's urban areas are summarized in Tables 2 and 3. (Analyses have been based on information contained in the origin-destination studies cosponsored by the U.S. Department of Commerce, Bureau of Public Roads, the respective state highway departments, and local government agencies.) These tables show that (a) the number of daily trips ranges from 1.6 to 2.5 per person, and from about 5 to 8 per dwelling unit; (b) the number of persons per dwelling unit ranges from about 2.2 (in Fort Lauderdale), to about 3.4 (in Charlotte); (c) the number of cars per dwelling unit ranges from about 0.8 (in Fort Lauderdale, Washington, and Chicago) to about 1.1 (in Phoenix and Reno); (d) car occu-

TABLE 2

GENERATION OF TRAVEL BY URBAN RESIDENTS[1]

Area	Year of Survey	Population in Study Area	Trips per Person	Persons per Car	Trips per Dwelling	Persons per Dwelling	Cars per Dwelling
Chicago, Ill.	1956	5,169,663	1.92	3.85	5.96	3.10	0.80
Detroit, Mich.	1953	2,968,875	1.77	3.51	5.88	3.31	0.94
Washington, D.C.	1955	1,568,522	1.67	3.75	5.05	3.02	0.81
Pittsburgh, Pa.	1958	1,472,099	1.61	3.75	5.26	3.26	0.87
St. Louis, Mo.	1957	1,275,454	1.94	3.48	6.05	3.12	0.90
Houston, Texas	1953	878,629	2.22	3.43	7.16	3.22	0.94
Kansas City, Mo.	1957	857,550	2.18	3.26	6.69	3.07	0.95
Phoenix, Ariz.	1957	397,395	2.29	2.87	6.88	3.01	1.05
Nashville, Tenn.	1959	357,585	2.29	3.35	7.52	3.28	0.98
Chattanooga, Tenn.	1960	242,000	2.17	3.32	7.22	3.33	1.00
Ft. Lauderdale, Fla.	1959	210,850	1.69	2.72	3.63	2.15	0.79
Charlotte, N.C.	1958	202,272	2.36	3.28	8.10	3.43	1.05
Reno, Nev.	1955	54,933	2.48	2.43	6.87	2.77	1.14

[1]Compiled from various summaries of origin-destination data for each urban area.

TABLE 3

TRIPS BY URBAN RESIDENTS ACCORDING TO MODE IN STUDY AREAS[1]

Area	Year	Trips								Avg Car Occupancy	Trucks (%)
		Driver (x 10^3)	Passenger (x 10^3)	Transit (x 10^3)	Total Auto and Transit (x 10^3)	In Autos (%)	In Transit (%)	Truck (x 10^3)	Total Veh (x 10^3)		
Chicago	1956	4,811	2,706	2,414	9,931	75.7	24.3	828	5,639	1.56	14.7
Detroit	1953	2,991	1,394	879	5,264	83.3	16.7	495	3,486	1.46	14.2
Washington	1955	1,278	709	639	2,626	75.7	24.3	219	1,497	1.56	14.6
Pittsburgh	1958	1,292	603	482	2,377	79.7	20.3	229	1,521	1.47	15.1
St Louis	1957	1,359	731	387	2,477	84.4	15.6	280	1,639	1.54	17.1
Houston	1953	1,085	616	252	1,953	87.1	12.9	202	1,287	1.57	15.7
Kansas City	1957	1,108	577	185	1,870	90.1	9.9	181	1,289	1.52	14.0
Phoenix	1957	586	266	58	910	93.6	6.4	168	754	1.45	22.2
Nashville	1959	493	263	63	819	92.3	7.7	91	584	1.54	15.6
Ft Lauderdale	1959	238	114	5	357	98.6	1.4	31	259	1.48	12.0
Chattanooga	1960	312	174	39	525	98.6	7.4	64	376	1.56	17.0
Charlotte	1958	303	140	35	478	92.7	7.3	52	355	1.46	14.6
Reno	1955	81	53	2	136	98.5	1.5	22	103	1.65	21.4

[1]Obtained from origin-destination studies in each area.

pancy ranges from 1.4 to 1.7 persons per trip, averaging about 1.5; (e) commercial vehicles accounted for between 12 and 22 percent of vehicle trips; and (f) more than three-fourths of all urban travel is by car.

Figure 2 relates trip generation in these communities to city size and structure. The interplay between city population, density, and trip generation is apparent; the number of daily person trips in vehicles decreases as the size and/or density of the community increases (in large cities like Detroit and Chicago, the urban residents make about 2 trips per day, whereas in smaller cities like Reno, the average is 2½ or more trips per day). These differences may be attributed to greater car ownership and dependence on the private car for transporation, comparative availability of parking spaces, shorter average trip lengths, and the relatively few destinations within walking distance.

Based on the origin-destination data in these cities, urban trip generation has been related to car ownership in Table 4. Inasmuch as car ownership depends largely on economic status, urban trip generation reflects the economic ability to travel. As a result, there is an inverse relationship between trip generation and car ownership; the greater the number of persons per car, the lower the daily trips per person, and the number of trips per car.

Car occupancies for various trip purposes are related to car ownership in Table 5. The occupancies of work and shopping trips increase as the number of persons per car increases (i.e., as car ownership decreases). For example, when there are 1.5 to 2.0 persons per car, the work trip occupancy averages 1.10 persons per auto trip; when there are over 6 per car, work trip occupancy averages 1.60 per auto trip. Social trip occupancies are the same for all levels of vehicle ownership, although fewer social trips are made by families with low car ownership ratios.

These tables provide a basis for estimating the generation of travel by residents in a city; they enable zonal trip ends to be related to the various employment generators, retail sales, and recreational facilities for each zone considered.

Characteristics of Transit Riders

Characteristics of Chattanooga, Tenn., transit riders illustrate the socio-economic and socio-ethnic stratification of transit patrons. During an average 1960 weekday, persons in the Chattanooga area made about 29,300 transit trips (excluding school bus trips); of these, 12,600 (43 percent) were made to and from the central business district.

The distribution of these trips, according to occupation of transit riders, is given in Table 6. Housewives and retired persons made 26.3 percent of the transit trips to the central business district, and 25.3 percent of the central business district transit trips were made by store and office clerks. The remaining 48 percent were distributed among eight other occupation classifications.

The composition of transit trips with both termini in outlying areas of Chattanooga was strikingly different. Personal service workers accounted for 30.7 percent of the non-central business district trips; grammar and high school students, 17.9 percent;

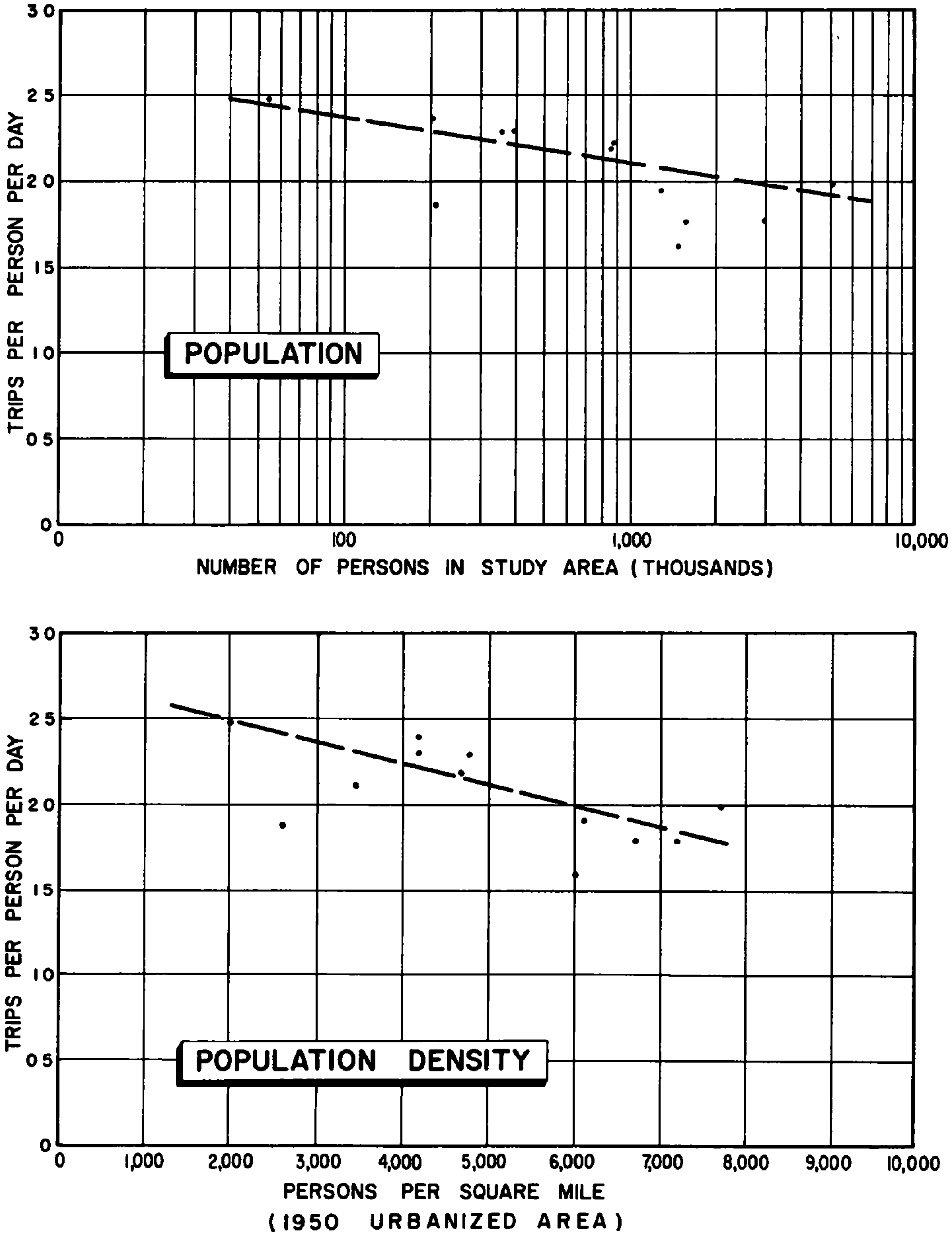


Figure 2. Trip generation related to city size and density.

and operatives and semiskilled workers, 15.5 percent. The remaining 36 percent were distributed among seven other occupational groups.

Personal service workers accounted for 27.3 percent of the total metropolitan area trips; housewives and retired persons, 16.6 percent; grammar and high school students, 15 percent; store and office clerks, 14.7 percent; and operative and semiskilled workers, 12.6 percent.

Most Chattanooga transit riders do not have a car available to them. Similarly, a study of car ownership in Hartford, Conn., showed approximately 39 percent of all bus riders without a car for family use, and, therefore, heavily reliant on bus transportation.

Walking distance patterns of transit riders in Chattanooga clearly show the value and limitations of public transportation. As shown in Table 7, some 72 percent of all transit riders are delivered to within one block of their downtown destination; 90 percent to within two blocks. At the non-central business district end of transit trips, two-thirds of all riders walk one block or less from the bus stop; and about 85 percent two blocks or less. Thus, transit provides "door step" service within the core area, but its service elsewhere is limited to areas within short walking distances of bus stops.

A study of the socio-ethnic composition of Chattanooga transit riders indicates that nearly two-thirds of all transit riders were women. Nonwhite female residents generated nearly a quarter of all transit trips, although they constituted under 10 percent of

TABLE 4

URBAN TRIP GENERATION RELATED TO CAR OWNERSHIP[1]

Avg. No. Persons per Car in Zone	Avg. Daily Trips per Person, All Modes	Driver Trips per Car
1.5 - 2.0	3.2 - 3.6	3.4 - 5.0
2.0 - 2.5	2.6 - 3.2	3.5 - 4.9
2.5 - 3.0	2.2 - 3.0	3.7 - 5.5
3.0 - 3.5	2.0 - 2.5	3.5 - 4.4
3.5 - 4.0	1.6 - 2.0	3.1 - 4.9
4.0 - 5.0	1.4 - 1.9	2.9 - 4.6
5.0 - 6.0	1.2 - 1.6	2.5 - 3.7
6.0+	0.9 - 1.2	2.3 - 3.7

[1]Compiled from origin-destination study in various urban areas.

TABLE 5

URBAN CAR OCCUPANCIES BY TRIP PURPOSE RELATED TO CAR OWNERSHIP[1]

Avg. No. Persons per Car	Average Auto Trip Occupancy for			
	Work	Shopping	Social	All Purposes
1.5 - 2.0	1.10	1.30	2.35	1.4 - 1.6
2.0 - 2.5	1.20	1.40	2.35	1.4 - 1.6
2.5 - 3.0	1.25	1.45	2.35	1.4 - 1.6
3.0 - 3.5	1.30	1.45	2.35	1.4 - 1.6
3.5 - 4.0	1.35	1.45	2.35	1.4 - 1.6
4.0 - 5.0	1.40	1.45	2.35	1.4 - 1.6
5.0 - 6.0	1.50	1.50	2.35	1.5 - 1.7
6.0 +	1.60	1.55	2.35	1.6 - 1.8

[1]Compiled from origin-destination studies in various urban areas.

the entire metropolitan area population. (The Chattanooga standard metropolitan area had a total 1960 population of 283,169 of which 17.5 percent were nonwhite. Of 29,296 transit riders, 24.5 percent were nonwhite female, 39.7 percent white female, 12.7 percent nonwhite male, and 22.7 percent white male.)

MODAL DISTRIBUTION

Knowledge of the factors that relate to the distribution of travel between alternate modes, particularly between transit and automobiles, is prerequisite to the development of a balanced transportation plan.

Principal factors that affect the choice of travel mode include city size, density, and age; the composition, distribution, and economic levels of urban residents; and the quality of existing transportation facilities. Impediments to automobile travel (topographic barriers, high densities, and resulting congestion) for example, may be conducive to transit use.

TABLE 6

OCCUPATION OF TRANSIT RIDERS, CHATTANOOGA, TENNESSEE[1]
(1960 Average Weekday)

Occupation	Central Business District Trips		Non-Central Business District Trips		Total-All Metropolitan Area Trips	
	Total	%[2]	Total	%	Total	%
Professional and semi-professional	562	4.7	413	2.4	975	3.3
Proprietors, managers, and officials	360	3.0	265	1.5	625	2.1
Store and office clerks, inside salesmen, etc.	3,040	25.3[a]	1,263	7.3	4,303	14.7
Traveling salesmen, agents, canvassers, etc.	53	0.4	95	0.6	148	0.5
Craftsmen, foremen, skilled laborers, etc.	276	2.3[b]	710	4.1	986	3.4
Operatives and semi-skilled workers	996	8.3	2,682	15.5	3,678	12.6
Laborers and unskilled workers	679	5.7	1,484	8.6	2,163	7.4
Protective services, policemen, etc.	42	0.3	42	0.2	84	0.3
Personal service workers	1,250	10.4	5,301	30.7	6,551	22.3
Housewives and retired persons	3,168	26.3	1,688	9.8	4,856	16.6
High school and grammer school students	1,313	10.9	3,086	17.9	4,399	15.0
College and business school students	286	2.4	244	1.4	530	1.8
Total trip destinations	12,025	100.0	17,273	100.0	29,298	100.0

[1]Source: Transportation Program—Chattanooga, Tennessee, Wilbur Smith and Associates, 1961. Excludes school bus trips.
[2]Because the data were obtained from an approximate 5 percent sample, they are subject to some sampling variability. The following two examples illustrate this variability: [a]Approximate 95 percent confidence limits are 22.9 and 28.7 percent. [b]Approximate 95 percent confidence limits are 0.7 and 4.9 percent.

Predicting Travel Modes

City size and age are related to travel modes in Table 8. Within the cities listed, the proportion of travel by transit ranges from under 2 percent in Reno to over 24 percent in Washington and Chicago; downtown trips by transit range from about 11 percent in Phoenix to 71 percent in Chicago.

At first glance, transit use appears predominantly a function of city size. This, however, is not necessarily the case. The proportion of travel by transit, especially central business district travel by transit, appears to more closely correlate with 1920 central city population than with current population, as shown in Figure 3. Apparently, the composition and structure of central cities in 1920 is more descriptive of transit use than present population. Thus transit use appears closely related to those parts of urban areas that were developed as a result of, and tributary to, public transport routes. This is not to infer that transit potentials are static; rather, that the basic structure of the "transit-oriented" sections of the central city were well-crystallized by 1920.

Thus, population, per se, is not always representative of transit usage, particularly in light of recent population dispersion in many of the most rapidly growing urban areas.

Two other factors emerge as being significantly related to transit use; car ownership and population density. Car ownership and use, in turn, are related to socio-economic status—the lowest ownership and use of cars are in high-density low-income areas, and conversely.

TABLE 7

WALKING DISTANCE TO BUS STOP, TYPICAL WEEKDAY[1]

Distance from Bus Stop (blocks)	Walking Distance: Within CBD			Zone End of CBD			Non-CBD			All Transit Trips		
	Trips	%	Accum. %	Trips	%	Accum. %	Trips	%	Accum %	Trips	%	Accum. %
1	4,316	71 8	71.8	3,914	65.1	65.1	11,742	68.0	68 0	19,972	68 2	68.2
2	1,114	18 5	90.3	1,040	17.3	82.4	3,029	17 5	85.5	5,183	17.7	85.9
3	466	7 7	98 0	657	10.9	93.3	1,704	9.9	95.4	2,827	9.6	95.5
4	106	1 8	99.8	254	4.2	97.5	479	2.8	98.2	839	2.9	98.4
5	11	0.2	100.0	95	1 6	99.1	181	1.0	99.2	287	1.0	99.4
6	-	-	-	53	0.9	100.0	137	0.8	100.0	190	0.6	100.0
Total trips	6,013	100.0	-	6,018	100.0	-	17,272	100.0	-	29,298	100.0	-

[1]Source: Chattanooga 1960 Origin-Destination Survey (under preparation for U.S. Bureau of Public Roads and Tennessee State Highway Department by Wilbur Smith and Associates). Excludes school bus passengers.

TABLE 8

TRAVEL MODE IN RELATION TO CITY AGE[1]

City	1920 Population	Current Population (study area)	Households per Car	Product Cols. 1 & 3 (thousands)	Product Cols. 2 & 3 (thousands)	Percent of Total Internal Trips by: Auto	Transit	Percent of CBD Trips by: Auto	Transit
	(1)	(2)	(3)	(4)	(5)	(6)		(7)	
Chicago	2,701,705	5,169,663	1 25	3,777	6,462	75.7	24.3	29.0	71.0
Detroit	993,678	2,968,875	1.06	1,053	3,147	83 3	16.7	54.8	43.2
St. Louis	772,897	1,275,454	1.11	858	1,416	84.4	15.6	53.2	46.8
Pittsburgh	588,343	1,472,099	1.15	676	1,693	79.7	20.3	49.0	51 0
Washington	437,571	1,568,522	1.23	538	1,929	75.7	24.3	56.9	43.1
Kansas City	324,410	857,550	1.05	341	900	90.1	9.9	69.6	30 4
Houston	138,276	878,629	1.06	147	931	87.1	12.9	74.0	26 0
Nashville	118,342	357,585	1.02	121	365	92.3	7.7	79.7	20.3
Chattanooga	57,895	242,000	1.00	58	242	92.6	7.4	83.8	16.2
Charlotte	46,388	202,272	0.95	44	192	92.7	7.3	86.1	13.9
Phoenix	29,053	397,395	0.95	28	378	93.6	6.4	89.3	10.7

[1]Compiled from U.S. Census and origin-destination studies.

Accordingly, a correlated analysis of these variables is developed in Figure 4 and and Table 9. (The curves were developed before the plotting of data for Chattanooga, which conforms closely. Houston, in terms of current transit usage, is about 6 percent, and falls closely onto the curves.) The various scatter diagrams show strikingly consistent relationships between the choice of travel mode, urbanized area population density, and car ownership. The curves were first plotted as straight lines on normal probability paper, indicating that the data may be approximated by a cumulative normal distribution. On cartesian coordinates they plot as a series of ogives, with the steepest points where 50 percent transit use is anticipated.

The curves show that transit use increases rapidly as the number of persons or households per car increase and that it decreases as the cars per household increase. The best fits were obtained when transit usage was directly related to the combined

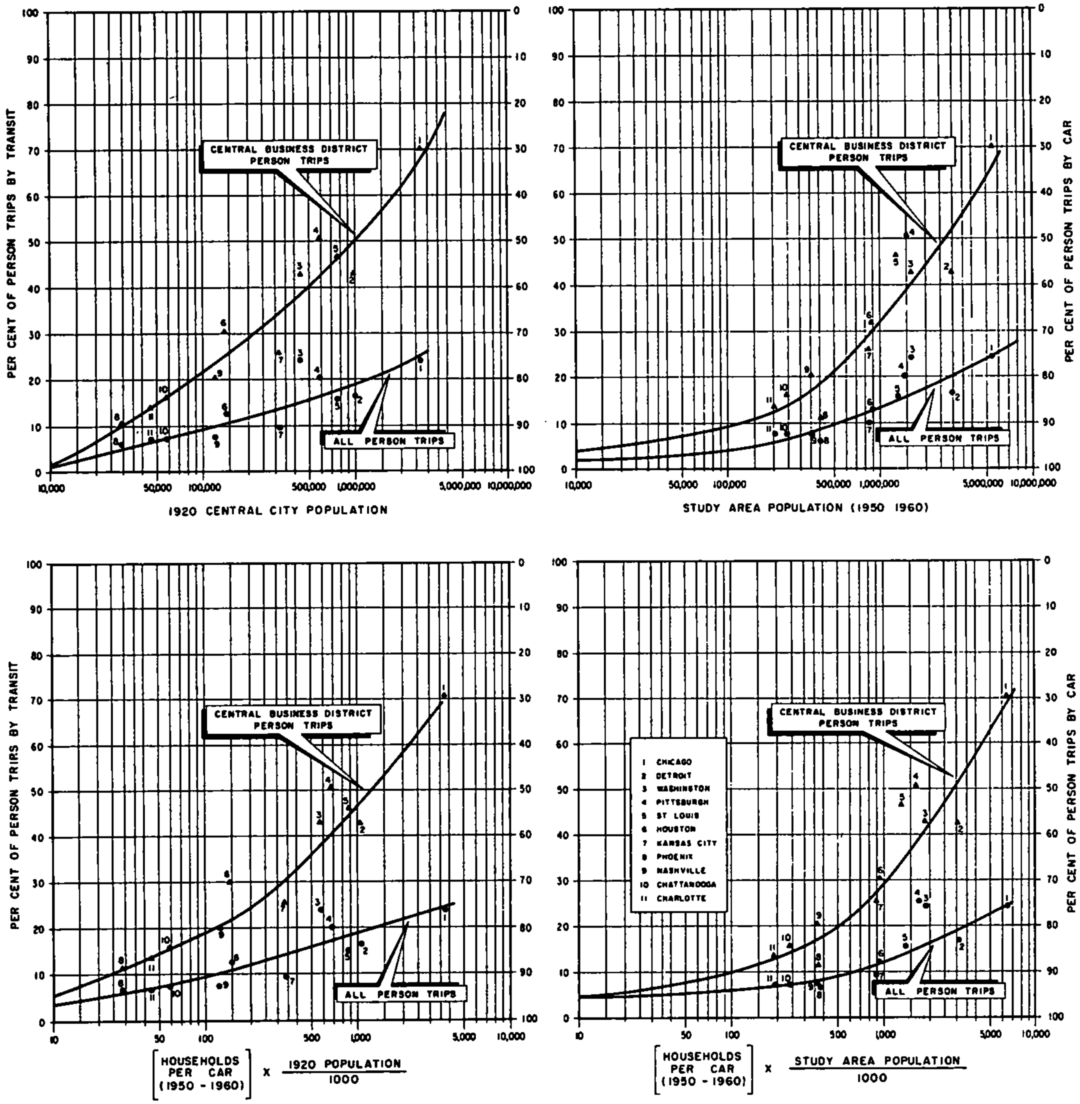


Figure 3. Effect of population on travel mode.

effects of households per car and population density—using both parameters tends to recognize aspects of change within an urban area. These findings are substantiated by the transit use analyses found in the Chicago and Pittsburgh area transportation studies, which indicated that car ownership and net residential density were the two principal determinants of travel mode. A study prepared by the Michigan State University Institute for Community Development and Services showed transit use related to size, age, and density of cities.

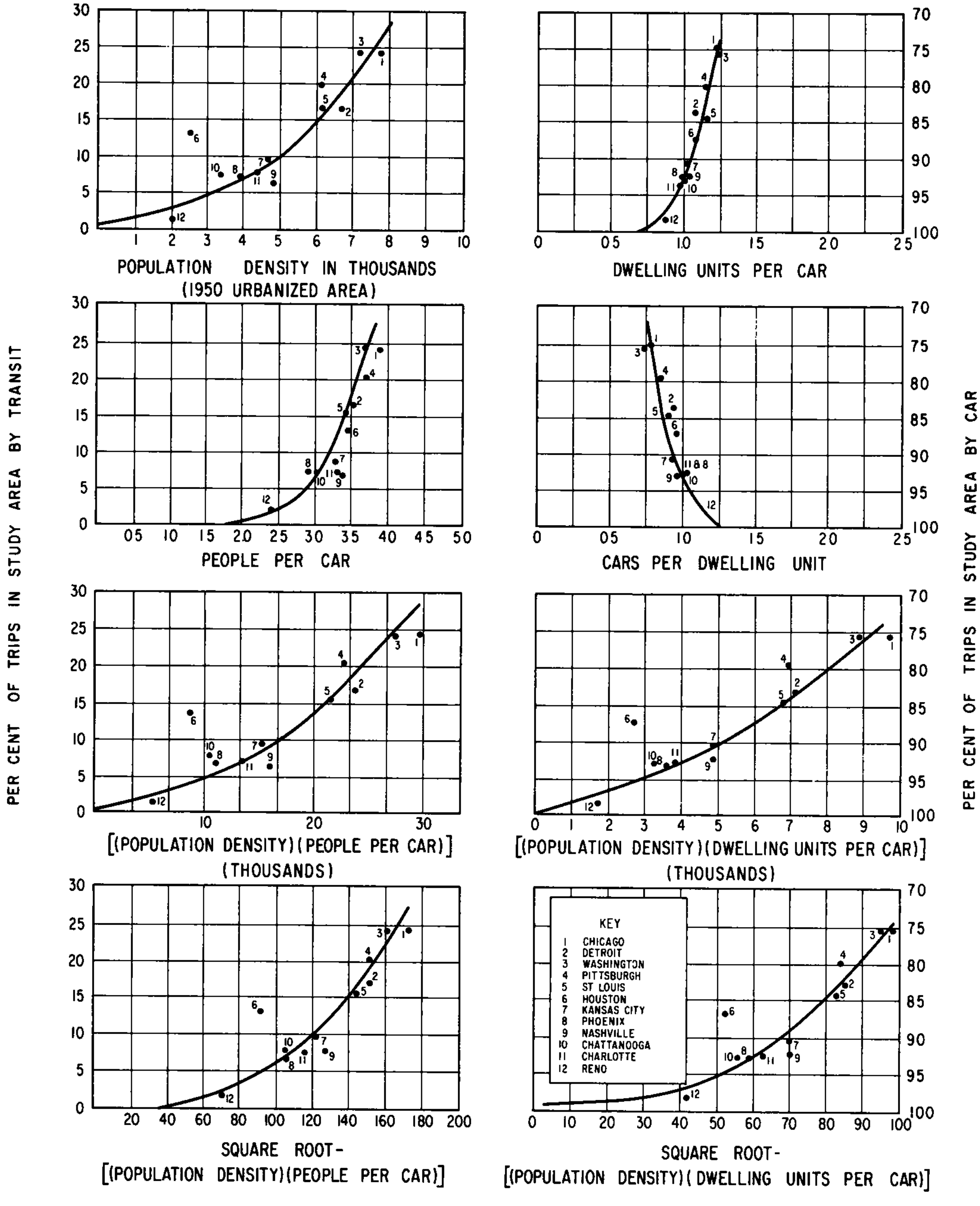


Figure 4. Travel mode relationships.

Similar relationships between the proportion of transit trips to or from the central business district, car ownerships, and population density are shown in Figure 5. The proportion of CBD trips by transit increases as the population density increases and as car ownership decreases, but at a much steeper rate than for all transit trips within an urban area. The curves show the specialized use of transit in serving the central business district, particularly in the large, high-density urban areas.

TABLE 9

TRANSIT USE IN TYPICAL URBAN AREAS[1]

City	1950 Urbanized Area Pop Density	People per Pass Car (study area)	Dwelling Units per Car (study area)	Product (Cols 1 & 2)	$\sqrt{Col\ 4}$	Product (Cols 1 & 3)	$\sqrt{Col\ 6}$	Percent of Internal Person-Trips by		Percent of CBD Person-Trips by	
								Auto	Transit	Auto	Transit
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)		(9)	
Chicago	7,713	3 85	1 25	29,695	172	9,641	98	75 7	24 3	29 0	71 0
Detroit	6,734	3 51	1 06	23,636	154	7,138	84	83 3	16 7	56 8	43 2
Washington	7,216	3 75	1 23	27,060	164	8,875	94	75 7	24 3	56 9	43 1
Pittsburgh	6,045	3 75	1 15	22,669	151	6,952	83	79 7	20 3	49 0	51 0
St Louis	6,146	3 48	1 11	21,388	146	6,822	83	84 4	15 6	53 2	46 8
Houston	2,594[2]	3 43	1 06	3,897	94	2,750	52	87 1	12 9[3]	74 0	26 0
Kansas City	4,687	3 26	1 05	15,280	124	4,921	70	90 1	9 9	69 6	30 4
Phoenix	3,921	2 87	0 95	11,253	106	3,725	61	93 6	6 4	89 3	10 7
Nashville	4,821	3 35	1 02	16,150	127	4,917	70	92 3	7 7	79 7	20 3
Chattanooga	3,329	3 31	1 00	11,019	105	3,329	58	92 6	7 4	83 8	16 2
Charlotte	4,085	3 28	0 95	13,399	116	3,881	62	92 7	7 3	86 1	13 9
Reno	2,000[4]	2 43	0 88	4,860	70	1,760	42	98 5	1 5	NA[5]	

[1]Sources: U S. Department of Commerce, Bureau of Census, origin-destination studies in each area.
[2]Houston about doubled its city limits before 1950 census, thus, area actually urbanized at time of study had much higher density
[3]Reported at 6 percent 1959-60
[4]Estimated.
[5]NA-not available.

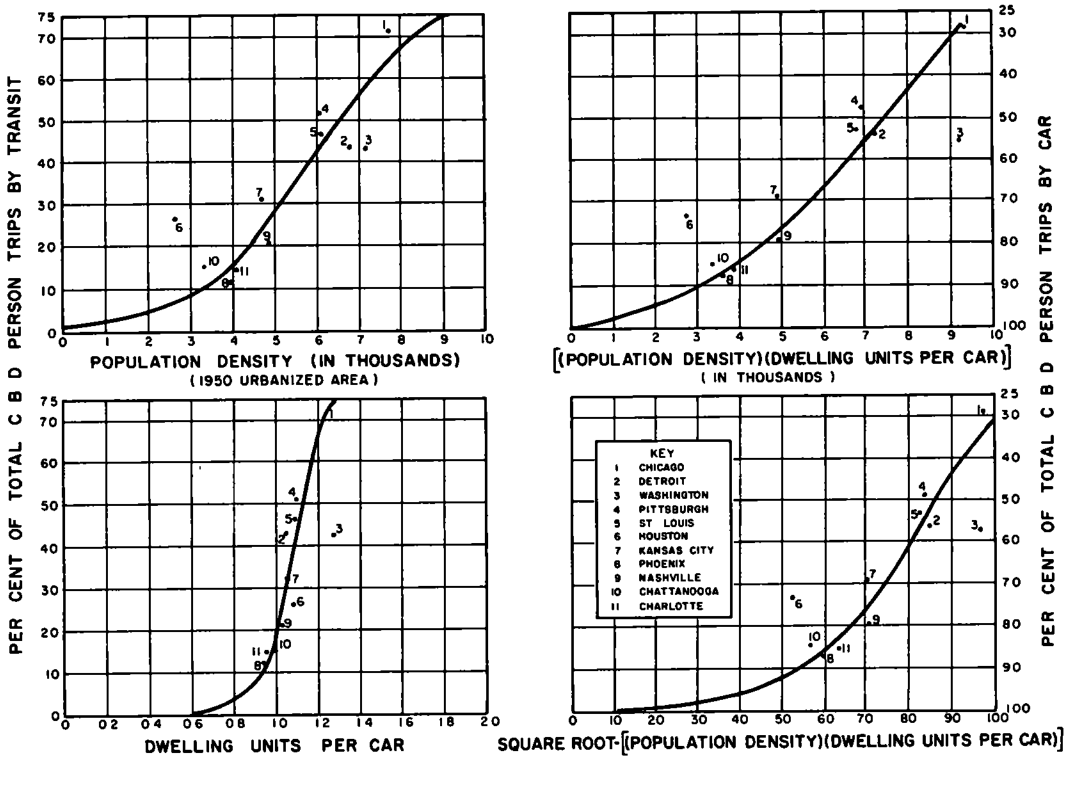


Figure 5. Central business district travel mode relationships.

From these analyses, it is possible to derive a generalized relationship for the predicting of over-all transit or auto use in any urban area. These generalized transit use curves are shown in Figure 6. The "travel mode factor" represents the product of urbanized area population density and households per car divided by 1,000 and is plotted along the x-axis; the percentages of all trips made by transit and auto within the urban area are shown along the y-axis.

Transit use increases as population density and/or the number of households per car increase: the greater the density and the lower the car ownership, the greater the proportion of travel by transit; where two areas have the same densities, the area with the greater car ownership will generally develop fewer trips by mass transit; similarly, where two areas have the same car ownership, the area with the greater population density will generate more transit trips.

Most American cities today have travel-mode factors under 10—the practical range of the curve. New York City, of course, is the notable exception. The curves confirm the thesis that the old, densely populated cities, usually with the low car ownership and large populations, have the greatest proportions of transit travel—their physical layouts, land-use patterns, and central business district intensities were usually crystallized before the widespread use of the automobile. Cities that evolved in the motor age and that are growing rapidly today, are less intensely developed and are more automobile-reliant.

Transit is most widely used in the peak hour. Accordingly, travel-mode curves have also been developed for one-directional and two-directional peak-hour travel; these curves are shown in Figure 7. One-directional peak-hour transit travel has been assumed to be twice as peaked as highway travel, and two-directional peak-hour transit travel has been assumed to be 50 percent more peaked than highway travel. The total travel in the peak hour has been assumed as AT + (100-T) when T is the percent of 24-hr transit travel and A the relative ratio between transit and auto travel. The percent peak-hour transit travel is therefore $\frac{AT}{T(A-1)+100}$. In this regard, of all 24-hr traffic

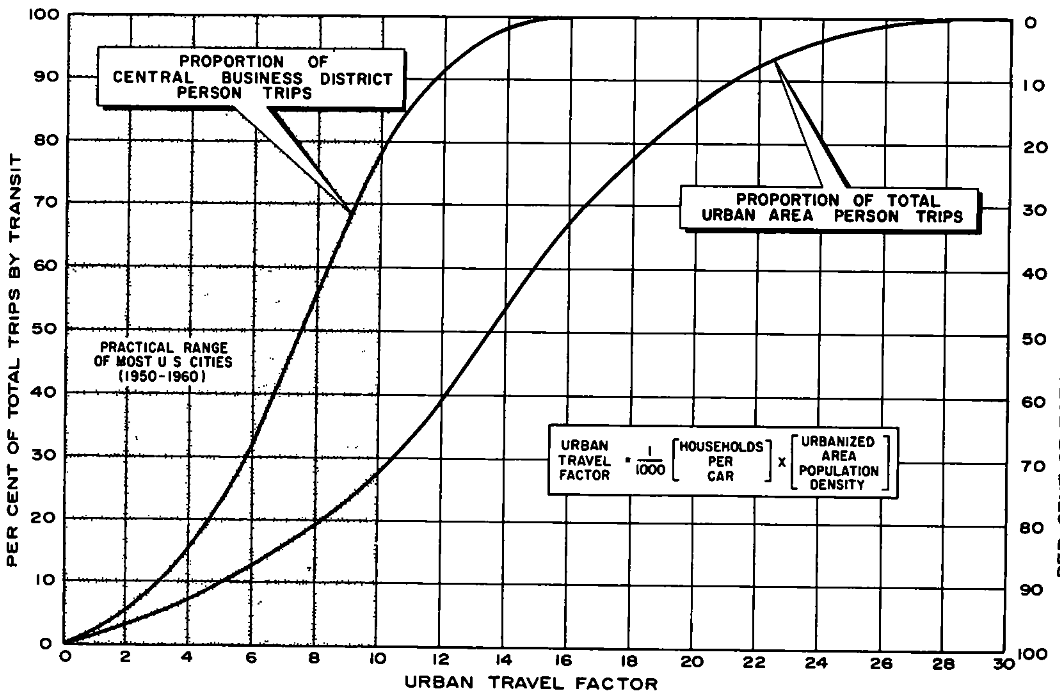
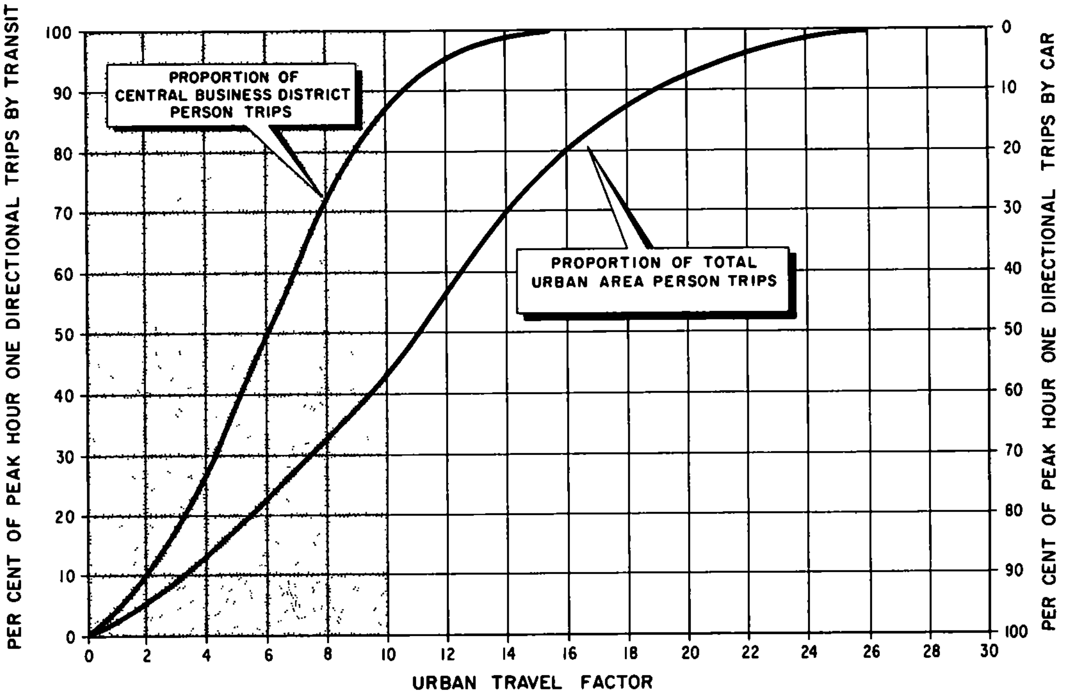


Figure 6. Generalized travel mode curves.



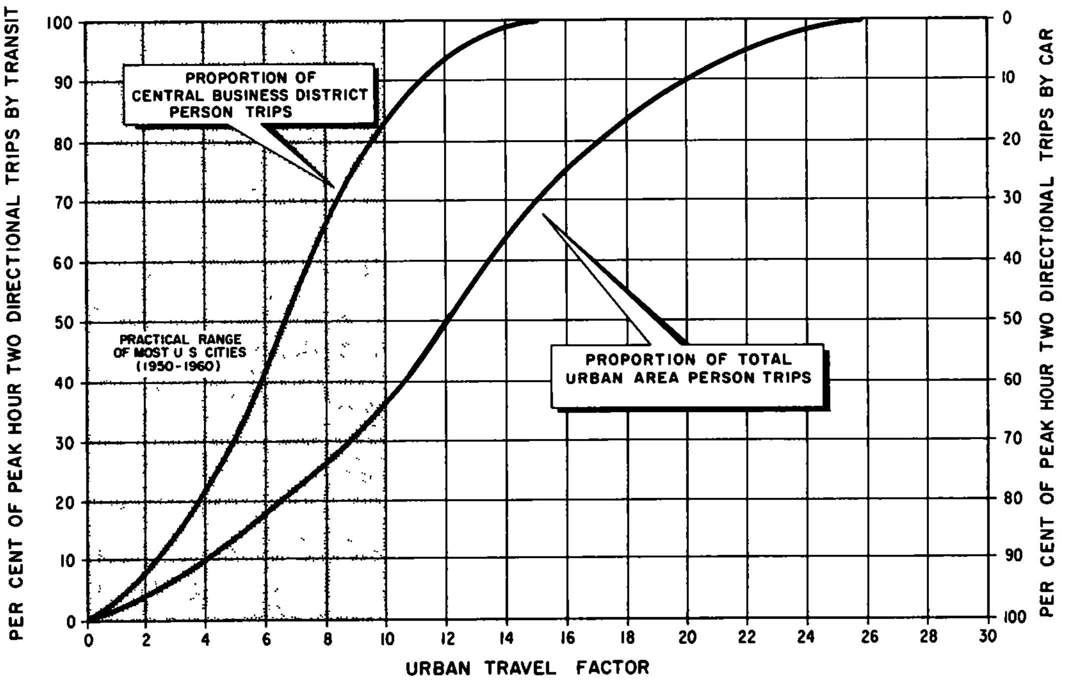


Figure 7. Generalized peak-hour travel mode curves.

leaving St. Louis Central Business District in 1957, 26 percent was by transit, and 42 percent of the peak-hour exist movement was by transit. This corresponds to a value of A equal to 2.

In a large urban area with a transit use-factor of 10 (typical of Chicago, Washington, and Philadelphia), approximately 83 percent of all PM peak-hour trips leaving the CBD would be made by transit. In cities with a transit use-factor of 5, (typical of medium-sized cities like Nashville) about 40 percent of all PM peak-hour trips leaving the CBD would be by transit.

Predicting CBD Travel Modes

Travel modes of trips to or from the central business district are compared with the modal split of all trips in Figure 8. Again, there is a consistent pattern; knowledge of either attribute (i.e., the CBD modal split, or the city-wide modal split) permits estimation of the other. Values obtained from the travel mode curve have been superimposed on the actual data; except for extremities, the trend is linear.

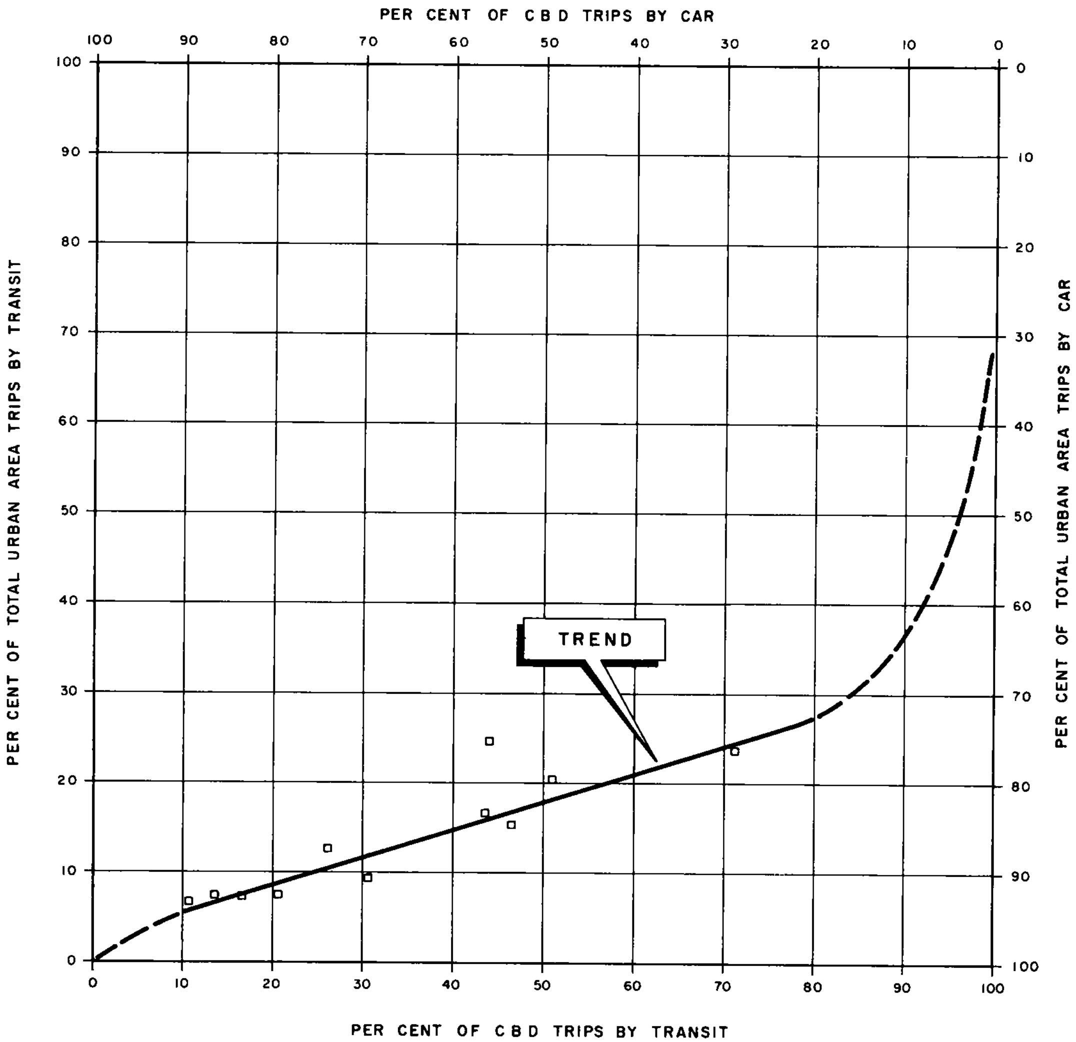


Figure 8. Comparative travel modes, central business district and entire urban area.

As previously indicated, the proportion of CBD trips by transit is generally two or three times as great as all transit trips within an urban area. For example, in Chicago, about 71 percent of all CBD trips are made by transit, whereas only about 24 percent of all trips in the area are made by this mode. In Phoenix, (with a low population density and high auto ownership) about 11 percent of CBD trips are made by transit compared with only 6 percent of all trips within the area; the bulk of both city-wide and CBD trips are made by car.

Travel modes are also influenced by the distribution of population relative to the central business district. Figure 9 shows for four cities (Charlotte, Houston, Tacoma, and Honolulu) the relative proportion of CBD trips per thousand persons decreases as distance from downtown increases. Transit trips decrease more rapidly than total trips per unit of population, dropping to zero at the limits of the service area.

In the four cities graphed there is a general similarity in patterns—the CBD trip generation curves decay at about the same rate. Here, the "interactance" effect of competing generators is at work; as travel time-distance downtown becomes longer, more opportunities exist for interception or attraction of travel by other areas.

The modal split of CBD trips at various distances from the central area (Fig. 10) clearly reflects the importance of close-in areas to transit. In Charlotte, Tacoma, and Houston there is a consistent decline in the proportion of CBD trips by transit as distance from downtown increases. Topography, in restricting developmental corridors, has placed a large transit-oriented populace about 5 mi from downtown Honolulu.

There is another striking aspect about these curves. The proportion of CBD trips by transit is greatest in 1947 (Honolulu) and least in 1958 (Charlotte). Again, the impact of increasing car ownership and population density on travel mode, in particular on transit patronage, is apparent.

From the preceding analyses, it is evident that the magnitude and modal distribution

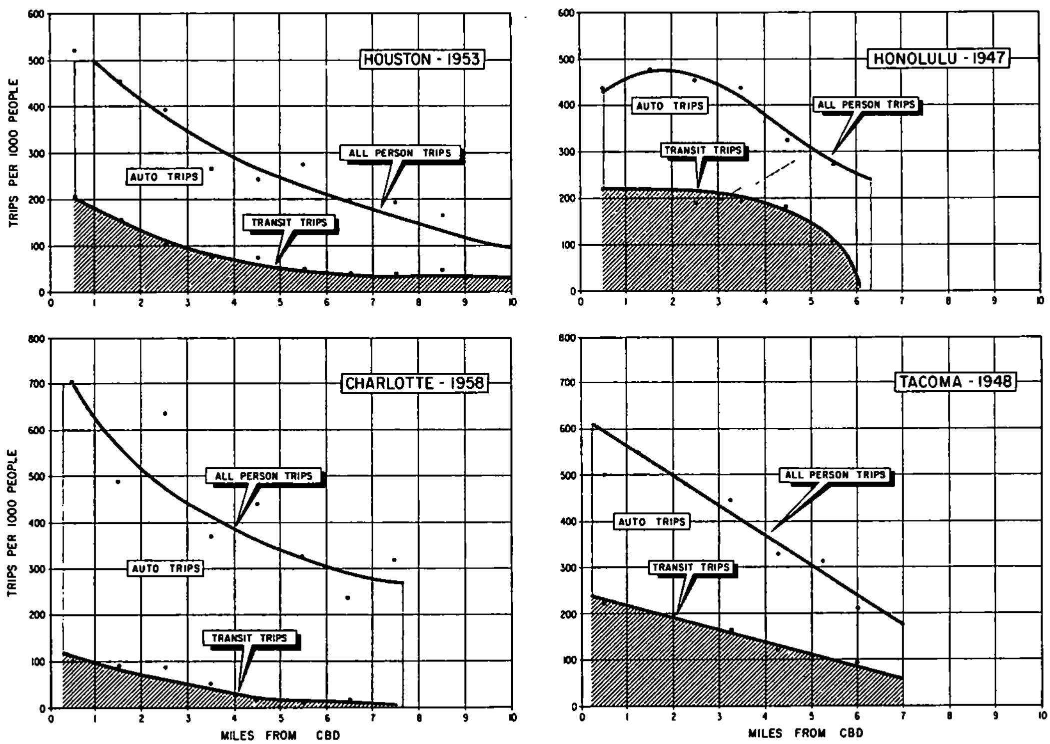


Figure 9. Central business district trip attraction.

of central business district trips depend on the nature and intensity of downtown development. To some extent, this is a function of size and age of the central city; more significantly, it depends on the density of destinations within the downtown area, and on the concentration of work trips.

An exploratory analysis of the relation between travel mode and CBD land use showed a general increase in transit usage as office space (or office space per capita) increased. A somewhat more significant relationship was found when the density of CBD origins and destinations was related directly to travel mode (see Table 10). Symbolically, this may be written as:

$$P = f\left(KS^x \frac{(PH)^y}{(AC)} D^z\right)$$

$$= f(KS^x F^y D^z)$$

in which

P = percent of trips by transit;
A = square miles;
S = transit service factor;
H = households in urban area;
C = cars in urban area;
D = downtown concentration factor;
K, X, Y, Z = constants; and
F = travel mode factor.

For example, Chicago has about 9,000 CBD person trip-ends per sq mi; Detroit and Washington, 450; Charlotte, 150. In Table 10, the areas of the central business districts conform with those defined in the origin-destination studies, and do not, therefore, fully reflect relative intensities with the core areas; nonetheless, experimental plots indicate that this data, used in conjunction with population density and car ownership, tend to improve the predictability of central business district transit trips. Accordingly, this leads to the following generalized model for the prediction of downtown modal distribution of travel; transit usage is proportional to the products of population

TABLE 10

DENSITY OF TRAVEL TO AND FROM TYPICAL CENTRAL BUSINESS DISTRICTS

Survey Area	Population	Area of Central Business District[1] (sq mi)	CBD Person-Trips[2] (thousands)	CBD Person-Trips per Sq Mi of CBD (thousands)	Percent of CBD Person-Trips by	
					Auto	Transit
Chicago	5,169,663	1 0[3]	932	932	29.0	71.0
Detroit	2,968,875	1.1	511	465	56 8	43.2
Washington	1,568,522	2.0[3]	883	442	56.9	43.1
Pittsburgh	1,472,099	0.5	154	308	49.0	51.0
St. Louis	1,275,454	0.7[3]	250	357	53.2	46.8
Houston	878,629	0.9	351	390	74.0	26.0
Kansas City	857,550	0.9	213	236	69.6	30.4
Phoenix	397,395	0.7	130	186	89.3	10.7
Nashville	357,585	0.6	128	213	79.7	20.3
Chattanooga	242,000	0.3	76	253	83.8	16.2
Charlotte	202,272	0.7	105	150	86.1	13.9

[1]Source: origin-destination surveys in each area.
[2]Trips to or from central business district.
[3]Excluding mall, riverfront areas, and lakefront areas.

density, households per car, and density of downtown destinations, as influenced by the transit service afforded.

Studies now under way in Baltimore and Norfolk are further exploring these relationships by analyzing data from individual zones and by very clearly delineating core, frame, and fringe within the central business district.

Summary and Interpretation

The most significant aspect of the modal distribution analyses is the close relationship between car ownership, population density, and mode of travel. These interrelationships are further emphasized by the summary of person-trip generation shown in Figure 11. This curve shows how transit, auto, and pedestrian trips vary as a function of the travel mode factor: transit and auto trips are based on the information obtained in the cities studied, whereas pedestrian trips have been estimated.

The number of transit trips per capita increases consistently with increasing concentration and decreasing car ownership, whereas the number of total person-trips in

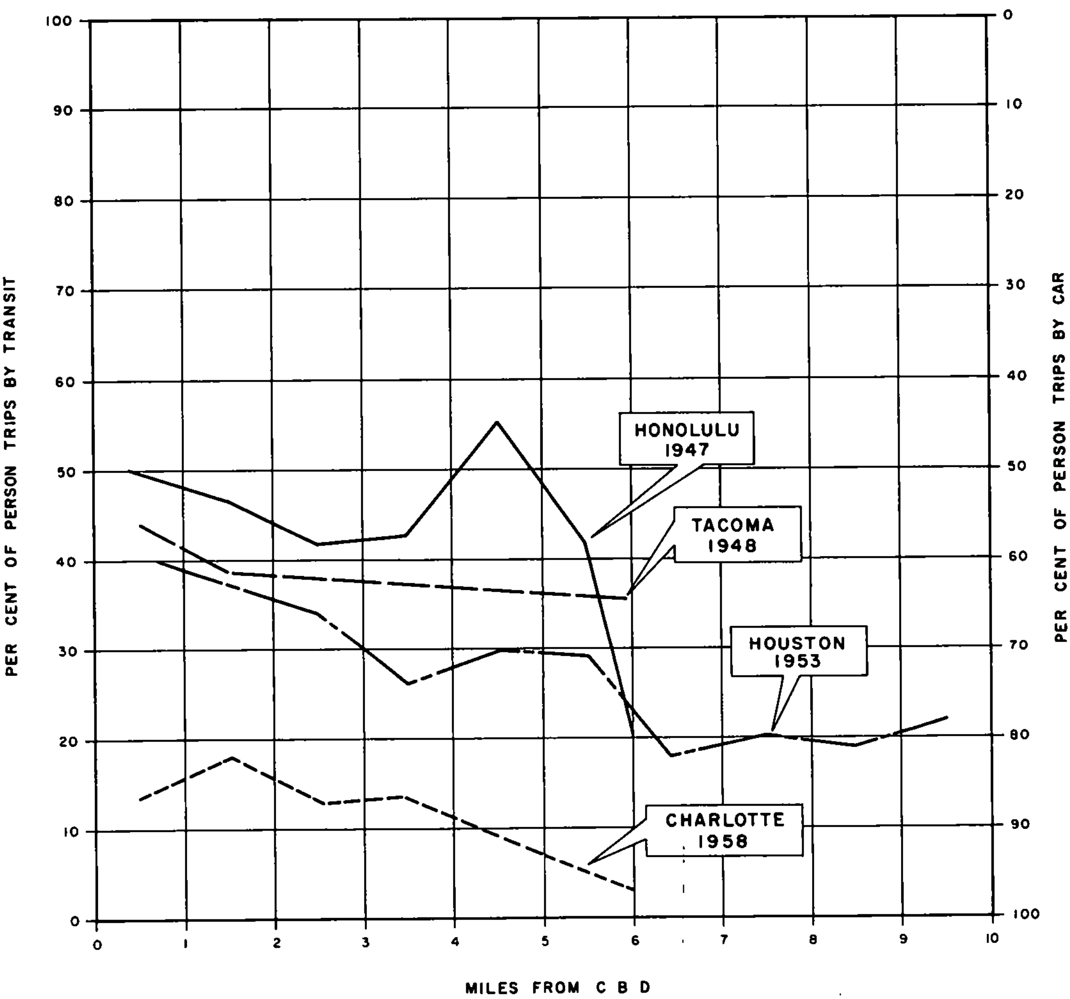


Figure 10. Travel modes of central business district trips in relation to distance from central business district.

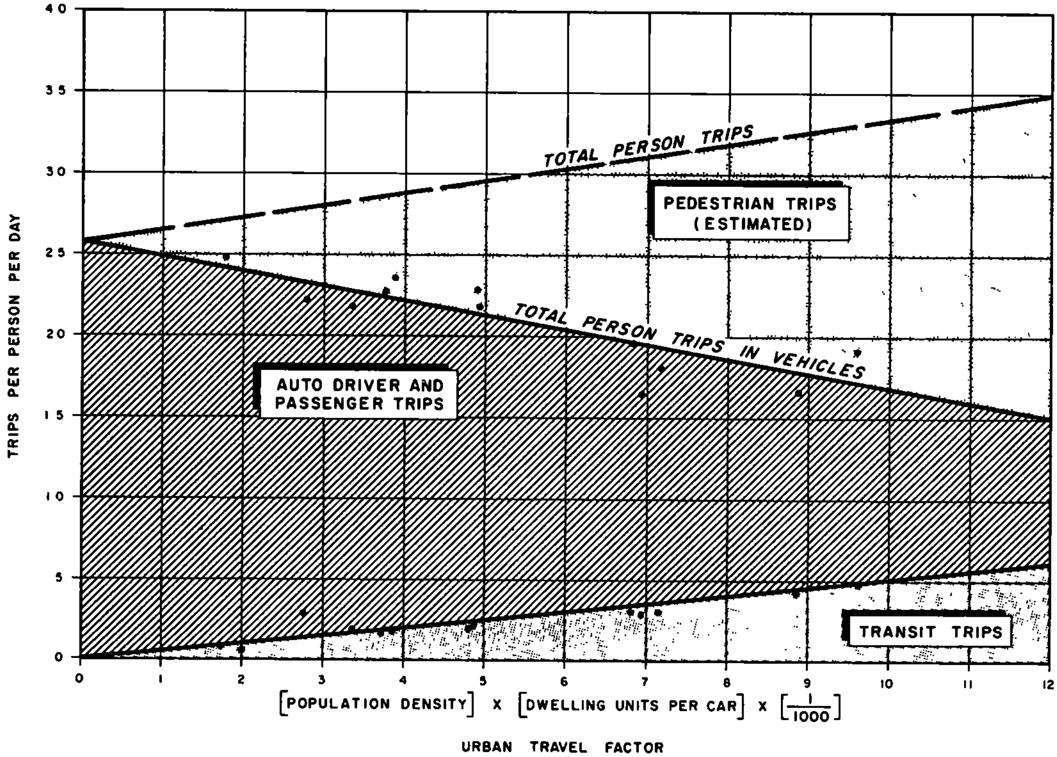


Figure 11. Summary of urban trip generation.

vehicles decrease; both trends appear linear. A city with a travel mode factor of 10 would generate 0.5 transit trips and 1.2 auto trips per person—a total of 1.7 person-trips in vehicles per day. Similarly, a city with a factor of 5 would generate 0.3 transit trips and 1.9 auto trips per person per day—a total of 2.2 person-trips in vehicles per day. Pedestrian trips increase rapidly as the travel mode factor increases. This is because the number of destinations within walking distance increases in very dense areas.

Inasmuch as car ownership will tend to become more uniform in urban areas, population density may emerge as a basic variable affecting over-all trip generation in urban areas. Population density, in turn, generally depends on central city densities because most suburban areas are developing at about the same density. As density increases, there is an increase in total person-trips, a decrease in person-trips in vehicles, and an increase in transit trips.

Compactness within an urban area could, therefore, be construed as a means of minimizing urban travel. This, however, is not the trend. As the desire for single family dwelling units continues to outpace the recentralization of cities, as car ownership and incomes rise, the trends will probably continue in the other direction. Improved mobility brought about by decreased travel times may also foster some dispersion.

Thus, because of changing urbanization patterns and socio-economic standards, transit assumes a new, often complementary, role. It will remain especially valuable in serving radial home-to-work CBD travel, and in maintaining compactness and concentration within the central business district; its future importance to downtown will be largely contingent on its past importance.

FREEWAY TRAVEL

Trip generation characteristics provide insight into the nature of urban vehicular travel. In combination with trip length characteristics, it is possible to determine the per capita vehicle-miles of travel within an urban area. The aggregate future use of highways in an urban area can then be related to the capacities afforded by various classes of highways.

Trip Length Calculations

Zone-to-zone movements tabulated in origin-destination studies provide a basis for

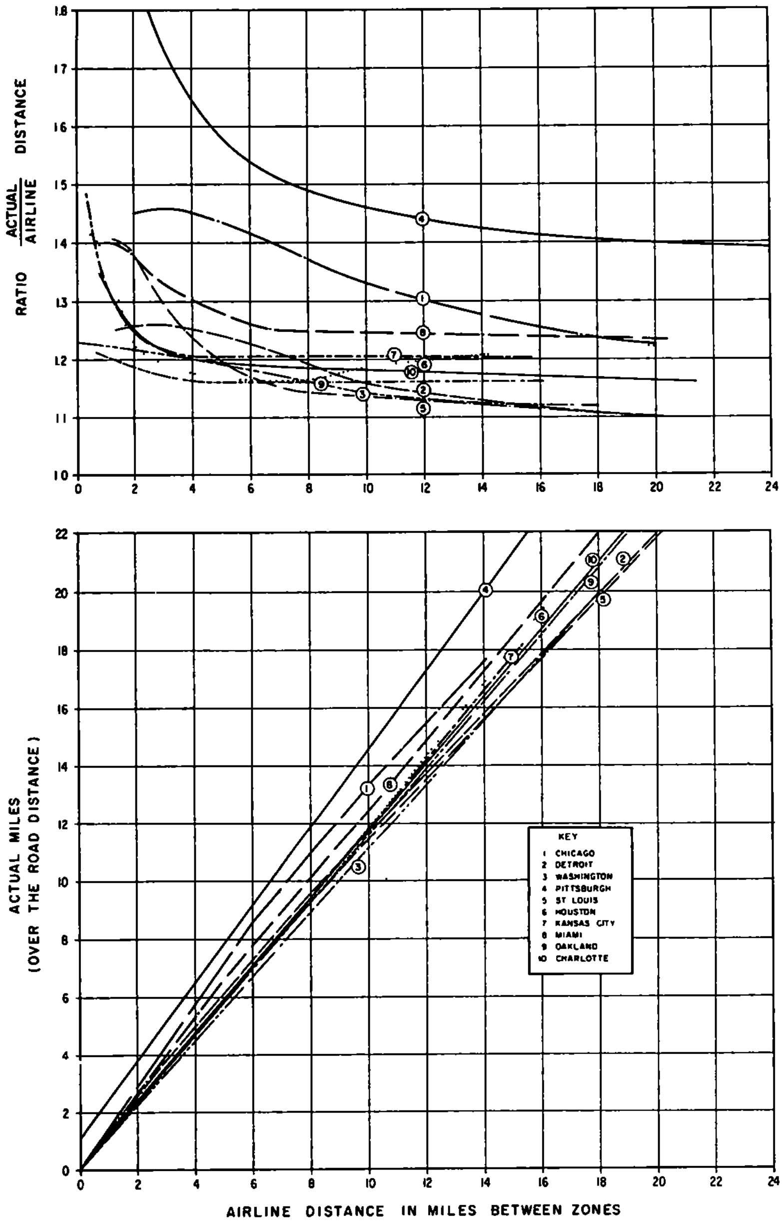


Figure 12. Trip length comparisons.

determining "airline" trip lengths. These "airline" distances should then be adjusted to represent actual "over-the-road" travel.

Actual and airline distances were calculated from random samples of interzonal movements for a series of urban areas. These comparisons (Fig. 12) show how the relationship between airline and actual distance depends on the configuration of the street system. In cities such as Detroit, Washington, and St. Louis, with radial-concentric patterns, actual distances are about 1.15 times the airline distance. Grid-iron street patterns, such as found in Chicago, require about 25 percent longer travel over the streets; in cities where street patterns are restricted by topography, as Pittsburgh, over-the-road distances are nearly 40 percent greater.

These trip-length relationships, by analogy, provide a basis for anticipating the ratios between airline and actual distance in any urban area. (Many of the recent computer programs being used in current origin-destination studies evaluate vehicle-miles of travel directly from basic information.)

Magnitudes of Urban Highway Travel

From analyses of origin-destination data in various cities, estimates were developed of total daily vehicle travel. Expressed on a per capita basis, present daily vehicular travel (i.e., driver trips) approximates 7 mi per urban resident. (The range is from

TABLE 11

GENERALIZED ROADWAY REQUIREMENTS, PER 10,000 POPULATION

Population of Urban Area[1]	Anticipated Percent of Total Travel on Freeway System[1]	Route-Miles of Freeway Required[2]	Route-Miles of Arterial Required[2]
10,000	20	0.4	4.8
75,000	30	0.6	4.2
500,000	40	0.8	3.6
1,000,000	50	1.0	3.0
5,000,000	60	1.2	2.4

[1] Source: (16).
[2] Calculated, assuming distribution of roadway facilities consistent with required capacities (or uniform demand per sq mi).

5 to 9 mi.) By 1980, assuming a continuing trend for greater vehicle use and continued urban dispersion, average daily vehicle-miles may range from 9 to 14 mi per capita (averaging about 10). By relating these unit values to estimates of future urban population, future urban freeway and arterial use has been derived for 1972, 1975, and 1980 (16).

Earlier studies have found apparent justification nationally for approximately 10,000 route-mi of urban freeway for 1960; 13,600 for 1972; 14,500 for 1975; and approximately 16,000 urban route-mi for 1980. By way of comparison about 3,000 urban freeway-mi are currently in operation.

Although urban Interstate highways as presently defined comprise some 5,000 mi of the system, about 6,700 mi currently lie within areas essentially urban in character. The expansion of urbanization will increase the average diameter of cities thereby encompassing additional rural Interstate mileage on the radial routes that serve each community. By 1972, about 8,400 route-mi of the presently defined Interstate system will probably be urban; by 1975, about 8,850 mi; and by 1980, approximately 9,600 mi. Thus, about 62 percent of the apparently needed route-miles urban freeways will likely be supplied if the Interstate system is completed by 1972.

TABLE 12

PRESENT AND ANTICIPATED CAPACITIES, KEY SCREENLINES, ST. LOUIS, MO.[1]

Screenline	Possible Capacity		Percent Increase
	Present	Anticipated	
Lindbergh Boulevard			
Surface streets	21,000	33,250	58
Expressways	3,600	16,200	350
Total	24,600	49,450	101
City Limits			
Surface streets	35,540	42,250	19
Expressways	0	34,200	0
Total	35,540	76,450	115
Kings Highway			
Surface streets	30,130	40,280	34
Expressways	3,600	36,000	900
Total	33,730	76,280	127
Grand Boulevard			
Surface streets	29,100	31,250	7
Expressways	3,600	30,600	750
Total	32,700	61,850	89
Natural Bridge			
Surface streets	17,900	19,550	9
Semi-expressways[3]	-	8,000	-
Subtotal	17,900	27,550	54
Expressways	-	28,800	-
Total	17,900	56,350	202
Delmar			
Surface streets	29,260	31,450	7
Semi-expressways[3]	-	8,000	-
Subtotal	29,260	39,450	35
Expressways	-	28,800	-
Total	29,260	68,250	133
Choutea-Manchester			
Present	25,480	32,420	27
Semi-expressway[3]	-	5,400	-
Subtotal	25,480	37,820	48
Expressways	5,400	28,800	433
Total	30,880	66,620	116
Chippewa-Watson			
Present	15,030	20,300	35
Semi-expressways[3]	-	-	-
Subtotal	15,030	20,300	35
Expressways	-	12,600	-
Total	15,030	32,900	119

[1]Source: (11).
[2]With improvements.
[3]Lindberg Boulevard, city limits expressway.

Analyses were made of the travel assigned to projected freeway systems in various cities as they relate to total urban travel. The proportion of trips and vehicle-miles of travel assignable to an adequate freeway system was found to increase as cities get larger: in cities under 100,000 people, freeways may carry up to one-quarter of all automobile travel; in urban areas of over 1,000,000 people, one-half or more of all such travel could be served by an adequate freeway system.

In most communities of less than 100,000 population, potential freeway volumes could generally be accommodated on high-type arterials. This is not the case in larger cities where demands closely match freeway capacities. As urban areas exceed 2,000,000, volumes potential to certain heavier traveled routes were found to exceed capacities provided under present concepts of freeway planning. These overloads result from the increased accumulation and concentration of travel desires within large areas, and from the convergence of freeway routes.

A comparison of projected urban freeway systems with the population of the areas they serve indicates that about 1 mi of urban freeway will be generally required per 10,000 residents. This tentative criterion should be modified when applied to the high-density central cities of the largest and oldest metropolitan areas, such as New York, Chicago, Philadelphia, and Boston, where public transportation, particularly rapid transit, provides effective service and where a sufficient network of freeways might be comparatively uneconomical to develop. Just as it is difficult to extend their transit potentials to all other urban areas categorically, it is equally inappropriate to apply nationwide freeway criteria without certain modifications.

Verification of Criteria

Development of equilibrium between the aggregate vehicle-miles of travel in an urban area performed on freeways, arterials, and other streets, and the capacity provided by each facility provides an alternate method of calculating the required route- and lane-miles. These relationships can be formulated as

$$V = K_1 \frac{M_f C_f}{P} = K_1 \frac{V_f}{P}$$

$$V = K_2 \frac{M_a C_a}{1-p} = K_2 \frac{V_a}{1-p}$$

$$V = V_f + V_a$$

in which

V = total vehicle-miles of travel performed;
V_a = total vehicle-miles of arterial travel performed;
V_f = total vehicle-miles of freeway travel performed;
C_f = freeway capacity (vehicle-miles per mile);
C_a = arterial capacity = $\frac{C_f}{3}$;
P = percent of total travel on freeways;
M_f = miles of freeway required;
M_a = miles of arterials and collectors required, and
K_1, K_2 = factors that compensate for the unequal distribution of demand throughout the urban area; if capacity were distributed precisely in accord with demand, these values would be unity. In these equations, the travel along local residential streets (usually about 5 percent of the total vehicle miles) has not been considered.

Based on these relationships, the required roadway facilities per 10,000 residents have been computed. These calculations summarized in Table 11 have assumed the following:

1. Daily travel equivalent to 12 vehicle-miles per urban resident.
2. A freeway capacity of 60,000 vehicles per day, and an arterial capacity of 20,000 vehicles per day.
3. Varying proportions of freeway travel—the proportions increasing as cities get larger.

The calculations have assumed that the route-miles of expressways and arterial facilities will be distributed in strict accordance with demand. Although such a precise, or optimum allocation of facilities is difficult to attain in practice, adjustments in lane-miles may compensate, to a large extent, for the nonuniform loading; for example, multilane freeways could have daily capacities as great as 120,000 to 150,000 vehicles per day, per mile of route. Similarly, the average daily travel (expressed in vehicle miles per capita) approximates 7 mi per capita per day, and is expected to increase to 10 mi per capita per day by 1980 (16), and is somewhat below the 12 mi per capita used above. Thus, Table 11 reflects factors of conservatism that tend to compensate for the variabilities in the distributions of roadway supply and demand.

The roadway requirements for cities of various size are given in Table 11, and tend to substantiate the 1 mi of freeway per 10,000 residents criterion; for example, an urban area with 1,000,000 population would require approximately 1 mi of freeway and 3 mi of arterial per 10,000 residents; about 50 percent of all its travel would be on freeways.

Freeway requirements will also depend on population density. The average spacing for eight-lane freeways should approximate 4 mi for a population density of 10,000 persons per mi. Assuming travel of 6 mi per capita per day on freeways, and an average freeway capacity of 120,000 cars per day on eight-lane freeways, the formula is

$$G = \frac{2C_f}{dpv}$$

in which

G = average grid spacing in miles;
C_f = average daily freeway capacity;
d = population density, persons per square mile;
p = percent of total travel on freeways; and
v = total daily travel expressed as vehicle-miles per capita.

For an over-all gross density of 20,000 persons per sq mi, the average freeway grid spacing should be about 2 mi—virtually the minimum spacing commensurate with adequate geometric design. For a density of 20,000 persons per sq mi, arterials would have to be spaced at intervals of ⅓ mi.

From these calculations it appears that an over-all central city density of about 20,000 persons per sq mi is the maximum concentration of people that can be accommodated by freeways and arterials, based on the preceding spacing criteria. (Such densities, however, are not common nor are they being attained in most areas of new urban growth.)

TABLE 13

SUMMARY OF CAPACITY GAINS, ST. LOUIS METROPOLITAN AREA[1]

Facility	Present	Anticipated	Percent Increase
Surface	203,440	250,750	23
Semi-expressway	-	21,400	-
Subtotal	203,440	272,150	33
Expressway	16,200	216,000	1,235
Total	219,640	488,150	122

[1]Source: (1).

Freeway Services

The present patterns of regional development accentuate the need for new transportation facilities. Freeways will increase the accessibility and attractiveness of the central business district; they will permit through traffic to bypass the downtown area; they will reduce travel times, operating costs, and accidents. Although the effective capacity of an urban transportation system can be increased in many ways, the greatest increases are presently taking place through the development of freeway systems.

St. Louis, Mo., is a lucid example of the service afforded by freeways. The aggregate one-direction peak-hour "possible" capacity in 1957 across eight "screenlines" totaled about 203,000 vehicles per hr on arterials and 16,200 vehicles per hr on freeways. Tables 12 and 13 show that maximum improvements to arterial streets would increase the total existing capacity about 47,000 vehicles per hr, 21 percent; and development of a semi-expressway would increase this capacity about 21,000 vehicles per hr, 10 percent. The completion of the freeway system would increase the existing capacity an additional 200,000 vehicles per hr, 91 percent. Thus, of a total 122 percent increase over existing peak-hour capacity, freeways would provide about three-fourths of the gain. Improvements to arterials would be relatively economical to achieve and could be accomplished while freeways are still under construction. They would, however, accommodate only a fraction of the anticipated traffic increases.

SYSTEMS APPROACH

The vast impact of transportation facilities on community growth and development requires a total "systems" approach involving all modes of transportation and all interested organizations and governmental agencies.

In the past, too many transportation plans, studies, and improvements were developed in relative isolation, concentrating almost entirely on one specific mode, and often overlooking the basic intereffects of "feedback" between transportation and land use.

Models and Synthesis

Analyses of numerous comprehensive origin-destination studies have revealed various statistical relationships between travel and population and economic indexes. Precise mathematical formulas have been developed to define the effect of income, density, car ownership, and other variables on travel mode and rates of trip generation.

Economics dictates that trip lengths be determined largely by trip purpose; persons are willing to travel much farther to work, for example, than to shop or school. The travel pattern of a particular zone is determined by the relative location of various competing opportunities (places of work, recreational facilities, shopping centers, schools, etc.) throughout the community, and the availability and quality of the transportation facilities affording access to each using travel time as a measure of the latter, the forces attracting travel can be precisely measured. The average family in a large urban area, for example, can be expected to make six or seven trips daily, while higher income families have been observed to make as many as 10 or 12 trips. Trip generation is also sensitive to population density, with families in dense urban core areas showing much less mobility than those in auto-oriented suburban areas.

TABLE 14

COMPARISON OF CHATTANOOGA SCREENLINE CROSSINGS, 1960[1]

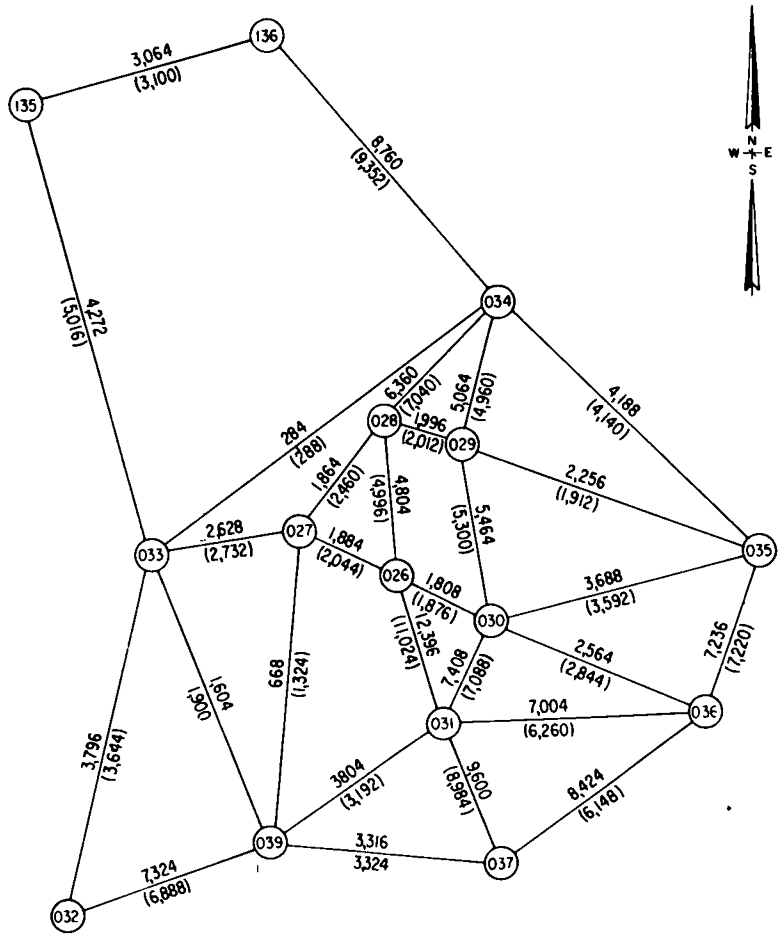
Total Trips					Work Trips				
Link	Bridge	Synthetic Data	O-D Data	Percent	Link	Bridge	Synthetic Data	O-D Data	Percent
256-547	Olgiati	12,416	12,836	96 7	256-547	Olgiati	6,736	6,964	96 7
257-243	John Ross	17,208	17,356	99.1	243-257	John Ross	8,244	7,624	108.1
440-494	Thrasher	6,400	7,700	83.1	440-494	Thrasher	2,132	2,116	100.8
Total		36,024	37,892	95.1	Total		17,112	16,704	102.4

[1]Source: (17).

"Models of system performance" permit analytical evaluation of alternative transportation networks through the use of statistical and probabilistic techniques. Such factors as travel speeds, capacity restraints, travel costs, and land impacts may be analyzed for different modes in various combinations and benefits of each alternative system compared.

Illustration of Synthesis

Models must, of course, be tested against real situations before they can be considered adequate. Such tests, involving re-creation of current travel patterns through the application of models to current land-use data were conducted during 1960 in Chattanooga, Tenn., in conjunction with the Tennessee State Highway Department and the U.S. Bureau of Public Roads as prototypes for similar syntheses (17). These studies assumed that the models would be applicable in making future travel projections if they could



NOTE
ZERO VOLUMES NOT SHOWN

LEGEND

245 ACTUAL VOLUMES

(174) SYNTHETIC VOLUMES

Figure 13. 1960 actual and synthetic traffic volumes, central business district, Chattanooga, Tenn.

re-create current travel patterns accurately. Accordingly, synthesized 1960 travel patterns were compared with actual movements recorded in the 1960 origin-destination study.

The model involved two basic areas of work: (a) estimation of the number of trips, by mode of travel with origins and destinations in each zone of the study area, and (b) distribution of trip ends between all possible zone pairs. The study was primarily designed to test the trip distribution model and was based on an analysis of the 384,500 internal passenger car trips (70 percent of the total vehicular trips) within the study area.

To test the reliability of the model, comparisons were made between synthetic trip estimates and actual origin-destination data. Comparative assignments to a "spider web" network connecting all adjacent downtown zone centroids is shown in Figure 13.

TABLE 15

COMPARISON OF TRIP LENGTHS, CHATTANOOGA, 1960[1]

Trip Length (min)	Auto Driver Trips		Percent of Total		Cumulative Percent	
	O-D Data	Synthetic Data	O-D Data	Synthetic Data	O-D Data	Synthetic Data
0	41,640	43,292	14.88	15.14	14.88	15.14
1	1,040	2,184	0.37	0.76	15.25	15.90
2	8,536	13,224	3.05	4.62	18.30	20.52
3	13,904	18,896	4.97	6.61	23.27	27.13
4	21,512	19,348	7.69	6.76	30.95	33.89
5	21,416	20,408	7.65	7.14	38.60	41.03
6	17,848	17,776	6.38	6.22	44.98	47.25
7	17,136	17,212	6.12	6.02	51.10	53.27
8	16,132	16,904	5.76	5.91	56.87	59.18
9	12,947	13,212	4.63	4.62	61.49	63.80
10	13,136	12,876	4.69	4.50	66.19	68.30
11	12,104	11,448	4.32	4.00	70.48	72.30
12	10,392	10,480	3.71	3.66	74.22	75.96
13	9,144	9,928	3.27	3.47	77.49	79.43
14	9,468	9,236	3.38	3.23	80.87	82.66
15	8,148	7,720	2.91	2.70	83.78	85.36
16	7,404	6,308	2.65	2.20	86.43	87.56
17	7,240	5,580	2.59	1.95	89.02	89.51
18	5,000	4,052	1.79	1.42	90.80	90.93
19	6,832	4,076	2.44	1.43	93.24	92.36
20	3,508	3,624	1.25	1.27	94.50	93.63
21	3,700	3,248	1.32	1.14	95.82	94.77
22	2,756	2,348	0.98	0.82	96.80	95.59
23	2,108	2,092	0.75	0.73	97.56	96.32
24	1,676	1,672	0.60	0.58	98.15	96.90
25	1,400	1,636	0.50	0.57	98.66	97.47
26	956	1,584	0.34	0.55	99.00	98.02
27	776	1,168	0.28	0.41	99.28	98.43
28	548	1,140	0.20	0.40	99.47	98.83
29	420	772	0.15	0.27	99.62	99.10
30+	1,060	2,572	0.38	0.90	100.00	100.00
Total	279,887	286,016	100.00	100.00		

[1]Source: (17).

Approximately three-quarters of all synthesized trip linkages within the central area were within 15 percent of the actual values. Comparable accuracy was found for other trip linkages within the study area.

A comparison of actual and synthetic volumes crossing the Tennessee River screenline are compared in Table 14. The assigned screenline crossings totaled 36,000 and comprised about 95 percent of the observed ground count. Synthesized work trips across the Tennessee River screenline accounted for about 102 percent of the actual work trip crossings.

A more detailed comparison of trip lengths, in terms of travel time is given in Table 15. Intrazonal trips (indicated as 0 min in length) amounted to about 15 percent of the total trips in both actual and synthetic data. The average trip length in terms of minutes of offpeak driving was calculated as 8.54 min from the survey data and 8.32 min from the synthetic data—a difference of less than 3 percent.

These and other syntheses currently under way appear to provide a rational approach to the planning and design of urban transportation systems. Although much work remains to be done, tools are emerging to aid the predictive process.

TOWARDS ACHIEVING BALANCE

Population projections in North America foresee no slackening in growth rates throughout the remainder of this century. Cities will proliferate and change in shape and structure commensurate with changes in economy, technology, and the desires of their populace. During the past 20 or 30 years there has been a tendency for central city densities to decrease in population, employment, and other types of land use; although the distractions of an economic recession in the 1930's and a great war in the 1940's tended to obscure this trend. The "normal" decade of the 1950's seems to confirm it and give it perspective. These changes have taken place despite enormous urban growth and have been accompanied by pronounced changes in the form of urban transport. Private per-capita car ownership throughout large urban areas has increased several times in the last 30 years; public transportation has declined sharply.

These trends seem likely to continue. Although patterns of land use and choice of travel mode may be guided to some extent—in some cases encouraged and in other cases restrained—it is not likely that the trends can be completely reversed short of a drastic change in the basic environment, such as could be brought about by a war or strong government edict. Although a city can adapt over a period of years to any transportation form, once it has adapted, it can no longer fully re-create its earlier condition. Though it is easy to anticipate various technological advances, it is difficult to evaluate fully their impacts on urban structure and economy.

American cities are served today by two forms of personal transportation strikingly different in their characteristics and adaptability to the evolving city form—the private automobile and the public transit vehicle. Their relative merits are in large measure complementary. The private vehicle best serves movements that are dispersed in space and time (e.g., suburbia); successful public transportation is contingent on the concentration of travel (e.g., close-in, densely populated CBD-oriented parts of the central city). Achieving balance between the modes, therefore, depends on achieving balance between the spatial concentration and dispersion of activity within the urban region. Thus, transportation and land-use elements should be conceived and planned as an integral system, attaining complementary relationships that re-enforce each other.

Modal Interrelationships

Several tentative and generalized indicators emerge from the preceding analyses, showing how the various forms of transport serve the evolving urban complex and how balance may be attained in accommodating the traveling public. Some of the findings, particularly relevant to freeways and rapid transit are summarized as follows:

1. Size of Urban Area.—Rapid transit systems have generally been successful where urban areas exceed 2,000,000 people; however, some rapid transit may also be desirable in certain areas between 1,000,000 and 2,000,000 population. Under present

concepts of freeway planning, when urban areas exceed 2,000,000, volumes along heavier-traveled routes may exceed capacities provided by eight-lane freeways (16).

2. Density.—Rapid transit systems appear generally to require densities of 14,000 to 20,000 persons per sq mi throughout substantial corridors within central cities. Where densities exceed 20,000 persons per sq mi, extremely close spacing of freeway and arterials is required. Within this range of densities, construction costs of transit facilities appear to be substantially less than those for freeways.

Much work remains to be done in determining the relative construction costs of rapid transit as compared with freeways under varying intensities of development. Preliminary analyses seem to indicate that for gross population densities of less than 15,000 to 20,000 per sq mi, construction of freeways is less expensive than that for rapid transit and the subway construction ($16,000,000 to $20,000,000 per mi) becomes less expensive only when gross population densities exceed 25,000 to 30,000 per sq mi. Rapid transit busways would generally be less costly than freeways, except for needed downtown distributor and terminal facilities which would substantially increase their costs.

Rapid transit could probably be developed in central cities with densities ranging from 10,000 to 15,000 per sq mi. (At present, central city densities of 15,000 or more per sq mi are usually found only in cities of over 1,000,000 population.)

3. Urban Travel Factor. —Wherever travel mode factors exceed 7.0 (i.e., urbanized area densities of 7,000 per sq mi, and 1 household per car), rapid transit systems have been found to function effectively. In this regard, bus rapid transit could probably be developed in areas with factors of 5 to 9 and rail rapid transit could probably be developed in areas with factors of 8.

4. Central Area Concentration. —Systems of rapid transit have been found to function, and hence appear desirable, where the number of destinations per sq mi of CBD exceeds 300,000 persons.

A detailed analysis of the central business district is beyond the scope of this paper. It is nonetheless fully recognized that downtown, centrally located in the urban complex, is the focus of the highest densities of urban travel. For downtown to remain as the hub of the urban region, attractive accessibility must be provided; freeway, parking and transit facilities will all usually be required.

Parking facilities, both within the central area and at key transit stops, will become increasingly important and are an essential part of a balanced transportation system. In some cases free downtown parking (and transit) may be necessary to place the central area on a competitive basis with outlying commercial centers; in other situations pricing mechanisms may be designed to encourage short-term parking within key central areas.

The information set forth in this paper suggests how professionals may objectively approach problems of transportation planning. There is, of course, a constant need for additional research, verification, and analysis. The analyses set forth have merely begun to explore the numerous applications of data already collected.

REFERENCES

1. Blumenfeld, H., "Transportation in the Modern Metropolis." Queen's Quart., 67:No. 4 (Winter 1960).
2. Davis, H.E., and Kennedy, N.W., "Some Aspects of Urban Transportation Planning." Symposium on Urban Survival and Traffic, King's College, University of Durham, England (April 10-14, 1961).
3. "Land Use and Traffic Models." Jour. Amer. Inst. Planners, 25:No. 2 (May 1959).
4. McMillan, S.C., "Recent Trends in the Decentralization of Retail Trade." Traffic Quart., 16:No. 1 (Jan. 1962).
5. "Metro." American Automobile Assoc. (1961).
6. Metropolitan Area Transportation Studies by State Highway Departments in conjunction with U.S. Bureau of Public Roads in Chicago, Detroit, Chattanooga, Pittsburgh, Washington, Nashville, Charlotte, Phoenix, Reno, Fort Lauderdale, Kansas City and Houston.
7. Paranka, S., "Urban Transportation Dilemma." Bureau of Business and Economic School of Business Administration, Georgia State College of Business Administration, Research Paper 21 (1961).

8. Public Roads, 30:No. 2 (April 1959).
9. Reinsberg, M., "Growth and Change in Metropolitan Areas and Their Relation to Metropolitan Transportation—A Research Summary." Transportation Center, Northwestern Univ., Evanston (1961).
10. "Research Memorandum—Transportation for Future Urban Communities." Rand Corporation, Santa Monica (Aug. 1961).
11. "St. Louis Metropolitan Area Transportation Study, 1957-1970-1980." W.C. Gilman and Co.
12. Schwartz, A., "Forecasting Transit Usage." Pittsburgh Area Transportation Study (1961).
13. Smeed, R.J., "The Traffic Problem in Towns." Manchester Statistical Soc. (Feb. 1961).
14. Smith, J., "Some Social Aspects of Mass Transit in Selected American Cities." Institute for Community Development, Michigan State Univ. (1961).
15. Smith, W.S., "Urban Transportation Tasks of the Future." Annual Meeting, ASCE (Oct. 16-20, 1961).
16. Wilbur Smith and Associates, "Future Highways and Urban Growth." Automobile Manufacturers Assoc. (Feb. 1961).
17. Wilbur Smith and Associates, "Statistical Evaluation of Mathematical Projection Model." Chattanooga (1961).

Metropolitan Area Approach to Comprehensive And Coordinated Transportation Planning

PAUL OPPERMANN, Executive Director, Northeastern Illinois Metropolitan Area Planning Commission, Chicago

Although metropolitan transportation planning has improved through the years, and is probably at an all-time high as far as urbanization is concerned, there are still certain important elements that have not been dealt with adequately. Experience in the Chicago metropolitan area has brought some of these elements to light. These are defined, their implications are indicated, and suggestions are made for their inclusion.

• THE SUBJECT OF THIS PAPER is the relationships of highway functions and programming to metropolitan area planning. They are increasing in scope and appear to be taking on greater importance in new and changing situations.

Statewide highway systems exist in all regions of the United States and comprise a national highway system. Large-dimensioned as these highway plans are, focused as they are on meeting highway needs and serving the important purposes of highways, they do not necessarily fit well and serve fully other transportation needs and other, nontransportation needs of the states, the regions, and the nation.

The broad transportation requirements of the nation as a whole clearly are not met fully by a national highway transportation system. There are several other national transportation systems and services that meet parts—other than highways—of the nation's transportation requirements. There are railways, airways, waterways, and pipelines that, together with highways, comprise national, state, and local transportation facilities and services, serve the national interest and jointly meet its requirements, however adequately or insufficiently, as the case may be.

Each person at this meeting has a specialty, and whatever it may be—administrative, professional, research, technical, in the public area or the private sector—is, being a specialty, partial.

The specialties are related, sometimes closely, sometimes loosely. Today, modern conditions require that these specializations be associated, or coordinated. The economy, in this pluralistic society, is highly specialized. For example, there are steel, electrical and insurance cities; food, fiber and timber territories; predominantly native born or foreign born but inevitably "mixed" cities and regions are found in the continental society. Yet, these and much more are associated, or coordinated, in the generalized image of America and in the culture term "American."

Population growth and area expansion generate need of housing, education, recreation, transportation facilities, and services. Income, jobs, and job training cannot be disassociated from technological change and its implications. Taxation and fiscal implications of these create problems of staggering proportions. Both the private sector and the governments face together the present conditions and attempt somehow to estimate and project the future changes.

In facing them, researching them, analyzing them, in formulating policy positions required for programming, the necessity to "associate the specialties" appears to be gaining in recognition by the decision-making ranks of the nation's life at the level of the national, state, and local governments; in command posts of commerce and industry; and in the universities and the professions.

The metropolitan area approach appears to offer a vantage and a posture whereby growth, development and change at local levels may be dealt with more effectively, with appropriate roles of states at that level and with the federal government at the national level. Urban transportation is not a purely local matter. It is integral with other important community functions and altogether have state and federal "relatedness." The problem is not divisible today and is not soluble by adding up separate, piecemeal actions or "solutions." A metropolitan area approach may suggest some useful answers, both in "associating the specializations" (and the specialists) and in demonstrating ways to generalize them in a manner contributing answers to community problems being pursued widely today across the country.

A METROPOLITAN AREA APPROACH

It will be useful to list some of the growth and development problems universal in cities and urban regions throughout the United States today—most acute and difficult of solution in the large and fast growing industrial states, and most pressing in the metropolitan areas of those states.

At the level of municipal and county governments, there are

1. Tax problems—fiscal inadequacy.
2. Planning and regulating orderly and efficient growth.
3. Achieving coordination in growth and development with contiguous or closely related jurisdictions, especially in metropolitan areas.

At the state level, there are

1. Tax probems—fiscal inadequacy—real or supposed tax and fiscal inequity in relation to the federal government, municipalities, counties, special (purpose) district governments.
2. Providing legislative, administrative, financial, and technical assistance and guidance to statewide growth and development (including distressed areas) to achieve orderly, efficient, and competitive state development over-all; and as a state policy framework to counties, municipalities, and special districts and affecting the role of agriculture under conditions of strong urban and industrial growth trends.

At the federal (or national) level, there are

1. Tax problems—fiscal questions. For example, the proportion of federal revenues to be devoted to state and local purposes, appropriate (and acceptable) principles and methods for distributing and supervising such federal "assistance."
2. The appropriate role of the federal government in relation to the states and local communities (including the agricultural aspects) serving the national interest, avoiding infringement of constitutional rights of the states and their localities ("creatures of the state"), yet providing national guidance and a national "framework" of social, economic, and physical (physiographic) character, if there are to be unities of form and function of the state, regional, and local communities comprising the nation.

These broad "growth and development" categories are admittedly designed and stated for the purpose of this brief paper. They are selected and subjective, but are relevant to the following proposition: the metropolitan areas of the nation are useful, offering a vantage and a posture whereby growth, development and change at local, state, and national community levels may be dealt with more effectively.

To illustrate the argument, the following typical or characteristic programs currently operative in a great many cities, and in a substantial minority of the nation's metropolitan areas (as designated by the Census Bureau), serve the present purpose. Both programs are "growth and development" oriented: (a) housing, urban renewal, and planning; (b) transportation (highways, transit, mass transportation).

These two programs clearly involve the federal, state, and local governments. As the bulk of the country's population and population growth, tangible and intangible resources, and growth and development activity is concentrated in metropolitan areas (and they are expected to concentrate there increasingly), it may be logically claimed that a strategy and tactics of growth and development ought to consider seriously the role and uses of metropolitan areas for "associating the specialties," for achieving coordination of growth and development from the local community up and from the national level down. The matter may be examined more concretely from the vantage of a specific metropolitan area—the northeastern Illinois metropolitan area, comprising Chicago and six counties enclosing it—choosing an example from the field of transportation.

The federal government, by means of both regulatory and tax authority, and direct or indirect financial aids, influences the policies, programs, and operational practices of highways, railways, airways, waterways, and pipelines active in interstate commerce. In some cases the federal government establishes national standards that directly reflect in location planning of certain systems (interstate highways) and systems including terminals (civil and military airways). However, all transportation operates in states and serves local units of governments. It is therefore subject to state regulatory (also tax) agencies in these cases. In many metropolitan areas all major types of transportation operate. Yet the federal government does not plan locations, does not coordinate or insist on coordination, of the physical or operational characteristics of any transportation media. The 1961 Housing Act takes limited initiative in this direction.

It will perhaps be argued that this is a proper task for the states. Yet the states also regulate and tax and leave locations and their planning to the municipalities and the counties.

The federal government (Landis Committee, Committee on Interstate and Foreign Commerce, National Transportation Policy Report, and the Advisory Commission on Inter-Governmental Relations) is currently analyzing, preparatory to legislation, the tax and regulatory imbalance that have developed between modes and among carriers in the same or other modes. Assuming that there will be alterations in the balance or lack of it among modes and that legislation will change, affect, or even "correct" these functional inadequacies, inequities or injustices, the effects gradual though they may prove will be effective in the states, counties, cities, and metropolitan areas.

Transportation technology is changing and may change more drastically and rapidly than in any previous period. Transport media are land occupiers, sometimes competitors in land acquisition or "logical" occupance. Airways, in particular, require new substantial land areas to serve jets and growth in military and private flying needs.

Federal and state governments are both involved in and affected by the policies at their respective levels and may be presumed to have, and in fact acknowledge they have, a concern with the relationships of transportation modes and operations in cities and in metropolitan areas in which cities cluster around the metropolitan center and urban growth spreads out into the countryside.

The land-use analysis, the coordination of many competing land occupiers, and the regulation of each by itself and of its relation to others are left to cities or counties, acting under laws established by the state. There is no specific lead in these matters affecting the national interest in growth and development and there is only a bare beginning in some states to establish a lead from the state level indicative of a state "public interest."

The second example relates to housing, urban renewal, and planning. These programs—financial support and technical aid to housing, planning (city, county, metropolitan area and state), and urban renewal—are operating throughout the country—unevenly, it may be said, in range, quality, and degree of local acceptance. The metropolitan areas are replete with activity. The HHFA and the BPR, both in Washington and in their administrative regions, are undertaking to implement formally a joint order to "associate their specialties"; in other words, to facilitate coordination, to bring the housing and highway programs into relationship, wherever possible.

A condition of federal approval of housing and renewal grants is an effective local planning program. Mass transportation planning and capital equipment grants are conditioned upon a metropolitan area plan in being or in preparation. These appear to be ordinances in the right direction, on the right course, although there appears to be a larger extent of need and an opportunity of more substantial dimensions.

This is the opportunity in the metropolitan areas to "associate the specialties" on a wider and deeper front by means of a comprehensive and coordinated approach through metropolitan planning—admitting the limitations and granting the difficulties of a still relatively new approach and of an advisory agency not operational in powers that does not and presumably will not concern itself with structural changes in governments traditionally serving metropolitan areas.

People are closer to the many local governments in each metropolitan area than they are to metropolitan government. Thus, the local governments are more readily subject to their wishes. Whatever its theoretical or presumed merits, metropolitan government has no lobby, no following, and as yet no constituents or electorate.

The northeastern Illinois metropolitan area is served by a planning commission established by the Illinois legislature in 1957. Its jurisdiction of six counties whose central city is Chicago contains nearly 1,000 local governments, 6,250,000 inhabitants in an area of 3,700 sq mi.

Its Commission of 19 citizen members, with a staff of about the same number, and a budget of around $250,000, has researched land use, population, future employment, and the requirements of the area of jurisdiction affecting first flood control and drainage, water supply and waste disposal, open space and recreation. The Commission in the present year will undertake to utilize its studies concerned with these functions, and others not specified here, in analysis of comprehensive transportation and land use relationships, building on available studies of many relevant kinds and initiating others required but not yet available.

It has already been demonstrated in the Commission's short history that much can be accomplished in selective researches to indicate the profile of the metropolitan area's growth and development problems and challenges of established (or at least present) trends. Intergovernmental relations are bringing together representatives, officials, and citizens to achieve improved coordination of planning and programming of development through continuing cooperation.

For the long pull, however, the long-term, comprehensive, and coordinated metropolitan area plan to guide future growth and development does not appear ready to reveal its secrets, nor does it yet appear to be susceptible to more than tentative, generalized option projections.

To date, the most favorably circumstanced, most affirmatively contributive of these projective studies are those of the type of the Chicago Area Transportation Study and especially the Penn-Jersey Study, with its five clearly stated and testable alternative comprehensive schemes.

There are actual limitations, however, to these or any other metropolitan plans so far produced, and they have to do, not with techniques, but with the question of governmental policies and relationships and the problem of "associating the specialties."

These limitations have to do with the difficulty of preparing with any demonstrable logic, definitiveness, or conviction, metropolitan area plans that lack the following necessary conditions:

1. A lead must be furnished by the federal government establishing guidelines, however broad and general they may of necessity be, indicative of the national interest in urban and rural land use, resource use and conservation, and rationalization of transportation, for the nation and its physiographic divisions.
2. A lead is needed from the state government indicative of the state's role and policy intentions affecting these matters.
3. A research and development program is required—one which is conceived and initiated in response to national, state, regional, and local needs. The purpose would be to identify broad research needs, with high priorities identified for early attention, and accompanied by proposals for public discussion and action on how such research might be accomplished by government, universities, industry, and others.
4. Use should be made of the resource allocation principle, at all governmental levels, as a stimulus to coordination of fiscal management and physical planning in the localities and metropolitan areas. The capital improvements programming technique is perhaps the most readily adopted use of this principle, and might therefore receive earliest application.

5. A lead is required from the federal government, which is the only place from which it properly can emanate, on the extent to which national security factors are to be reflected in growth and development policy and planning.

6. If comprehensive planning is to be achieved, stimulation, guidance, organization, and coordination are needed at the levels of the municipalities and the urbanizing counties to provide a framework within which local officials can work with metropolitan, state, and federal agencies. The effective federal-state-county administrative coordination of programs long ago achieved by the U.S. Department of Agriculture might be cited as an example.

7. Land policies are needed in urban and especially metropolitan areas, including research-derived conclusions and recommendations affecting central city and central city core functional roles in metropolitan complexes. Density standards, circulation system principles and mode "balance," dispersal or concentration (or both in balance), industry, housing and community facility standards (including options) are ingredients that should be available and utilized (perhaps within nationally formulated "value systems").

In conclusion, tax and fiscal problems, the extent and kind of federal and state responsibilities, coordinated planning and capital improvement programming, communications among affected governments and with citizens and community leadership, "association of specialists," and much in addition will be served and will serve the public interest well if the metropolitan areas are utilized as testing laboratories for the range of matters treated in this paper.

A Method for Attaining Realistic Local Highway System Plans

K.W. BAUER, Assistant Director, Southeastern Wisconsin Regional Planning Commission, Waukesha, Wisconsin

Because of the growing importance and influence of the work of the urban planner with its attendant impact on the development of highway transportation systems and consequently on the work of the highway engineer, the State Highway Commission of Wisconsin, in conjunction with the University of Wisconsin and the U.S. Bureau of Public Roads undertook a study and evaluation of local highway system planning in Wisconsin.

The study took somewhat over one year to complete and utilized research techniques developed by the social, as well as the physical, sciences. The purpose of the study was to determine the existing status of local highway planning in Wisconsin, to determine the effectiveness of local plans in actually achieving integrated urban highway systems, to isolate and analyze any strengths or weaknesses in the existing planning process, and to outline a method of effecting the attainment of current and realistic long-range highway system plans in urban areas.

The results of the study establish for the first time in Wisconsin a framework for the factual evaluation of local highway planning. Based on such findings the study recommends revised highway planning procedures that should result in the preparation of practical and workable local highway system plans that can be cooperatively adopted and jointly implemented by the various levels and agencies of government, and that should provide the key to integrating land use and transportation system planning in the state's rapidly expanding urban areas. The recommended procedure involves important changes not only in organization and staff requirements at the state level but also in administrative policies and practices, and in the scope, detail, and technical content of both state and local long-range highway system plans.

• THE NATION'S POPULATION is currently undergoing an unprecedented growth and urbanization. The widely dispersed characteristics of this urbanization with its accompanying dependence on motor vehicle transportation have created severe pressures to extend urban street systems and to widen, realign, and reconstruct existing trafficways. These urban street systems form important links in the national highway network and are essential to its proper functioning. Moreover, these urban street systems form the framework for the nation's urban development and, as such, determine to a large extent the character and pattern of that growth. The importance of the local highway systems to the sound development of urban areas as well as to the proper development of the national highway transportation system requires that these local systems receive the cooperative attention of both the city planner and highway engineer.

The recent exchange of criticism between city planners and highway planners in connection with the construction of the National System of Interstate and Defense Highways has rather dramatically highlighted the importance of highways in urban development and the need for cooperative planning of highways in urban areas. This exchange of criticism has been reflected, probably to the detriment of both professions, in the popular press as well as in the professional planning and engineering journals. It has been the cause and subject of several important national conferences of city planners, highway engineers, public work officials, and leaders from government, commerce, and industry, such as the Hartford Conference (held at Hartford, Conn., September 1957, sponsored by the Connecticut General Life Insurance Company) and the Sagamore Conference (held at Syracuse University, October 1958, sponsored by the American Municipal Association, AASHO, the Automotive Safety Foundation, and HRB).

As a result of the findings and the recommendations of the Sagamore Conference on Highways and Urban Development, the U.S. Bureau of Public Roads directed its regional and division engineers to effect the attainment of current and realistic urban highway plans for each urban area within its jurisdiction, these plans to be cooperatively developed and endorsed by all agencies concerned.* This directive indicated that these plans must not only be adequate for future traffic needs but must be in harmony with, and an integral part of, the over-all plans for urban area growth and development. As a logical first step toward this objective the Bureau, in a subsequent directive,** requested that an inventory of the existing planning situation in the local communities be made by the individual state highway agencies, and provided standard questionnaires for such an inventory. Accordingly the State Highway Commission of Wisconsin from March to September 1960 conducted a local planning inventory in Wisconsin and in August 1960 activated an Urban Planning Section in its Planning and Research Division. The need to analyze and evaluate the results of this inventory as well as to devise a sound procedure for carrying out the directive of the Bureau of Public Roads to effect the attainment of current and realistic urban arterial highway plans for each urban area resulted in the undertaking of a special research study and evaluation of local highway system planning in Wisconsin.

PURPOSE AND OBJECTIVES

The purpose and general objectives of this special study were (a) to determine the extent to which municipalities in Wisconsin have actually prepared long-range plans for the development of integrated urban street and highway systems and have actually attempted to implement these plans through legislative action and administrative practices; (b) to determine the effectiveness of these plans and plan implementation devices in actually achieving integrated urban highway systems; (c) to isolate and analyze any strengths or weaknesses in the existing local highway planning processes, and (d) to outline a method of effecting the attainment of current and realistic local highway system plans in urban areas and suggest possible changes in the legislative framework or administrative practices that might improve the local highway planning processes, with particular emphasis on possible functions of the State Highway Commission.

METHODOLOGY

The study was based on an analysis of a statewide local planning inventory covering 32 cities and villages in all, including all municipalities in the state with population of 25,000 and over. Using the results of this inventory, six cities were selected for more intensive study, and the following research procedure applied:

1. All existing plan documentation including land-use, arterial street, and highway system, and community facilities plans, all existing plan implementation devices including zoning, subdivision control and official map ordinances, and capital improvement and urban renewal programs along with copies of the official proceedings of the local plan commission and common council, were collected from each city studied. These data were reviewed and analyzed for possible impact on the highway planning

---

*See Circular Memorandum to all Regional and Division Engineers, from Ellis L. Armstrong, Commissioner, U.S. Bureau of Public Roads, Subject: Urban Highway Planning; 25 Nov. 1959.

**See Circular Memorandum to all Regional and Division Engineers, from G.M. Williams, Assistant Commissioner, U.S. Bureau of Public Roads, Subject: Inventory of Urban Planning; 28 Jan. 1960.

process as well as a provision for measuring the over-all status of local planning in each city studied.

2. For each city having a highway plan the extent to which this plan had been actually implemented through major highway construction undertaken since the adoption of the plan was then determined by a series of overlay maps. The overlay map process clearly indicated any serious discrepancies between the adopted local highway system plans, actual major highway construction, and established Federal Aid System routes. Each major discrepancy indicated by the overlay map process was regarded as evidence of a possible breakdown in the local highway planning process.

3. Each such possible breakdown was then investigated through structured interviews directed toward an analysis of the local highway planning process. Interviews were held in each case with individuals active in the local planning process, including engineers, planners, elected officials, and recognized community leaders.

4. The results of the structured interview were then summarized and analyzed in light of the factual information provided by the collection and analyses of the plan documentation, the official proceedings, and the overlay maps. This analysis was made on an individual, city-by-city basis and a body of material was thus created from which general conclusions were drawn about the specific fact situations involved in each case. In addition, because of the full range of planning experience represented by the cities studied, generalizations were drawn from the same body of material and are believed applicable on a statewide basis.

RESULTS AND CONCLUSIONS

Certain generalized conclusions pertinent to the purpose and objectives of the study have been drawn based on the research findings and on the results of the statewide urban planning inventory.

Current Status of Local Planning in Wisconsin

Somewhat less than one-third of the cities inventoried, which included all cities of over 25,000 population in the State, had prepared even rudimentary comprehensive community development plans. In other words, over two-thirds of the cities lacked such plans in spite of the fact that these cities had well-established plan commissions, that the State planning enabling act clearly indicated that it is the duty and function of the local plan commissions to prepare and adopt such plans, and that this legislation has been in effect for about 40 years in Wisconsin.

Further, about one-half of the cities inventoried had prepared an arterial street and highway system plan of sorts, even though some of these had no comprehensive plan. Moreover, of the cities that had prepared such arterial street and highway system plans about 60 percent had done so without the collection of essential traffic data and about another 45 percent had done so without the collection of essential land-use data.

All of the cities inventoried had adopted zoning ordinances, all but two had adopted subdivision control ordinances, and about one-half had adopted capital improvement budgets, although only one-third of these cities had prepared comprehensive plans. About one-half had adopted official maps, although 40 percent of these had not developed arterial street and highway system plans. It is apparent that in some cases the plan implementation devices are being used to implement long-range plans, whereas in other cases the implementation devices are simulating or substituting for the necessary long-range plans.

Effectiveness of the Plans and Plan Implementation Devices

From the results of this study it is concluded that existing local arterial street and highway system plans have been quite ineffective in actually achieving integrated urban highway systems in Wisconsin. It was found rather conclusively that state and federally aided highway improvements undertaken since the adoption of the plans that did exist in the cities studied were not implementing those plans. For example, the overlay map studies showed that in the city having the most extensive highway construction activity of those cities studied, and the second most extensive construction activity in the entire state, about one-half of the total capital investment in such construction resulted in highway improvements that departed significantly from the adopted plan, a plan that was only five years old. The structured interviews conclusively showed that where such construction did conform to local plans this conformance was not due to such construction being used in a positive manner to implement effectively the objectives expressed in the plans, but was instead almost completely coincidental.

The study further indicates that the relationships existing between the State Highway Commission and the State's urban areas regarding highway plan preparation and implementation are generally unsatisfactory to both the State and the local agencies, and existing plans were more apt to serve as a center of dispute than as a basis for close liaison and cooperation. It may be of particular concern to the Highway Commission that the study indicated that 59 percent of the lay leaders and 79 percent of the technicians interviewed believe that the local plans did not have the understanding, acceptance, or support of the Highway Commission. In fact only 35 percent of the lay leaders and 33 percent of the technicians, and the latter group included the district highway engineers, believed that the cooperation of the highway commission in plan preparation has been satisfactory in the past. Similarly, only 53 percent of the lay leaders and 40 percent of the technicians believed that the cooperation of the State Highway Commission has been satisfactory in plan implementation. In short, the study clearly demonstrated that the existing local arterial street and highway system plans are not serving as statements of mutually agreed on, long-range objectives to guide and coordinate the highway plan implementation activities of all levels of government toward the ultimate attainment of practical and workable urban highway systems. The highly unsatisfactory situation in this respect apparently represents an almost total breakdown of the local highway planning process in Wisconsin.

Factors Contributing to the Breakdown of the Planning Process

The results of this study indicate that several factors contribute to this apparent breakdown of the local highway planning process.

The first and probably most serious contributing factor, found to exist in all of the cities studied that had prepared and adopted highway plans, concerns the technical adequacy of the plans themselves from an engineering standpoint. This factor probably more than any other is basic to the widespread breakdown of the local highway planning process. The study found that existing local highway system plans are little more than intuitively created street patterns rather than engineered systems designs based on quantitative analyses, and as such, are not a sound basis for capital investment. Further, these plans do not provide the necessary and desired long-range solutions to the urban traffic and transportation problem.

It is significant that the State Highway Commission completed a comprehensive origin and destination survey in each of the four cities studied that had adopted plans before the highway plan preparation and that the resulting traffic data were made available to the local governments in time for the planning work.

In some cases the traffic data was used in the local arterial street and highway system plan preparation in a "qualitative" manner only through intuitive application of the planning data and visual examination of the existing traffic flow diagrams and trip desire lines as revealed by the origin and destination survey. In other cases it was apparent that the origin and destination data, and the existing traffic patterns and desire lines which this data established had been used directly as a "qualitative guide" to judgment in evolving the plans. In addition, certain portions of these plans had been quantitatively tested by the time-honored system of projecting existing traffic patterns by applying a single expansion factor to existing traffic volumes.

It is significant, indeed of central importance to this study, that in no case was any attempt made to relate trip generation to land use, to apply such trip generation factors to the future land-use plan or projection to simulate future traffic patterns, or to assign this simulated future traffic demand to the proposed system in order to analyze the system capacity. The technical adequacy or feasibility of these existing system plans is, therefore, at least subject to question and it necessarily follows that these plans cannot serve as expressions of agreed on objectives among the various agencies involved in highway planning and plan implementation. The traffic and highway engineers interviewed were particularly critical of this lack of applied systems analysis and design in local highway plan preparation and indicated that such lack made the existing plans largely unworkable.

Urban highway system plans prepared without such traffic systems analysis provide no basis for agreement on the feasibility and soundness of the plan, either between the city and the state or between local line and planning departments, and therefore fail to fulfill the basic purpose and function of such a plan. Moreover, a plan that is not an engineered systems design may actually create more problems than it solves. Proper quantitative analyses assure full use of basic planning and traffic data often collected at great expense, but as indicated by the study, used to a very limited degree if at all.

The study revealed, and this should be significant to all highway agencies, that this lack of technical adequacy is known and fully understood by only a few technicians closely involved in planning and plan implementation. Consequently when the highway agency is called on to implement portions of an adopted plan and refuses to do so on the basis of traffic assignments and cost benefit ratio studies, it is apt to be regarded as obstructionist, and public relations accordingly suffer severely.

A second major factor contributing to the breakdown in the highway planning process concerns the lack of a documented state-wide, long-range highway system plan. As a consequence, local plans are being developed without any real knowledge of the long-range plans of the State Highway Commission itself as to the ultimate future treatment of the major intra- and inter-regional traffic corridors. Because the highway network forms the basic framework for urban growth and development today and because any changes in this network have far-reaching effects on the urban pattern, it becomes very difficult if not impossible to formulate sound local plans except within the context of a broader plan which expresses regional and state highway transportation needs. In this respect, the term plan implies documentation, for only through adequate documentation can a plan serve as a statement of mutually agreed on long-range objectives.

A third major factor concerns the existing federal aid systems, which simulate long-range highway system plans per se but do not reflect the local plans. Major highway construction implements the plans expressed in the aid systems and, therefore, if local highway plans are to be meaningful (that is, are to be successfully implemented), provision must be made to adjust the federal aid systems to the plan at the time of plan adoption.

A fourth major factor concerns the lack of active participation at all levels of government by key line agencies who are ultimately responsible for plan implementation in the technical aspects of the plan preparation beyond data collection. This factor is certainly related to the first and most basic contributing factor, inasmuch as the lack of technical adequacy is at least partially the result of a lack of direct participation in the plan preparation by technicians of the key city line departments and the State Highway Commission. The lack of such direct participation in plan preparation is also an important factor in the decided lack of interest by line agencies in active plan implementation.

Other factors apparently contributing to the breakdown of the local highway planning process but perhaps somewhat less critical than the major factors just enumerated include the following:

1. A definite lack of any common understanding of many of the terms and concepts involved in local arterial street and highway system planning. Inasmuch as agreement on terminology and the basic concepts that such terminology might represent is necessary to ready communication and understanding among the various individuals and groups involved in local planning, a need appears to exist to establish common definitions of terminology and concepts relating to urban planning on a statewide basis. The study indicates that agreement is lacking on such important matters as the definition of the purpose and function of an arterial street and highway system plan, the definition of the term "urban area" itself, the desirable delineation of both planning areas and

planning responsibilities by governmental levels, and the definition, function, and application of plan implementation devices.

2. The apparent weakness of certain widely used plan implementation devices, and the decided lack of application of other more effective plan implementation devices to arterial street and highway system plan implementation.

3. A lack of stability in the local highway system plans due to a general lack of understanding, acceptance, and support of the plans by the public and, sometimes under pressure from segments of the public, by elected officials. The ease and rapidity with which the local plans are often revised when a specific improvement project implementing the plan meets stiff local resistance has made the highway engineer question the integrity of the plans and be unwilling to invest any money in stage construction based on ultimate plan proposals.

This study was undertaken with the expectation that some of the breakdown in the local planning process would be attributable to the ineffectiveness of the local plan commissions in getting common council support for their recommendations. The study, however, revealed the contrary to be true and it can only be concluded that any changes in the local planning procedures at this time should be built around the plan commissions and should seek to strengthen the commissions and their role in plan implementation.

RECOMMENDATIONS

Any procedures to effect the attainment of current and realistic urban arterial street and highway plans for the urban areas of Wisconsin should include the following:

1. Assuring the technical adequacy of these plans; i.e., their ability to meet the future traffic demands that will be placed on the proposed facilities from both an engineering and a financial standpoint, as well as the proper integration of the highway and land-use development.

2. Assuring the incorporation of intra- and inter-regional transportation needs in the local plan proposals, thereby integrating state and local highway system planning.

3. Assuring effective plan implementation so that the planning is for action and not merely "for the sake of planning," as appears to have been the case too often in the past.

4. Functioning substantially within the framework of the existing state planning enabling legislation as it affects local planning.

The following method of effecting the attainment of practical and workable local highway system plans in Wisconsin was proposed as a result of this study. It is thought that this procedure, if adopted, will overcome all the major weaknesses found by the study in the existing local highway planning process and permit local arterial street and highway system plans to be cooperatively developed, endorsed, and implemented by all agencies concerned. An outline of the recommended procedure follows:

1. The State Highway Commission should actively encourage the preparation of documented comprehensive community development plans, including arterial street and highway system plans, for each urban area in Wisconsin. It is recommended that, for planning purposes, the definition of urban area be not that definition specified by established policy interpretation of Title 23, U.S. Code, Section 101, but be "An area including and adjacent to a municipality or other urban place of five thousand or more as shown by the latest available federal census and in the case of incorporated municipalities, including the extra territorial plat approval jurisdiction of the municipality as defined by Section 236.02(2) of the Wisconsin Statutes."

Such plan preparation could be most effectively encouraged through the establishment of a firm policy that after an established cut-off date no more federal and state aids will be made available for new construction in urban areas that do not have such plans prepared and adopted.

This recommendation would effectively overcome any weaknesses in the local highway planning process now stemming from a lack of documented local plans.

2. To assure the technical adequacy of future plans the State Highway Commission should offer to extend limited technical assistance and advice to the local units of gov-

ernment during plan preparation through a staff familiar with both land-use and highway system planning techniques. It is most significant that in the interview process this was the most frequent need voiced by interviewees. It was mentioned by 89 percent of the interviewees, or specifically by 100 percent of the technicians and 74 percent of the lay leaders. This assistance and advice should be initiated during the basic data collection phases of the planning work, continue during the sketch plan phases of both the land-use and highway system plan, and extend to a review and analysis of the final local highway system plan.

The Commission's assistance and advice should be directed toward two primary objectives: (a) the incorporation of intra- and inter-regional transportation needs in the local plans, and (b) the assurance that the finished plan is technically sound and workable.

The attainment of the first objective implies the preparation of a documented statewide long-range highway system plan by the State Highway Commission. In interview process the second most frequent need voiced by interviewees was for a documented long-range State Trunk Highway system plan. This was mentioned 24 times, or by 55 percent of the interviewees, or specifically 59 percent of the technicians and 50 percent of the lay leaders. Such a statewide plan should include a "master plan" setting forth the general location of the major traffic corridors, and in general terms the type of facility required to meet the ultimate traffic demands of these broad corridors. Such a general plan should be prepared within the context of a comprehensive statewide development plan based on the careful collection and analysis of population, economic, and land-use data. Consequently the proper preparation of such a statewide highway system plan should be a joint effort between the Planning Division of the State Department of Resource Development and the State Highway Commission.

A general plan of this sort, though necessary as a statement of agreed on, statewide long-range objectives, is, however, quite ineffective as a basis for extending technical planning assistance and advice to local governments. The proper extension of such assistance requires the preparation of precise and definitive plans, beyond the general plan stage, setting forth the ultimate development of each of the traffic corridors specified on the general plan. Such plans should set forth proposals as to centerline location, ultimate rights-of-way width required, type of access control to be exercised, and type and location of interchanges and grade separations. Although such definitive plans are most easily prepared along existing locations, seeking to preserve the capacity and life of such locations; surveying, mapping, and electronic computing techniques now available make the preparation of such definitive plans along new locations equally feasible without the need of resorting to expensive and time-consuming field surveys. In Wisconsin such plans can be developed entirely on photogrammetrically compiled topographic maps, the control for which consists of monumented U.S. Public Land Survey corners tied to the State Plane Coordinate system. Such maps and monumented permanent control permit precise and accurate field identification of the proposed facility location as well as land acquisition therefor without the need for traditional and expensive centerline location surveys. Such precise plans are not to be regarded final and inflexible solutions to the intra- and inter-regional transportation problems, but rather as sound points of departure against which any proposed development alternatives can be evaluated. The preparation of such definitive plans would do much to allow local planners to bring the full weight of plan implementation devices at the disposal of the local governments to bear on the reservation and advance acquisition of right-of-way as well as to assist these planners in making intelligent recommendations on desirable land-use and development alternatives. The benefits possible to both the state and local units of government from the preparation and application of such definitive plans are great indeed. Such possible benefits include the following:

(a) Reservation and advance acquisition of necessary right-of-way at undeveloped land prices. In this respect, the full benefit of local plan implementation powers can be realized through the application of the official map and of subdivision control in urbanizing areas to reserve and acquire right-of-way at no cost to the governmental units involved.

(b) Permitting private capital to be intelligently invested in urban development with full knowledge of highway improvements contemplated, thus protecting both the stability of the private investment and the capacity of the proposed highway improvements.

(c) Permitting the development of integrated highway systems through careful stage construction directed toward ultimate objectives.

(d) Assuring the best possible investment of public funds in highway improvements, as well as the protection of this investment from premature obsolescence.

The attainment of the second objective (namely, that of the technical adequacy of the finished plans) requires that local arterial street and highway system plans be the product of a quantitative systems design wherein the major street pattern itself and the capacities of sections and intersections of this pattern are carefully fitted to projected traffic loads. Methods are now available by which this can be done quite readily and, considering the benefits to be derived, quite economically. These methods have been developed through the application of operations research techniques to highway planning studies and are equally applicable to large and small communities. Though a detailed account of the techniques required is beyond the scope of this study, a brief outline of the highway systems design approach required to prepare an adequate plan might be in order. It consists of the following:

(a) Relating trip generation directly to land use. Presently this requires the classical type of origin and destination survey but eventually it may be possible to simplify these surveys greatly or even eliminate the need for such surveys entirely.

(b) Establishing the future land-use patterns. This may be done on the basis of a prepared land-use plan, a land-use projection based on an urban area growth model, or a "planned projection" that would use a growth model to establish ranges within which policy decisions can be made and that indicates not only feasible but also optional choices.

(c) Having established future trip generation factors and future land use, establishing total trip generation for the design year or design area. It is the future land-use pattern that determines the future origins, destinations, and travel linkages and not the existing origin and destination survey data.

(d) Converting trip generation to travel pattern (future desire lines) by a model expressing zonal inter-change. Some models do this by expanding interchange volumes between pairs of zones as found in an origin and destination study and then adjusting for the mutual effects of interchanges among all zones by an iterative process; others synthesize the interchange patterns on the basis of rationally developed but empirically adjusted models.

(e) Developing a planned network of facilities to serve the volumes and location of these projected travel demands, making quantitative assignment of this demand to the proposed network, and adjusting the network if necessary to relate planned capacities to future loads, thereby attaining a workable system.

Because these systems design techniques require experienced staff and access to high-speed computers and computer programs, it is recommended that the State Highway Commission offer, as the major part of its participation in the local plan preparation, to review and analyze the local highway system plan to assure its sound foundation in an engineered systems design.

The attainment of this second objective may also require some review by the State Highway Commission of the engineering feasibility of the plan in respects other than traffic capacity, as well as some assistance in cost analysis.

3. On completion of the local arterial street and highway system plan it should be formally adopted by both the local plan commission and the State Highway Commission as well as by the local common council. It should be formally agreed among the parties involved that on mutual adoption no major changes in the highway system plan or in the land-use plan that supports it are to be made unilaterally by the agencies involved without first resubmitting the proposed changes to the State for a systems analysis. Any major changes in either the land-use or the highway plan could then be intelligently reviewed in light of how the proposed changes might affect both the ultimate highway system and the urban pattern.

4. On mutual formal adoption of local arterial street and highway system plan the existing federal aid systems should be adjusted to the plan in an optimum manner thereby assuring sound plan implementation through state and federally aided highway improvement projects and to limit the state's responsibility in plan implementation.

5. Finally, the planning staff of the State Highway Commission, through the district offices, should then continue to maintain a close liaison with the local government with respect to highway planning matters, offering to extend such assistance and advice on plan implementation as may be requested by the local governments.

CONCLUSIONS

The adoption of the local highway planning procedures recommended herein by the State Highway Commission should result for the first time in the preparation of practical and workable local highway system plans that can be cooperatively adopted and jointly implemented by the various levels and agencies of government. The recommended procedures should, moreover, serve to create a greater awareness of the importance of planning among city engineers, traffic engineers, directors of public works, and highway engineers than has been true in the past, as well as a greater willingness on the part of planners to allow the planning effort to become what it should be—an interdisciplinary team effort. It should, thereby, provide the key to integrating land-use and transportation system planning in the state's rapidly expanding urban areas.

Contributions from Geography to Urban Transportation Research

ROY I. WOLFE, Geographic Advisor, Ontario Department of Highways

In recent years there has been an accelerating demand for attack on the problem of urban transportation, with emphasis on the need for interdisciplinary study of all relevant aspects of both the city and the various forms of transportation.

As an integrative discipline that concerns itself, in part, with the way different areas on the earth's surface interact with each other, geography has much to offer toward meeting these needs. Its value is well recognized by urban planning bodies, but much less so by State highway departments, only two of which have geographers on their permanent staffs, doing the sort of work for which they were trained.

No more than a half-dozen papers have been presented by geographers at the annual meetings of the Highway Research Board, and it may therefore be of value to present a brief review of the geographic concepts that are applicable to urban transportation research. These concepts are not necessarily unique to geography, but the insights that arise from them may be. Among them are location theory, central place hierarchy, urban functional classification, regional land-use analysis, simulation models, systems analysis, graph theory, and especially new approaches to cartography, including use of machines in mapping, mathematical maps, and distortions that will clarify the relations between distance, cost, and time.

Many substantive studies have been performed on specific cities and highway problems, and the mass of material accumulated by geography departments in the universities can be of considerable value to local researchers from other disciplines.

• BEFORE the transportation needs of a city can be assessed, it is essential to learn not only the internal characteristics of the city itself but also its relations with the region of which it forms a part, with other cities, with the country as a whole, and in some cases, even with the rest of the world. Thus, for instance, to be able to assess the transportation needs of the city of Seattle, the following factors, among a great many others, need to be considered:

1. The peculiarities of the city's physical setting—its elongated form, its invasion by water bodies, the profusion of hills.
2. The specific climatic conditions, which make for transportation problems very much different from those of, say, Toronto.
3. The marked functional zonation, into central business district, residential and industrial zones, a university district, and the ever-spreading suburbs; and the effect that this zonation has on the pattern of strip generation.
4. The economic base of the city, which rests in large part on the aircraft and forestry industries.
5. Seattle's status as the chief center in the Pacific Northwest, and its relation to the lesser centers in Washington, Oregon, and Idaho, and to the Canadian city of Vancouver.

6. The effect of the mountain barrier that separates it from the bulk of the United States, and from most of its own state of Washington, too.

7. Its dependence on hydroelectric power from the Columbia and Snake Rivers, and the effect of negotiations with Canada on the availability of additional power.

8. Its special relation to Alaska.

9. Its role as a world port on the Pacific, and the competition for its hinterland offered by Los Angeles, San Francisco, Portland, Vancouver, and even Prince Rupert (the last for the Alaska trade.)

By design, this list has almost nothing to say about the factor that must be considered above all others: people, their social needs, their esthetic likes and dislikes, their individual reasons for living in the city and moving about and beyond it. These excluded questions are the domain of the sociologist and the architect, whose skills have been recognized as essential to the solution of the urban transportation problem. The one characteristic the items included in the list have in common is that, in one way or another, they involve relations between places distributed on the earth's surface. To that extent, they are all in the domain of the geographer.

The present paper briefly examines the field of geography and the specific contributions it has made to an understanding of the urban transportation problem.

So brief a survey of so broad a subject can provide few substantive details, nor are such details altogether essential in a paper that is intended merely to put on the record the work that geographers have done, in a place where it will be available to researchers from other disciplines in the field of urban transportation. Reference will be made to a wide range of representative studies, and those who wish to delve deeper will find in the Appendix a short list of bibliographic and review articles that will help them locate other reports in their field of special interest.

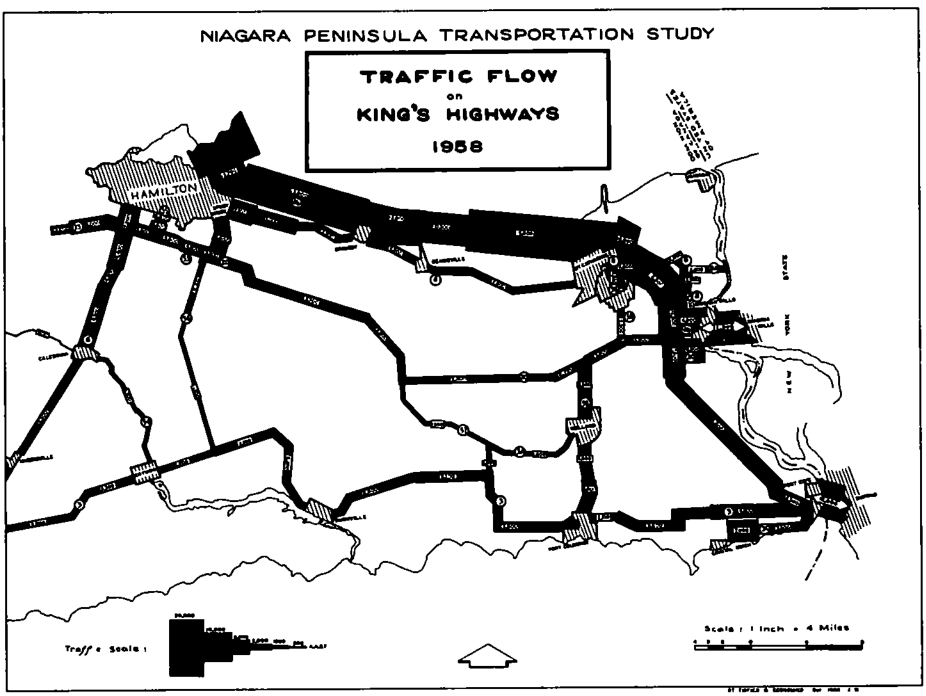


Figure 1. Information about traffic flow shown here used by engineers to help provide efficient facilities for movement. (From "A Highway Plan for the Hamilton-Wentworth Area," Dept. of Highways, Ontario (1961).)

THE FIELD OF GEOGRAPHY

Geography does not have a subject matter exclusively its own. What is unique to geography is its point of view, and nothing else. It is an integrative discipline; it tries to bring together all the phenomena that find an areal expression on the earth's surface, to discover and classify any uniformities that exist, and to clarify the causal relations between phenomena. In so doing, geography draws on a host of other disciplines for their special insights, thereby gaining a synoptic view of the problems that it examines.

As with other disciplines, there is no universally agreed on definition of the limits of the field. Engineers are familiar with the dictum, "Engineering is what engineers do"; similarly, "Geography is what geographers do." It does little good to define engineering in this way to geographers, or geography to engineers. But an example from each may help clarify at least some of the distinctions between the disciplines.

Figures 1 and 2 show two flow plans; the first is the flow of motor traffic on highways in a highly urbanized area, and the second, the flow of certain goods between one specific area in the United States and all others. The engineer uses maps such as that in Figure 1 to learn how much traffic each road in the area is expected to carry, so that he may make such changes in the road system as are necessary to allow the system as a whole to work efficiently; the geographer uses maps such as that in Figure 2 to learn something about the spatial interactions between the area under study and other areas. There is a very important distinction here, the distinction between the engineer's primary interest in the facilities for movement and the geographer's primary interest in the areas between which movement takes place.

Engineers will notice other differences between their ways of dealing with the problems of urban transportation and those of geographers, particularly academic geographers, in the discussion that follows.

Ullman's Concept of Spatial Interaction

Appropriately, the previous geographic example is taken from the work of Ullman (1),

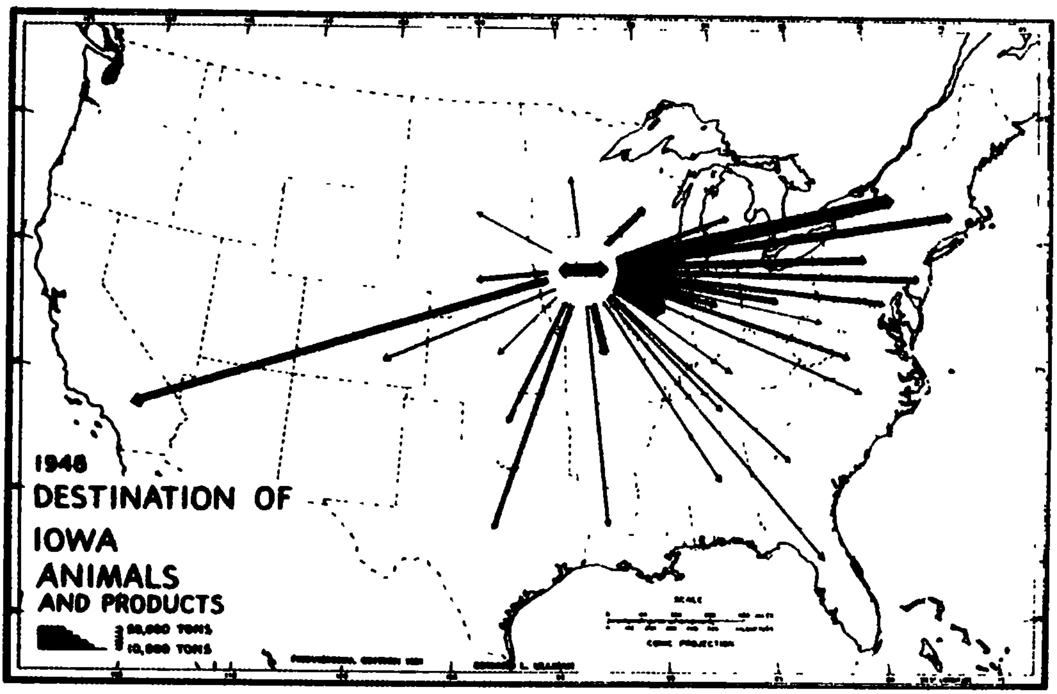


Figure 2. Information about commodity flow shown helps geographers gauge spatial interaction between areas. (From Ullman (1).)

for it is his conception of the primary concern of geography, as the study of spatial interaction, that may be suggested as a most fruitful theoretical foundation for the geographic study of urban transportation.

According to Ullman, there are three concepts that together are sufficient to explain the interactions between any two areas: the first is complementarity, the lack of something in one area that the other can supply; the second is intervening opportunity, which must be absent, otherwise the lack may be made up from this more convenient source; and the third, transferability, the sheer possibility of movement between the two areas taking place (1). It might be well to add a fourth concept, to take into account the action of the human will, which may disregard or change any or all of the other three. Because it may be peculiar to a given place or situation, perhaps it may be called idiosyncrasy.

These concepts are of direct relevance to the problem of urban transportation. For movement to take place between any two zones of a city, there must be complementarity between them; each must have something that the other needs; one may have workers, the other factories, one shoppers, the other stores. A newly created intervening opportunity may reduce the number of trips that formerly took place between two zones; for example, the building of a regional shopping center may cause fewer shoppers to travel from a nearby suburban residential area to the downtown districts. Of most direct concern to transportation planners are transferability and idiosyncrasy—planners may do their best to make convenient movement between two areas possible, by providing mass transit services, and yet these may go relatively unused, as people continue to overload the city's roads with single-occupant cars.

The field of geography, then, may be taken as the study of spatial interaction, which in turn involves a careful examination of the way specific areas differ from each other, and of the forces that these differences generate, which result in movement between the areas.

General Remarks on Geographic Techniques

The two techniques of which geography has traditionally made the most intensive use are the making of field trips and the compilation of maps. Indeed, these two activities fairly well sum up the popular idea of what geographers do—or did while they still had the chance. They went out to explore unknown places and came back with maps showing what they had seen. Of the two, it is the map that is most characteristic of geography.

Field trip and map, however, cannot by themselves tell the whole story. To them must be added the facts that can be gained only by the gathering of statistical information and its analysis. As with any other science, once masses of facts about a great many areas and their interactions have been gathered, the difficult tasks of generalization and the formulation of meaningful concepts must be undertaken. In this process there is necessarily a great deal of borrowing from other disciplines, such as geology, meteorology, geophysics, and especially with respect to the study of the city and of transportation, from sociology, economics, and history.

In geography, as in all sciences, there has been a prodigious leap forward in the last ten years. The solid foundation of direct, empirical observation is still there, as is the painstaking gathering of facts, but there has been evidenced an increasing sophistication in the analysis of these facts. Above all, a new school has emerged, the school of quantifiers, who are seeking to take advantage of recent advances in mathematical statistics, in operations research and linear programming, and in electronic computation, by use of which they hope to establish a set of geographic laws having a generality that has so far been impossible to achieve.

APPLICATION TO URBAN PROBLEMS

Internal Structure of the City

Some years ago the Wenner-Gren Foundation brought together scientists and scholars to discuss "Man's Role in Changing the Face of the Earth," of whom fully one-third were geographers (2). As students of the face of the earth, geographers are of course very

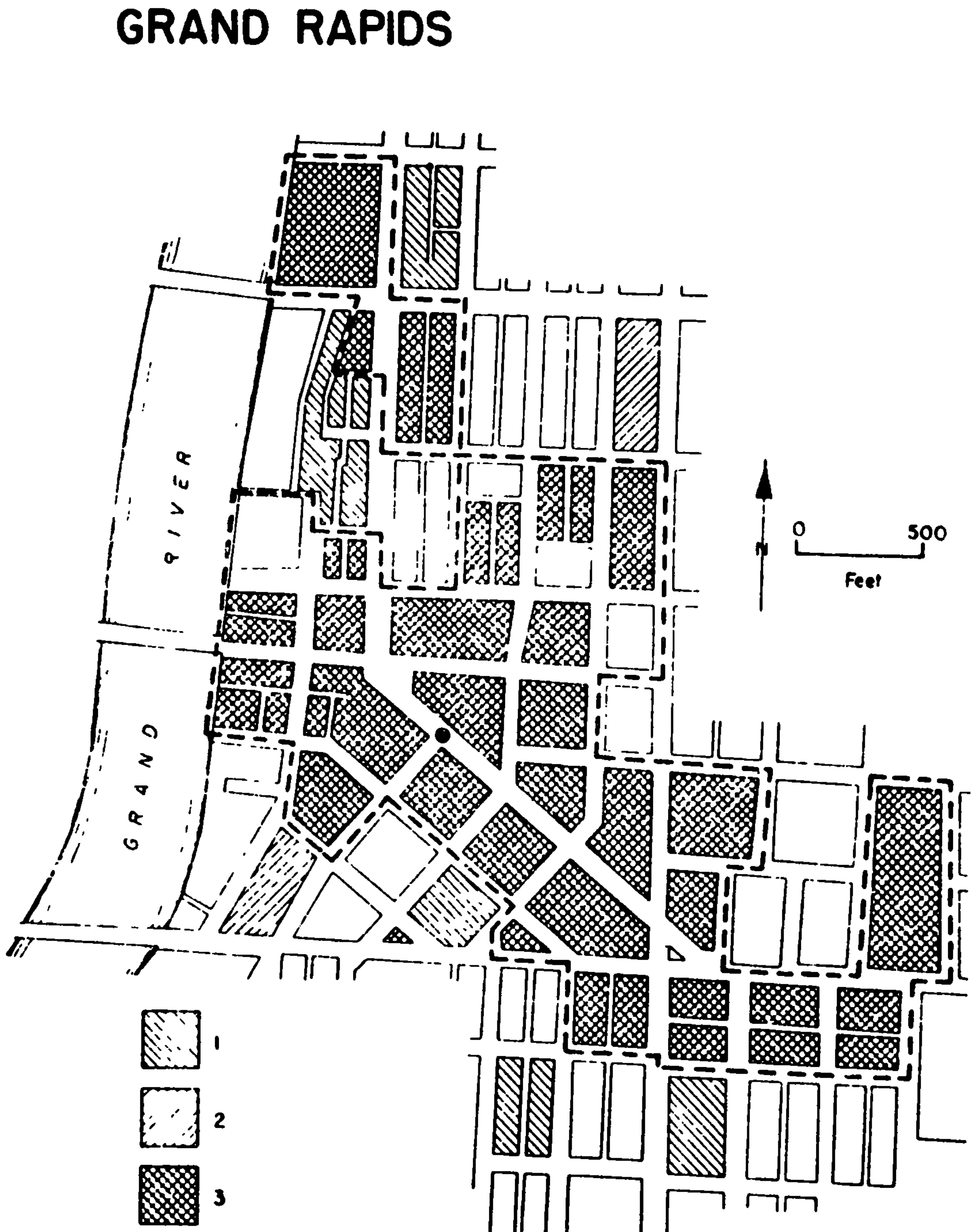


Figure 3. City blocks that make up CBD specified according to levels reached by their Central Business Height Index and Central Business Intensity Index. (From Murphy and Vance (5).)

much interested in the way man changes it, and in no way does he change it so radically, or in so readily observable a form, as in the construction of cities. Therefore, geographers have for a long time directed their attention at the city itself, the complexity of its organization, and the way different parts of it take on different physical qualities that correspond with their different functions.

There is a vast literature devoted to describing the growth and functional zonation of individual cities, and over a period of time the specific types of variations recurring in city after city have become recognized.

Too much attention need not be given here to this aspect of geographic work; all students of the city are aware of its functional zonation, and how much of their knowledge is attributable to the work of geographers, or of sociologists, is of little significance to them.

Two types of study, have concentrated on the very edge and the very center of the city, for in the interaction between these two parts of the city rise the most intractable of all problems in urban transportation.

The Rural-Urban Fringe. —On the edge of the city occurs the conflict between antithetical types of land use, with blocks of houses and factories pushing suburban development out onto once rural acres. Representative of such studies is the work of Krueger (3), who has become the recognized authority on the fruitlands of the Niagara Peninsula in Ontario, where some of the most valuable of the scarce tender-fruit acreage of this continent is fast disappearing under houses. In the United States, a similar phenomenon is occurring on a much vaster scale in Southern California, and it has been made the subject of a special supplement of the Annals of the Association of American Geographers (4).

The Central Business District. —Perhaps no single piece of geographic research has had so direct a bearing on all work on urban transportation as the study of the central business district by Murphy, Vance, and Epstein (5). Here, in a series of three papers, are presented exact quantitative methods for delimiting the CBD, a comparative study of CBD's in nine cities, and some conclusions about the internal structure of the CBD, based on the results of the comparative study (Fig. 3).

Murphy and Vance set themselves the essentially geographic task of defining a recognizably discrete region on the surface of the earth, a man-made region with characteristics of land use that are specific to it and are repeated over and over again in the landscape. Most important, they were determined to define the boundaries of that region in quantitative, objective terms, so that no matter who used the procedures they developed, the resulting conformation of the region should always be, within reasonably close tolerances, the same. They decided to use as the unit for describing this region, this central business district, not the lot, as had been usual before their time, but the whole city block. And the two criteria for measurement that they developed were the Central Business Height Index and the Central Business Intensity Index. The former is the number of floors devoted to the types of business characteristic of the central city, and is obtained by dividing the total floor area of all central business uses by the total ground floor area of the block. The latter is the percentage that the total floor area devoted to central business use makes up of the total floor space at all levels. Then they set up special rules by which they could designate entire blocks as being either in the central business district or outside it. They recognize the existence of a "core" area, an area that has since been intensively investigated by Horwood.

Horwood cooperated with Boyce in a program of studies that have materially advanced understanding of the effect of urban freeways on the city center. The results of their investigations were first presented before the Highway Research Board in January 1959 (6), and later the same year published in expanded form by the University of Washington Press (7, 52).

Durden and Marble (8) have pointed out that, although planners of the CBD have sought for a coherent body of ideas and concepts to provide perspective for their daily work, they have ignored theoretical developments in contemporary social science. They thereupon bring to the attention of planners a number of theoretical approaches from social science that the latter may find useful.

Location Theory. —Economists are paying increasing attention to that aspect of their field that closely approaches the bounds of geography—the economics of location. Geographers have been happy to make use of the results of their labors, and location theory is becoming a recognized field of geographic study.

Building on the foundation laid by Lösch (9), they have developed new techniques and

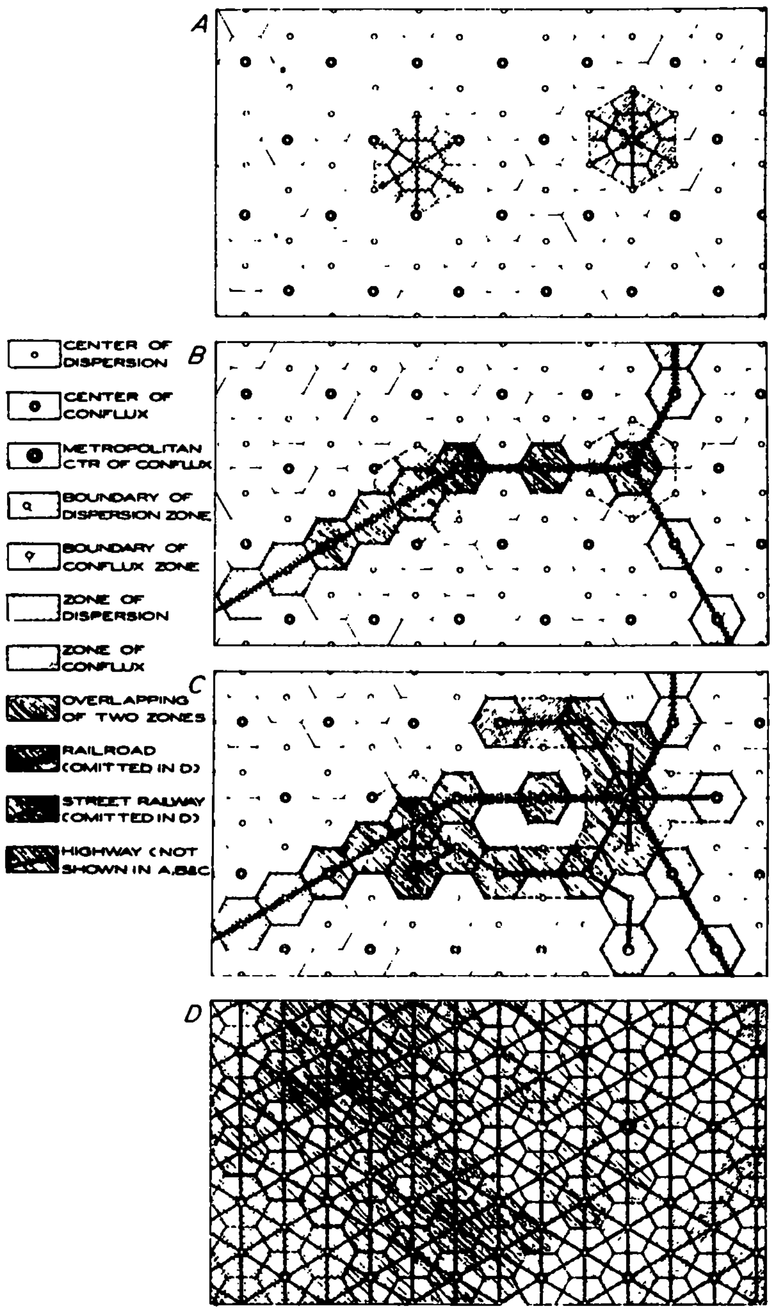


Figure 4. Christaller's hexagons used here to help lay theoretical foundation for empirical study of effects of changing technology of transportation on urban hinterlands. (From Vance (36).)

arrived at new theoretical concepts. Only a small part of location theory deals with the internal functional zonation of the city, but it is interesting and can lead to stimulating results. For example, if on a city map that gives nothing more than the distribution of population and of disposable income—nothing about the street pattern, functional distributions, residential areas, industry, or commerce—purely from theoretical considerations, exactly the right number of supermarkets, with each no more than a few hundred feet away from its actual location, can be exactly placed, then such results are something worth paying attention to. This is exactly what Getis (53) accomplished in his doctoral work on retail location in the city of Tacoma. If his results can be repeated for other cities, his technique should find ready application in urban transportation research.

External Relations of the City

The transportation needs of a city are determined not only by its own extent and the

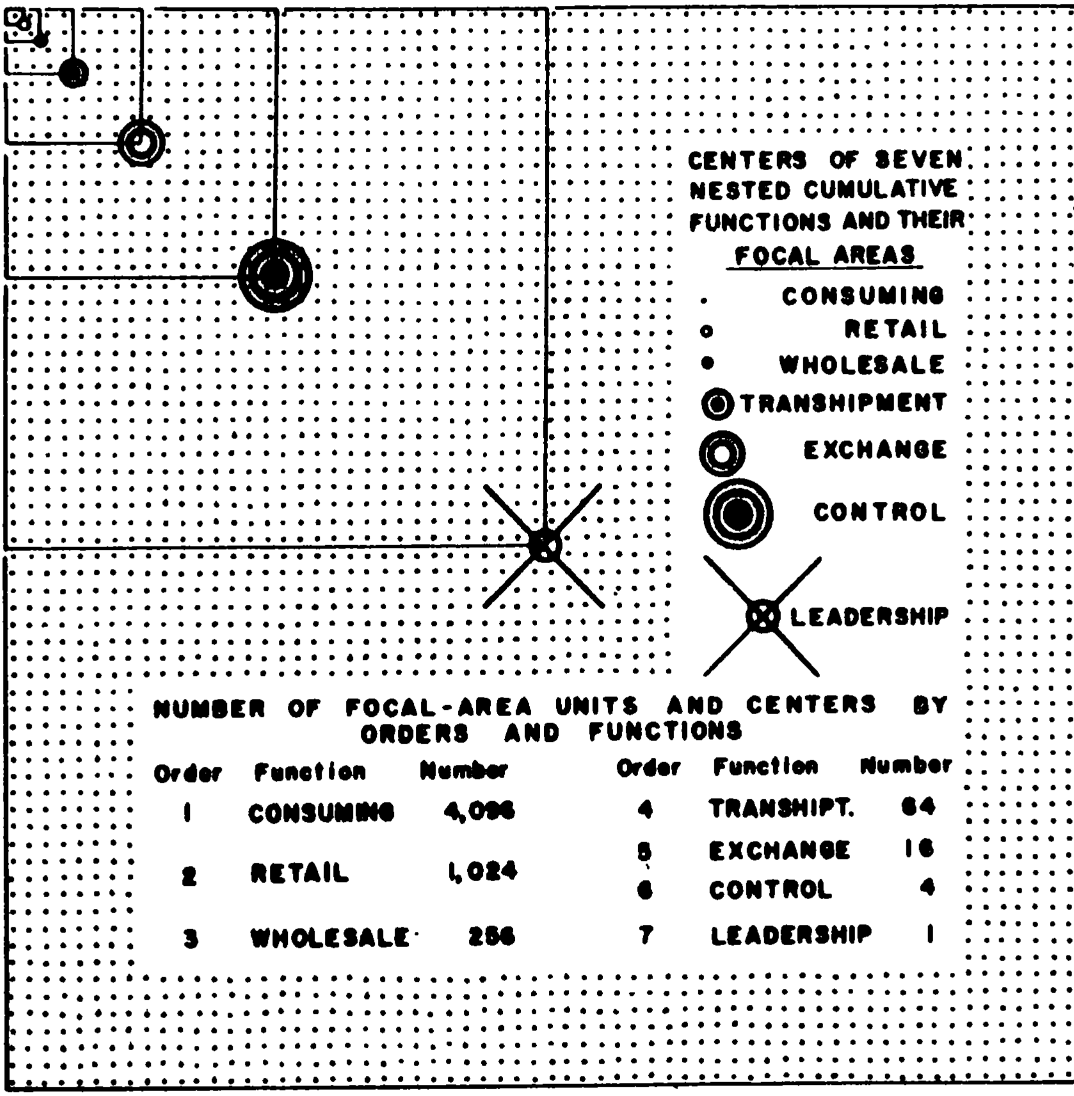


Figure 5. Nested hierarchy of central places. (From Philbrick (14).)

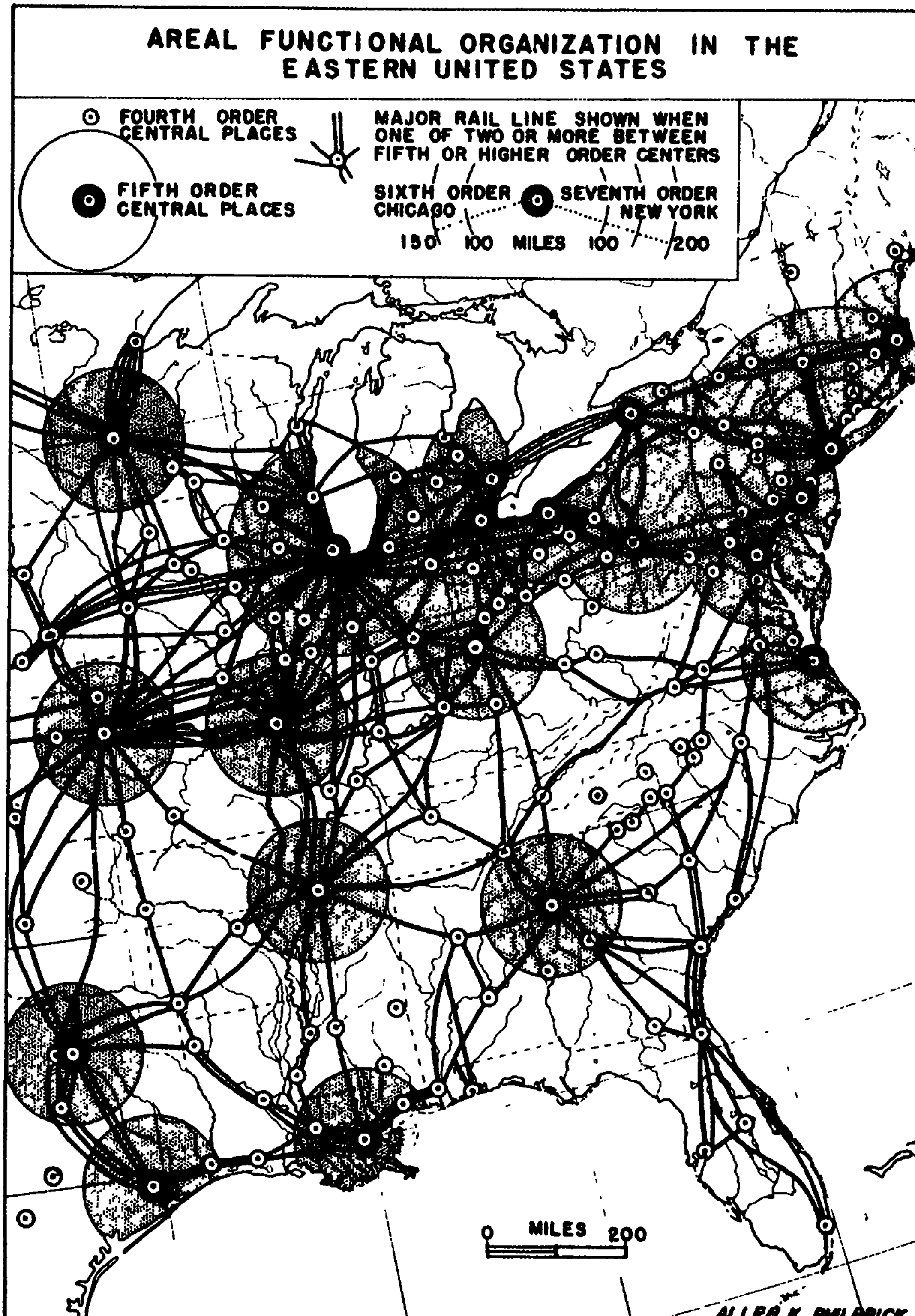


Figure 6. External transportation needs of cities conditioned by relations between these cities and others in hierarchy of central places. (From Philbrick (15).)

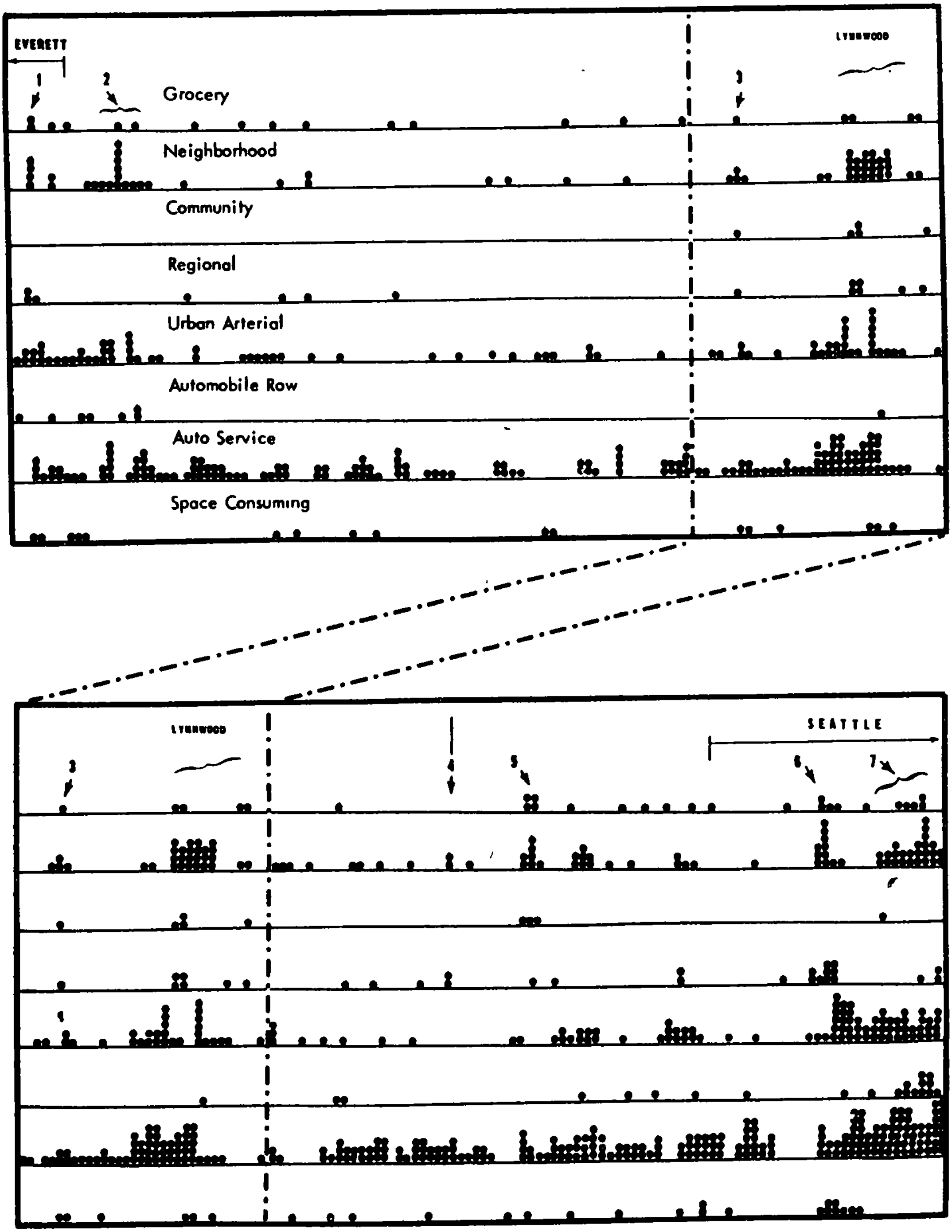


Figure 7. Problem of ribbon development along highways on outskirts of towns and cities related to those of urban sprawl and of premature obsolescence of highways. (From Berry (20).)

complexity of its own organization but also by the relation in which it stands to the surrounding countryside and to other cities. Indeed, its extent and complexity are themselves functions of its external relations; this is the subject of central place theory.

Central Place Hierarchy. —What causes a city to become great? Why does it inexorably arrogate to itself a greater and greater concentration of a country's or a region's population, wealth, industry, and cultural life? In what relation do the lesser cities of the country or region stand to this great city, and to each other? And what of the still lesser cities, towns, and villages: why are they where they are, of the size that they are, offering the precise services that they do? When all these questions are examined, a definite pattern begins to emerge, a pattern to which has been given the name "central place hierarchy."

The great city has been examined in such studies as Jefferson's "The Law of the Primate City" (10), which stimulated much subsequent research as, for example, by Stewart and Warntz (11), who separately and together have subjected the pattern to mathematical analysis. By far the greatest impetus to the study of central places has come from Christaller (12), who claimed to have discovered, in south Germany, a rigidly ordered hexagonal pattern (Fig. 4), to which he thought that the nested hierarchy of urban places everywhere would be found to conform. Further, there was not a gradual increase in population from the smallest place to the largest, but, instead, the places could be grouped in definite, discrete classes, and there were what might be called quantum jumps in population from class to class.

Christaller's work was first brought to the attention of American geographers by Ullman (13). Much work has since been done to test the validity of Christaller's ideas, and the results, though they have in no case confirmed the rigidity of his ordering, have been fruitful in pointing out other suggestive relations. Among the most interesting of such studies are those from which Figures 5 and 6 have been taken, by Philbrick (14, 15). Philbrick has ranked the central places of the United States in an ascending series of orders, from first to seventh (Fig. 5). All places in the eastern United States from the fourth order up, and the amount of railroad service each receives, are shown in Figure 6. This schematic presentation shows with great clarity how the amount of railroad service is related not only to the ranking of each place but also to its spatial position, and emphasizes the density of the rail network in the area contiguous to Lake Michigan and Lake Erie.

The conglomeration of cities on the eastern seaboard has received special attention. Jean Gottman (16) uses the term "megalopolis" to describe the coalescing of the spreading individual cities into this huge conglomeration. Jones (17) took a theoretical concept of Gottmann's and used it to reach an important insight about the city. Gottmann, interested in the development of political entities, has suggested that they come into being through the action of two somewhat opposed forces, circulation and iconography." The first term refers to both transportation and the communication of ideas; the second describes the whole system of symbols in which a people believes. Circulation is (in part) a system of movement, iconography of resistance to movement. The one makes for change, the other for political stability. Jones (17) suggests that:

> Many of the problems of a growing city arise from the fact that its circulation expands faster than its iconography. The metropolitan district outgrows the political limits, and vested local interests and loyalties make political expansion difficult. A sort of "metropolitan idea" may develop, leading usually to functional authorities rather than to political integration. There are a number of choices possible such as annexation of suburbs, city-county consolidation, metropolitan districts, functional authorities, state assumption of local functions.

Other concepts that have a bearing on the "metropolitan idea" are those of the "threshold" and the "range of a good," both of which have been given intensive study by Berry and Garrison (18, 19). The first deals with the size a city must achieve before it can support a given level of service (e.g., three doctors or five service stations), and the second, with the distance that people are willing to travel to purchase the good, whether a physical object or a service. In the application of these concepts to individual places a broad range of tools is brought into use: location theory and central place theory, the writing of Lösch and Christaller, the economic tools familiar to urban planners,

SEATTLE ISOCHRONES

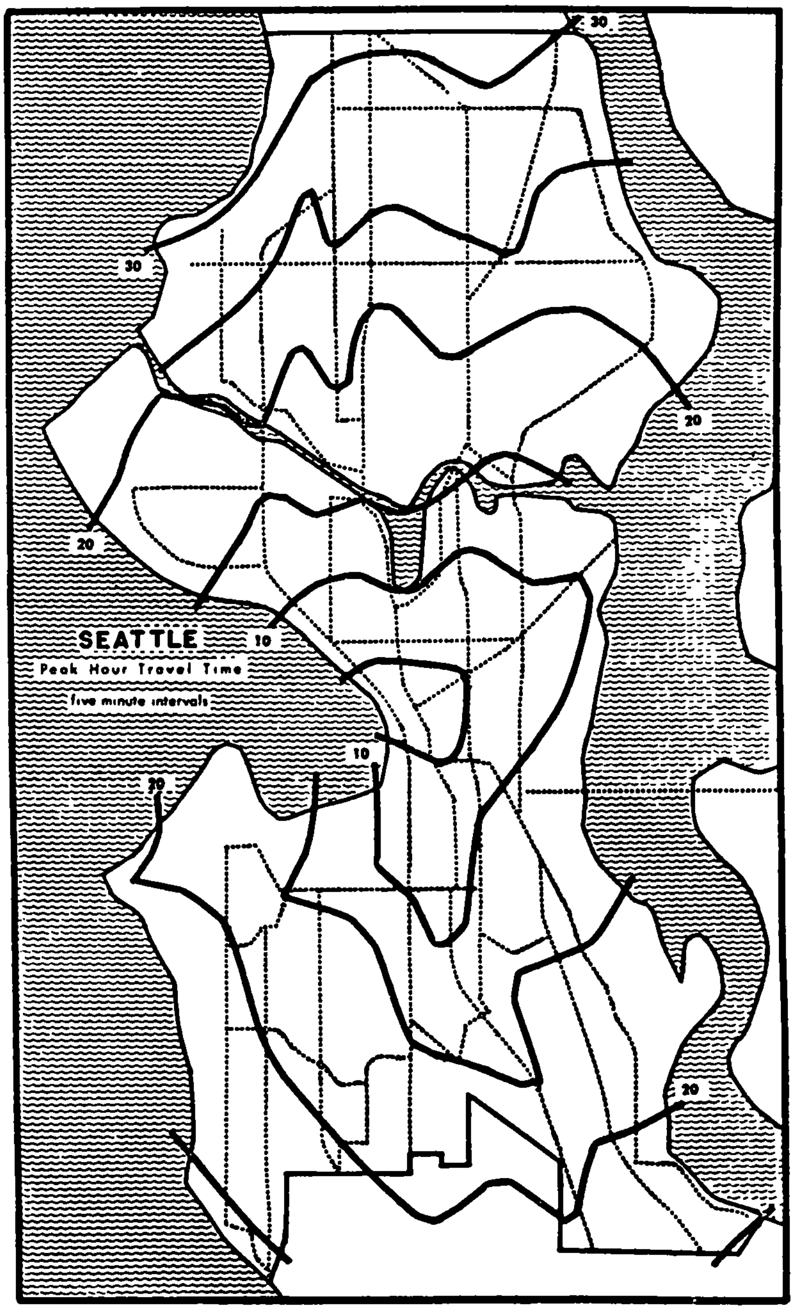


Figure 8. Together with Figure 9, a possible application of cartographic techniques of distortion to urban time-distance studies. (From Tobler (30).)

such as the basic-nonbasic concept and Leontief's input-output analysis; and this work in turn is used as the foundation for studies of urban transportation problems, as Berry (20) has done in his examination of ribbon development on the highway between Seattle and Everett (Fig. 7), and as he, Garrison, and others have done more comprehensively in their book, "Studies of Highway Development and Geographic Change" (21).

SEATTLE - TIME DISTANCES FROM CBD

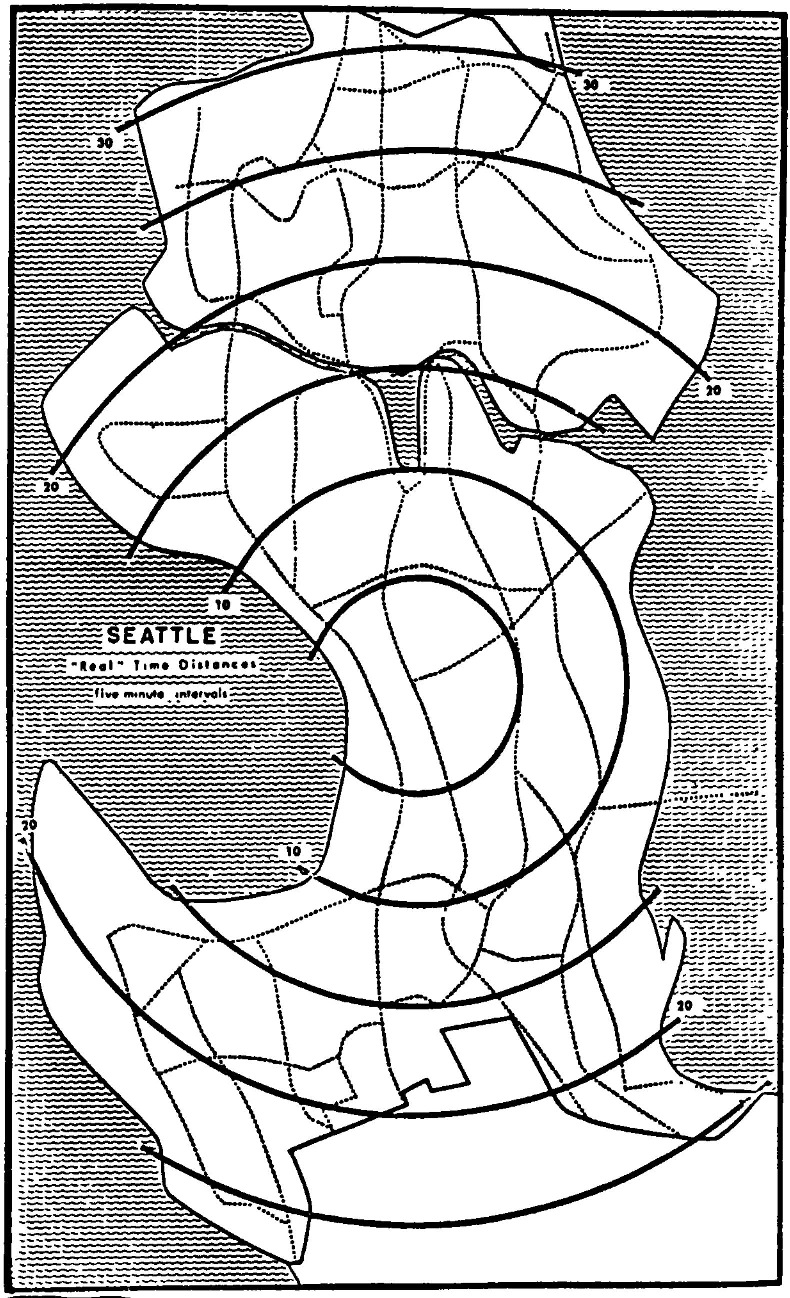


Figure 9.

Finally, there is the class of studies that groups cities in other ways, such as the functional classification by Harris (22) and the service classification by Nelson (23).

Quantitative Techniques

Although other geographers are making use of quantitative techniques of ever growing sophistication in attacking geographic problems, application of these techniques to urban transportation research is chiefly associated with two definite schools, that of the Swedish Royal University of Lund, and that of the University of Washington. Perhaps it is more appropriate to call the latter after its leader, William Garrison, for most of its members, including Garrison himself, have moved to other universities in the United States.

Over the last decade the Lund school has produced an exceptionally interesting body of work, much of it based on rigorous mathematical analysis. Merely to list a few of the titles is to suggest the relevance of this work to urban transportation research: "Bus Services, Hinterlands, and the Location of Urban Settlements in Sweden" (24); "An Analysis of Automobile Frequencies in a Human Geographic Continuum" (25), and "The Journey to Work from the Statistical Point of View" (26).

The school has been especially profilic in studies of migration, in which the journey to work, urban sprawl, and commutation take a prominent place. Special mention must be made of the work of Hägerstrand, in whose "Propagation of Innovation Waves" (27) and "Migration and Area" (28), original cartographic techniques are developed to help explain, respectively, the diffusion of (among other things) the ownership of motor vehicles among a population, and the relation between the distance separating two places and the number of people migrating from place to place.

As for the Garrison school, its pioneering work in location theory and on central place hierarchy has already been referred to. However, these by no means exhaust its range; members of the group have produced papers in which the latest tools of quantita-

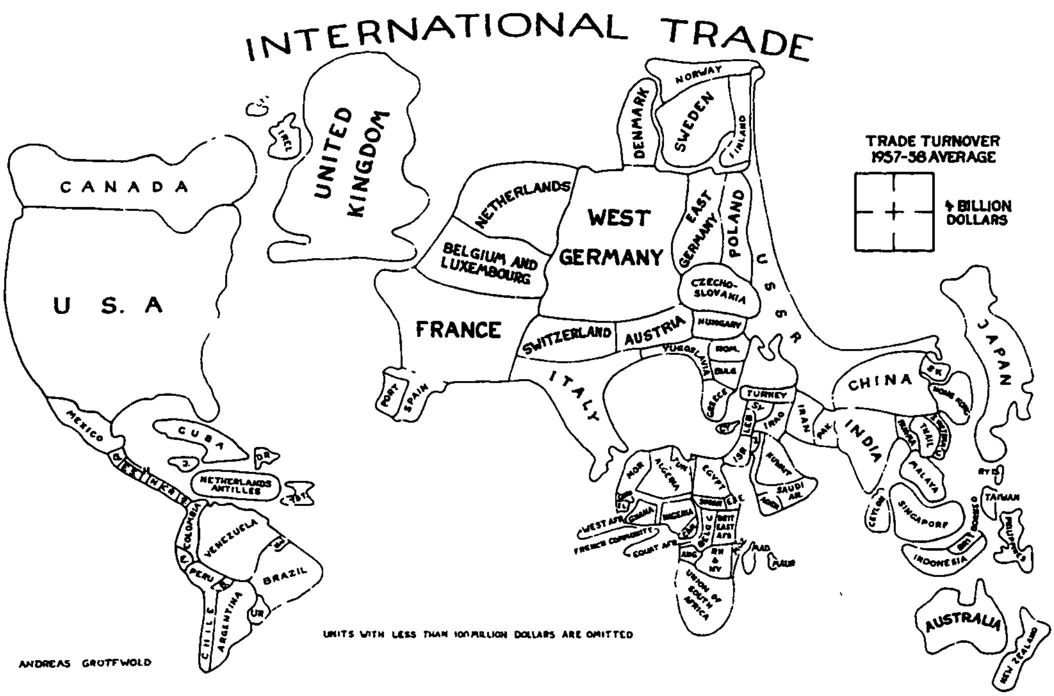
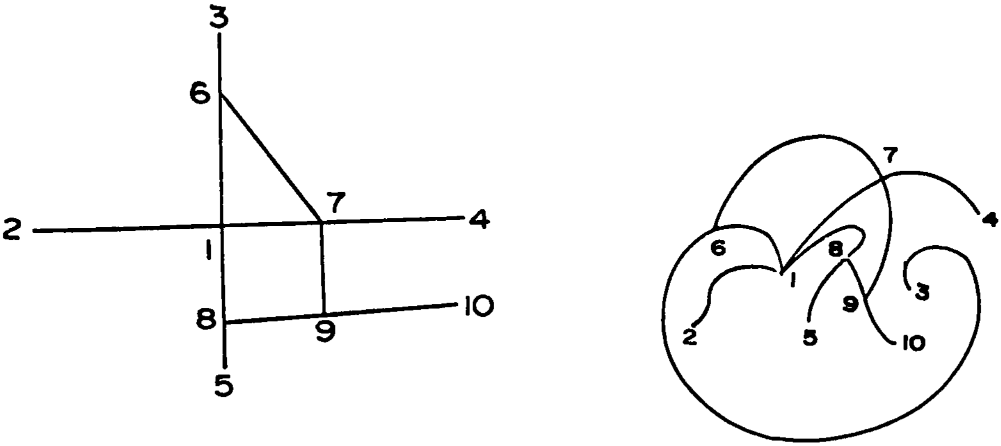


Figure 10. Map distortions used to highlight world relations in international trade. (From Andreas Grotewold, "Some Aspects of the Geography of International Trade." Economic Geography, p. 314 (Oct. 1961).)

TOPOLOGICALLY EQUIVALENT LINKAGES ·



A B

	1	2	3	4	5	6	7	8	9	10
1		1				1	1	1		
2	1									
3						1				
4							1			
5								1		
6	1		1				1			
7	1			1		1			1	
8	1				1				1	
9							1	1		1
10									1	

C

Figure 11. Graph theory, used in conjunction with map distortions, to facilitate use of electronic computers in mapping transportation networks. As long as connections between nodes and links remain the same, shape of map may be changed at will. (After Bunge (29).)

tive analysis—operations research, linear programming, regression analysis, simulation models, and graph theory—have all been put to use.

Cartographic Techniques

In urban transportation, time is of much more significance than distance. Maps usually give only an idea of the number of yards or miles between one point in a city and another, but are less exact in telling about the number of minutes or hours it takes, under given conditions, to move between these points. Mathematical techniques have been developed by Bunge (29) and Tobler (30), for example, for constructing map projections that tell about the time relations between points. Figures 8 and 9 show what happens when such a projection is made. In Figure 8 the shape and the street pattern of the city of Seattle are drawn to scale; at the peak travel hour, movement along some of the streets is faster than along others, so that the lines joining points of equal travel time are very irregular. In Figure 9 these lines of equal travel time, or isochrones, have been smoothed out into concentric circles centering on the CBD, with a resulting distortion of the shape and street pattern of the city. The areas nearest the CBD where travel is slower, are shown as enlarged (taking up more space, as it were, in the time dimension), whereas those further away are foreshortened.

Maps have been constructed on the same principles to show cost relations between points.

Map distortions can be used to highlight other urban relations (Fig. 10). Though their total land area is four times that of the United States, in this map the Soviet Union, China, and India together do not even equal the United States. Here at a glance is seen the relative importance in international trade of these four countries. Similar maps would be useful in emphasizing the internal relations of cities that have their effect on transportation, perhaps by eliminating such factors as topographic irregularities,

TRANSPORTATION PLAN for the HAMILTON-WENTWORTH AREA

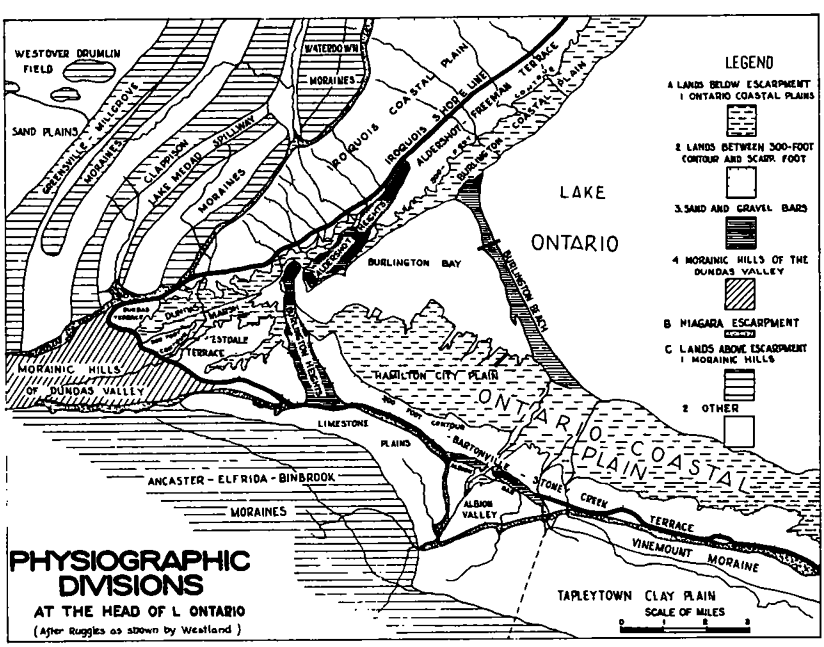


Figure 12. Map taken from thesis helped transportation planners understand physiographic problems. (After Westland (50).)

or unevenness of population density, or differences in suitability for different types of land use, which themselves bring distortions to the transportation pattern.

Map distortions might be used in conjunction with still another new cartographic technique, the use of electronic computers in mapping, to which Tobler has given a great deal of attention. Graph theory can be used to describe the system of nodes and links that makes up a city's street network, and these can then be readily translated into computer language. The simple street pattern in Figure 11 is topologically the exact equivalent of the seemingly more complex pattern in Figure 11, and the relations between the nodes and links of both are exactly reproduced in Figure 11. Because the topological equivalence is exact, no distortion of the shape of a city will affect its street network, as long as the pattern of nodes and links remains undisturbed. This procedure may find useful application in the setting up of a system of zones for origin-destination surveys, and the feeding of the necessary information into a computer.

The Commuting Problem

Mention has already been made of the Lund studies on the subjects of the journey to work and migration, both of which are aspects of the commuting problem. In Sweden great emphasis is placed on bus service, and this emphasis is paralleled in other European countries to a far greater extent than on this continent. Thus, the British geographers, Green (31) and Dickinson (32), use commuting by bus as a criterion for examining the relations between cities and their hinterlands in England and Germany, respectively. Dickinson has further discussed the problem of commuting by all transportation media available in a German industrial area (33). German geographers too have studied the public transport system; for example, the German study of the public transport system in Berlin before and after World War II (34). The destruction caused by war, the division into two sectors by a wall that has since become a physical fact, and the loss of many of the city's functions, have caused a shift in vitality from the central to the peripheral areas of Berlin. This shift is well illustrated in two traffic flow plans: whereas before the war the usual pattern obtained, of heavy traffic in the city center becoming progressively lighter as the outskirts are approached, after the war the pattern was reversed, and the heavier traffic is now found away from the central area. Studies such as this might well be brought to the attention of people working on civil defense plans.

On this continent, geographic work on mass transit is conspicuously meager. To be sure, there is a study on streetcar traffic, which appeared as long ago as 1917 (35), and which appears to be the only paper that discusses climatic effects on urban transportation from a geographic point of view. Finally, there is a paper by Vance (36), from which Figure 4 was taken, that may turn out to be as influential in the field of urban transportation geography as the previously mentioned series on the CBD, with which Vance was also involved. Vance uses what he calls "dynamic analysis," a stage-by-stage comparison of various conditions over time, to discover the effect of the changing technology of transportation on sources of labor supply, on the journey to work, on the shape of the city, and on its relations with satellites and suburbs. He makes the value of his work to planners explicit by discussing the application of his findings to the problems of urban planning.

Miscellaneous Transportation Studies

Waterways, railways, and airways have all received attention from geographers, but no very great proportion of their work has any direct relevance to urban transportation research. Indirectly, of course, almost any study of transportation has its bearing on cities, which are nodal points in all transportation networks.

Chicago, as a great transportation center, has received a commensurately detailed examination from this point of view. Representative studies that may be mentioned are those by Mayer on Chicago's relation to the St. Lawrence Seaway (37) and on its railway facilities (38); and by Taaffe on its air passenger hinterland (39). On ports in general, Weigend is among the chief authorities (40); and, though he restricts himself to European cities, Beaver (41) has some valuable comments on railway patterns near and within great cities.

The present catalogue of transportation studies may be rounded out by adding two that deal respectively with highways on the outskirts of cities and the streets within. The first, by Grotewold (42), examines one of the most difficult problems that highway planners have to contend with—the proliferation, on the highways passing through the rural-urban fringe, of commercial establishments that adversely affect the quality of traffic flow. The second, by Borchert (43), uses the density of the street network in an urbanized area (the number of street and road intersections per square mile) not only to discover the pattern of development in the past and in the present but to extrapolate that development into the future.

Geographers have been just as prone as other students of transportation to concentrate their attention on one or two transportation media, but with less excuse. As practitioners of a discipline that is, in its essence, an integrative and correlating discipline, they might have been expected to approach the problem of transportation, and particularly of urban transportation, on all its manifold fronts. Fortunately, geographers are becoming no less concerned than other scientists over the fragmentation that has so far characterized their work on transportation, and many more studies, such as that by Vance, will probably appear that examine urban transportation as a whole.

GEOGRAPHY AND THE HIGHWAY RESEARCH BOARD

Only within the last five years have highway planners been given the direct opportunity, at the meetings and in the publications of the Highway Research Board, of learning what geographers have been doing in their field. Although in all the highway departments of the United States there are only two geographers permanently employed at present, others have from time to time been brought in as consultants, or have served on such bodies as the Twin Cities Area Transportation Study, two of whose four top positions were occupied by geographers. Much more numerous are geographers associated with urban planning boards. But by far the greatest amount of geographic research on the city and on transportation is done in the universities.

The papers that geographers have presented before the Highway Research Board in the period beginning in 1957, when the first one appeared, have necessarily had a direct bearing on the interests of practicing planners, though in fact all but one of them were prepared by academic geographers. The exception was the very first to appear, which was presented by two geographers on the staff of a Canadian highway department, in conjunction with a highway engineer, on the subject of highway classification techniques (44).

The two state highway departments that have had the closest association with geographers in the universities have been those of Washington and Minnesota. These departments have collaborated with the Bureau of Public Roads and the state universities in conducting many economic impact studies, which have resulted in the publication of numerous papers under the joint auspices of all the bodies involved, among them such papers as that by Garrison and Marts on the influence of highway improvements on urban land (in Washington) (45), and by Borchert on commercial-industrial development along highways in the Minneapolis-St. Paul area (46).

The Highway Research Board has been informed of some of the results of this research; e.g., in a paper from Washington on application of linear programming techniques to analysis of highway networks (47), and one from Minnesota on the Twin Cities Study (48).

Only one paper to the Highway Research Board has been presented by a geographer who was not in any way involved with practical planning, but it was perhaps the most significant of all (49). For in it Murphy brought to the attention of highway workers the important insights that he and his colleagues have brought to the study of the central business district.

Thus, a beginning has been made towards acquainting highway workers with the results of geographic research on the city and on transportation problems.

STUDENTS' THESES

One last source of information must be mentioned, but this is perhaps the most valuable to local planners. Students preparing for undergraduate and graduate degrees are frequently assigned problems in urban and transportation research, and sometimes their reports contain information of great value. Geography departments in universities across the continent have great numbers of such reports, in the form of bachelor's, master's, and doctoral theses, which, because they are unpublished, seldom come to public attention, but which in many cases are well worth consulting. The map in Figure 12 comes from just such a thesis (50), and helped planners to familiarize themselves with the physiographic problems that had to be solved in laying out the future street and highway network of the city shown. The Ontario Department of Highways makes constant use of geographic theses prepared in universities throughout Canada and even abroad. Most assuredly, planners elsewhere can gain equal value from research done by university students on the cities in which those planners are interested.

INTERDISCIPLINARY COOPERATION

In the planning of transportation facilities for cities, voices from many disciplines must be heard, but it is the engineer who must have the last word, for his is the ultimate responsibility of providing the physical facilities themselves. Appropriately, therefore, the last words in the present paper will be given to two engineers, both eminent leaders in transportation research.

In his foreword to a report on the Woods Hole Conference on Transportation Research, Davis (51) wrote:

> Transportation affects, and is affected by, many economic, social and institutional factors. The competence of those engaged in the engineering and the physical sciences can be brought to bear on only a few of the aspects that are involved in the functioning of transport. It was recognized at the outset of this undertaking that adequate appraisal of the transportation situation would require the insights not only of the engineers and physical scientists, but also social scientists, economists, urban planners, lawyers, and others intimately familiar with the practical aspects of providing transport facilities and operating the services.

And here, from a personal communication written by John C. Kohl, are the words that best end this paper:

> [There is a need to] reinforce the currently hesitant approach by our own geographers who are lacking in conviction about their role in transportation planning. As a transportation engineer, I have long felt the need for geographers in planning activities.

REFERENCES*

1. Ullman, E.L., "The Role of Transportation and the Bases for Interaction." In "Man's Role in Changing the Face of the Earth." Univ. of Chicago Press, pp. 862-880 (1956).
2. Thomas, W.L., Jr., (Ed.), "Man's Role in Changing the Face of the Earth." Univ. of Chicago Press (1956).
3. Krueger, R.R., "The Disappearing Niagara Fruit Belt." Canad. Geog. Jour., 58:102-113 (Apr. 1959).
4. Thomas, W.L., Jr., (Ed.), "Man, Time and Space in Southern California: A Symposium." Annals, Assoc. of American Geographers, 49:No. 3, Part 2 (Sept. 1959).

*5. Murphy, R.E., Vance, J.E., Jr., and Epstein, B., "Central Business District Studies." Clark Univ., Worcester, Mass. (Jan. 1955).

6. Horwood, E.M., and Boyce, R.R., "Measurement of Central Business District Change and Urban Highway Impact." HRB Bull. 221, 40-55 (1959).

*Items preceded by an asterisk may also be found in "Readings in Urban Geography." Harold M. Mayer and Clyde F. Kohn (Eds.), Univ. of Chicago Press (1959).

7. Horwood, E.M., Boyce, R.R., et al, "Studies of the Central Business District and Urban Freeway Development." Univ. of Washington Press, Seattle (1959).
8. Durden, D., and Marble, D.F., "The Role of Theory in CBD Planning." Jour. Amer. Inst. of Planners, 27:10-16 (Feb. 1961).
9. Lösch, A., "Die Raumlische Ordnung der Wirtschaft." (Jena, 1944). Translated by W.H. Woglom and W.F. Stolper as "The Economics of Location." Yale Univ. Press (1954).
10. Jefferson, M., "The Law of the Primate City." Geograph. Rev., 29:226-232 (1939).
11. Stewart, J.Q., and Warntz, W., "Physics of Population Distribution." Jour. Regional Science, 1:99-123 (Summer 1958).
12. Christaller, W., "Die Zentralen Orte in Süddeutschland." (Jena, 1933). Translated by C. Baskin as "Central Places in South Germany." Bureau of population and Urban Research, Univ. of Virginia (1954).
*13. Ullman, E.L., "A Theory of Location for Cities." Amer. Jour. Sociol., 66:853-863 (May 1941).
14. Philbrick, A.K., "Areal Functional Organization in Regional Science." Papers and Proc., Regional Science Assoc., Vol. 3 (1957).
15. Philbrick, A.K., "Principles of Areal Functional Organization in Regional Human Geography." Economic Geography, 33:299-336 (Oct. 1957).
*16. Gottmann, J., "Megalopolis, or the Urbanization of the Northeastern Seaboard." Economic Geography, 33:189-200 (July 1957). (A book on the same subject was published in 1961 by the Twentieth Century Fund.)
17. Jones, S.B., "A Unified Field Theory of Political Geography." Annals, Assoc. of American Geographers, 4:120 (June 1954).
*18. Berry, B.J.L., and Garrison, W.L., "The Functional Bases of the Central Place Hierarchy." Economic Geography, 34:145-154 (Apr. 1958).
19. Berry, B.J.L., and Garrison, W.L., "A Note on Central Place Theory and the Range of a Good." Economic Geography, 34:304-311 (Oct. 1958).
20. Berry, B.J.L., "Ribbon Development in the Urban Business Pattern." Annals, Assoc. of American Geographers, 49:145-155 (June 1959).
21. Garrison, W.L., et al., "Studies of Highway Development and Geographic Change." Univ. of Washington Press, Seattle (1959).
*22. Harris, C.D., "A Functional Classification of Cities in the United States." Geograph. Rev., 33:No. 1, pp. 86-99 (1943).
*23. Nelson, H.J., "A Service Classification of American Cities." Economic Geography, 31:189-210 (July 1955).
24. Godlund, S., "Bus Services, Hinterlands, and the Location of Urban Settlements in Sweden." Royal Univ. of Lund, Sweden. Lund Studies in Geography; Series B: Human Geography No. 3 (1951).
25. Ajo, R., "An Analysis of Automobile Frequencies in a Human Geographic Continuum." Royal Univ. of Lund, Sweden. Lund Studies in Geography; Series B: Human Geography No. 15 (1955).
26. Grundström, M., "The Journey to Work from a Statistical Point of View." Royal Univ. of Lund, Sweden. Lund Studies in Geography; Series B: Human Geography No. 13, pp. 320-325 (1957).
27. Hägerstrand, T., "The Propagation of Innovation Waves." Royal Univ. of Lund, Sweden. Lund Studies in Geography; Series B: Human Geography No. 4 (1952).
28. Hägerstrand, T., "Migration and Area. Survey of a Sample of Swedish Migration Fields and Hypothetical Considerations on Their Genesis." Royal Univ. of Lund, Sweden. Lund Studies in Geography; Series B: Human Geography No. 13, pp. 27-158 (1957).
29. Bunge, W.W., Jr., "Theoretical Geography." Unpublished Ph.D. thesis, Univ of Washington (1960).
30. Tobler, W.R., "Map Transformations of Geographic Space." Unpublished Ph.D thesis, Univ. of Washington (1961).
31. Green, F.H.W., "Urban Hinterlands in England and Wales: An Analysis of Bus Services." Geograph. Jour., 116:64-88 (1950).

32. Dickinson, R.E., "The Geography of Commuting in West Germany." Annals, Assoc. of American Geographers, 49:443-456 (Dec. 1959).
33. Dickinson, R.E., "The Braunschweig Industrial Area." Economic Geography, 34:249-263 (July 1958).
34. Schroeder, K., "Der Stadtverkehr als Kriterium der Strukturwandlungen Berlins." Erdkunde, 14:29-35 (March 1960).
35. Van Cleef, E., "The Influence of Weather on Streetcar Traffic in Duluth, Minnesota." Geograph. Rev., 3:126-134 (1917).
36. Vance, J.E., Jr., "Labor Shed, Employment Field, and Dynamic Analysis in Urban Geography." Economic Geography, 36:189-220 (July 1960).
37. Mayer, H.M., "The Port of Chicago and the St. Lawrence Seaway." Univ. of Chicago Press (1957).
*38. Mayer, H.M., "Localization of Railway Facilities in Metropolitan Centers as Typified by Chicago." Jour. Land and Public Utility Econ., 20:299-315 (Nov. 1944).
39. Taaffe, E.J., "The Air Passenger Hinterland of Chicago." Univ. of Chicago, Dept. of Geography; Research Paper 24 (1952).
*40. Weigend, G.G., "Some Elements in the Study of Port Geography." Geograph. Rev., 48:185-200 (1958).
*41. Beaver, S.H., "The Railways of Great Cities." Geography, 22:Pt. 2, pp. 116-120 (June 1937).
42. Grotewold, A., and Grotewold, L., "Commercial Development of Highways in Urbanized Regions: A Case Study." Land Economics, 34:236-244 (1958).
43. Borchert, J.R., "The Twin Cities Urbanized Area: Past, Present, Future." Geograph. Rev., 51:47-70 (1961).
44. Wade, P.E., Truemner, R.B., and Wolfe, R.I., "Two New Classification Techniques." HRB Bull. 158, 27-34 (1957).
45. Garrison, W.L., and Marts, M.E., "Influence of Highway Improvements on Urban Land: A Graphic Summary." Univ. of Washington, Highway Economic Studies (1958).
46. Borchert, J.R., "Belt Line Commercial-Industrial Development: A Case Study in the Minneapolis-St. Paul Metropolitan Area." Univ. of Minnesota, Minnesota Highway Research Project (1960).
47. Garrison, W.L., and Marble, D.F., "Analysis of Highway Networks: A Linear Programming Formulation." HRB Proc., 37:1-14 (1958).
48. Borchert, J.R., and Carroll, D.D., "Time-Series Maps for the Projection of Land-Use Patterns." HRB Bull. 311 (1962).
49. Murphy, R.E., "The Central Business District and Its Implications for Highway Planning." HRB Bull. 221, 29-32 (1959).
50. Westland, S.I., "The Land Transport Geography of the City of Hamilton." Unpublished M.A. thesis, McMaster Univ., Hamilton, Ontario (1950).
51. Davis, H.E., "Conference on Transportation Research." National Academy of Sciences-National Research Council, Publication 840 (1960).
52. Huhtanen, R.J., Mika, P.J., Preston, R.E., and Murphy, R.E., "A Study of the Effects of Freeways on Central Business Districts." Studies in Economic and Urban Geography, Clark Univ. (1961).
53. Getis, A., "A Theoretical and Empirical Inquiry into the Spatial Structure of Retail Activities." Unpublished Ph.D thesis, Univ. of Washington (1961).

Appendix

BIBLIOGRAPHICAL MATERIAL

The fields of both urban and transportation geography are advancing so rapidly that bibliographies and collections of articles, no matter how painstakingly compiled, rapidly become out of date. Nonetheless, the book of readings in urban geography edited by Mayer and Kohn, in which many of the items referred to in the present paper are included (see footnote references), remains valuable, in that it gives an overview of the whole field of urban geography. The fact that no articles on urban street and highway problems are included indicates how recently these problems began to attract the attention of geographers.

For the relation of urban and transportation geography to the field of geography as a whole, see "American Geography: Inventory and Prospect," edited by Preston E. James and Clarence F. Jones (Syracuse Univ. Press, 1954). This compilation was published five years earlier than the book edited by Mayer and Kohn, and is due for revision. Still, it retains the permanent value inherent in any undertaking on which a group of first-rate authorities have cooperated.

Geographers depend to a very high degree on work performed in disciplines other than their own. The catholicity of their reading is illustrated in "An Annotated Bibliography of the Geography of Transportation," the largest part of which deals with urban transportation, compiled in 1961 by the author, with the help of Beverly Hickok, librarian of the Institute of Transportation and Traffic Engineering, University of California at Berkeley, and issued by the Institute as Information Circular 29.

More specialized, but still covering other disciplines besides geography, are a number of bibliographic studies conducted by Berry and by Garrison. The most ambitious of these is "Central Place Studies: A Bibliography of Theory and Applications," compiled by B. J. L. Berry and A. Pred, Bibliography Series 1; Regional Science Research Institute, Philadelphia, (1961). Berry has also published a paper on "Recent Studies Concerning the Role of Transportation in the Space Economy," Annals, Assoc. of American Geographers, pp. 328-342 (1959). Also W. L. Garrison surveyed the literature on "Spatial Structure of the Economy" in a series of three papers, also in the Annals, pp. 232-239, 471-482 (1959) and 357-373 (1960).

Finally, an invaluable source of bibliographical information for those interested in the whole field of location and central place theory, in simulation models (especially the gravity model) and other quantitative techniques, is W. Isard's "Methods of Regional Analysis," Technology Press of Mass. Inst. Tech. and John Wiley (1960).

Two geographic contributions of significance to urban transportation research have appeared since the present paper was delivered before the Highway Research Board. Each is by an established authority in the field.

The first, by Allen K. Philbrick, is on the subject of "Analyses of the Geographical Patterns of Gross Land Uses and Changes in Numbers of Structures in Relation to Major Highways in the Lower Half of the Lower Peninsula of Michigan," Michigan State Univ. Highway Traffic Safety Center and Department of Geography, East Lansing (1961). Philbrick's concept of the "dispersed city," which he prefers to that of "conurbation" or "megalopolis," as having none of the value judgments inherent in either, is here applied to research on the effect of highways on the use of the land that they serve. He demonstrates the existence of "zones of highway impact" of varying depth, and accurately and strikingly maps them by means of original techniques. Of exceptional value is the description of field methods that allow for extremely rapid and comprehensive taking of inventory of land use over large areas.

The second, by Edward J. Taaffe, is "The Urban Hierarchy: An Air Passenger Definition," Economic Geography, 38:1-14 (Jan. 1962), which describes the manner in which four cities in the United States (New York, Chicago, Los Angeles, and San Francisco) have achieved dominance with respect to air passenger traffic over all others. A distinct hierarchical pattern has emerged; thus, the cities of the Pacific Northwest focus on Seattle, which focuses on San Francisco, which focuses on Los Angeles. "For further empirical evidence as to the specific configuration of the urban hierarchy," Taaffe concludes, "it would seem profitable to examine the highway and rail linkages of individual cities through time, and to attempt to fit them into the broader spatial context of air passenger linkages." Of special interest is Taaffe's use of the gravity model to give a theoretical foundation to his empirical observations.

Both of these papers may be expected to lead to widespread research programs that will give planners valuable insights into the developing transportation needs of growing cities.

Predicting Future Demand for Urban Area Transportation

FREDERICK W. MEMMOTT, III, Transportation Research Engineer, Cerand Corp.; BRIAN V. MARTIN, Operation Research Staff, London Transport; and ALEXANDER J. BONE, Associate Professor of Transportation Engineering, Massachusetts Institute of Technology

This paper summarizes the results of a study of current principles and techniques for predicting the present and future demand for urban area transportation, often referred to as traffic estimation and assignment.

Emphasis is placed on the transportation planning process as a total process, requiring the integration of many of the interacting characteristics of the urban environment. The principal phases of the total process outlined are (a) inventories of existing conditions, such as land use, population, vehicle ownership, vehicular and personal travel, transportation facilities, and monetary resources; (b) estimates of future urban area growth in terms of population, economic activity, vehicle ownership, land use, and available transportation network; and (c) determination of future travel demand based on trip generation, modal split, interzonal transfers, and the assignment of traffic to transportation facilities. The feedback from level of service supplied by available facilities to traffic demand is stressed. Features of the transportation planning process where current methods appear inadequate are pointed out and recommendations are suggested for future research. An annotated bibliography includes 177 items pertaining to literature on predicting the future demand for urban area transportation.

• THIS PAPER presents a brief summary of a recently published compendium on current principles and techniques for predicting future demand for urban area transportation, often referred to as traffic estimation and assignment (1). This study was a joint highway research project of the Department of Civil Engineering, Massachusetts Institute of Technology, and the Massachusetts Department of Public Works.

The full report reviews the diversified methods and techniques available at the time of this writing, and published in numerous reports, books, magazines, and special conference papers. Alternate methods are compared, their basic assumptions identified, and their advantages and disadvantages qualitatively and quantitatively explored. The relation of traffic estimation and assignment to the transportation planning process is developed. Areas of weakness in current methods, where additional research and development work is needed, are identified and specific research topics suggested. The annotated bibliography is appended.

OBJECTIVES OF URBAN AREA TRANSPORTATION

Before proceeding to a discussion of the transportation planning process, some of the major objectives sought in providing adequate urban transportation is outlined as follows:

1. To provide sufficient capacity in the network of transportation facilities* to insure a specified level or levels of quality of service in speed and convenience of movement between or within all portions of the urban area. This implies that adequate facilities, satisfying the demand for trips concentrated in time during the day and in geographic location within the urban area, be available as needed.

2. To provide an adequate level of accessibility to and from all portions of the urban area, including the central business district. This is particularly relevant in considering improvements to or extensions of mass transportation facilities.

3. To provide the radial and circumferential facilities capable of handling the diffuse demand patterns created by large-scale low-density residential, commercial, and industrial development.

4. To provide the facilities made necessary by increased per capita automobile ownership and personal expenditures on transportation.

5. To satisfy the general demand for high-quality facilities offering increased vehicular speeds, personal safety, confort, and convenience.

The extent to which these objectives may be achieved will depend on resources available and over-all benefits derived. This report, however, deals only with procedures and methods for measuring and predicting objective requirements.

TRANSPORTATION PLANNING PROCESS

In determining both present and future requirements for facilities, the transportation planning process, as exemplified by the work of various urban transportation studies, is being increasingly utilized to effectuate comprehensive, region-wide planning. In the planning process,** consideration is given to all forms of transportation and to the expected future economic and social development of the area. Because urban transportation studies themselves encompass many varied aspects of the urban environment, they require the cooperation, consideration, and support of all organizations and individuals engaged in shaping the future of the urban area. This would include transportation and city planners, economists, social scientists, government officials, community interest groups, and other specialized personnel. Although many phases of a comprehensive urban transportation study are not the direct responsibility of the transportation planner, still he must be continually aware of the effects his plans will have on other aspects of the urban environment.

The desired result is a practical plan for specific improvements to existing facilities and the addition of new ones. The planning process, as described in general terms in this paper, translates present-day observed travel patterns into this master plan. The planning process consists of many distinct yet interrelated phases. The three main phases are inventorying existing or present conditions, estimating future urban area growth, and determining future travel demand. These three main phases are themselves subdivided into a large number of individual phases, which can be sequential, parallel, or both to other phases. It is probably true that no individual phase of the transportation planning process is truly independent of other phases. It is highly probable that the majority of the cause-and-effect variations encountered when studying phase interrelationships are unknown. Therefore, the interactions shown between major phases of the planning process represent only the readily understood and quantifiable relationships.

The total transportation planning process as developed to date is shown in Figure 1. Here the word "total" signifies its comprehensive and systematic approach to transportation planning. The principal phases in this process are as follows:

1. The Inventory of Existing Conditions
   a. Land use
   b. Population

---

*Unless otherwise indicated, the word "facilities" refers to transportation facilities in general.

**Unless otherwise indicated, the term "planning process" refers to the transportation planning process.

   c. Vehicle ownership
   d. Vehicular and person travel
   e. Transportation facilities
   f. Economic activities
   g. Available monetary resources
   h. Present trip generation
2. Public Policy Decisions
   a. Land use
   b. Transportation facilities
   c. Proposed transportation facilities
3. Estimates of Future Urban Area Growth
   a. Population forecast
   b. Economic activity
   c. Vehicle ownership
   d. Land use
   e. Transportation network
4. Estimates of Future Travel
   a. Future trip generation
   b. Modal split
   c. Interzonal transfers
   d. Assignment of interzonal transfers to transportation network
   e. Evaluation of the loaded network

The interactions between various phases of the planning process are shown in Figure 1 by solid lines for major relatives and by dashed lines for additional desirable interactions. The latter have not been included in most past urban transportation studies, although there has been an increasing tendency to utilize them in more recent studies. Inclusion of these interactions will produce a more flexible, responsive, and complete planning process, which in turn leads to more realistic and accurate results.

The procedure shown in Figure 1 is briefly described as follows: The planning process begins with inventorying existing conditions. These inventories are conducted simultaneously. Analysis of data collected provides the basic information necessary to determine present trip generation characteristics. The inventories also provide data from which estimates of future urban area growth can be determined. Estimates of future trip generation and a trial future transportation network are likewise determined from inventory data and from hypothesized patterns of future urban growth. From estimates of future trip generation and the proposed network, the locations and amount of future travel is determined and assigned to specific facilities. The results of this assignment are then evaluated in terms of the desired level of service plus the social and economic consequences to the community developing as a result of the trial network. Inevitably some revision to the network will be necessary or desirable, and the information obtained during this trail assignment is used to modify results obtained in earlier phases of the planning process. Then another trial assignment is made to a revised transportation network. This process is repeated until the desired results have been achieved.

Figure 1 shows the total transportation planning process in over-all perspective. Table 1 gives each phase in greater detail and the methods, procedures, and principal data are indicated.

FUTURE RESEARCH

Although much has been accomplished in formulating and improving estimation and assignment techniques, the study has revealed many aspects of the planning process as warranting further investigation. Time does not permit a thorough development of each of the topics suggested. Instead, they are presented as a series of unanswered questions. It is hoped that the challenge of these questions may help stimulate further research effort in this field. The coverage achieved is by no means complete; rather it represents a planning-orientated sample of work that must eventually be accomplished.

The propositions are presented in the same general order as shown in Figure 1 and outlined previously. Phases under "Inventory of Existing Conditions" are not included because they represent the accumulation and manipulation of past data. Three blocks under "Estimates of Urban Area Growth" (Population Forecast, Economic Activity, and Vehicle Ownership) are likewise omitted, because they relate to disciplines somewhat removed from the recognized professions of transportation and urban planning.

Public Policy Decisions

1. General. —Basic to all transportation planning studies is a consideration of the goals of urban transportation and means for satisfying them.

Often one hears the statement that transportation planning is more a function of unpredictable public policy decisions than one based on the detailed plans and estimates of responsible professional engineers and planners. This statement itself indicates the importance of studying the institutions and contributors involved in formulating transportation policies. Specifically, through what institutions are public policy decisions affecting transportation made? How can the channels of communication, required coordination, and the specific process of evaluating the proposed alternatives be improved between the many formal and informal, public and private transportation policy groups, so that the seeming endless conflicts can be minimized? What additional legislative and judicial arrangements should be implemented to assist in public participation and review of transportation alternatives, and to minimize the excessive or adverse influ-

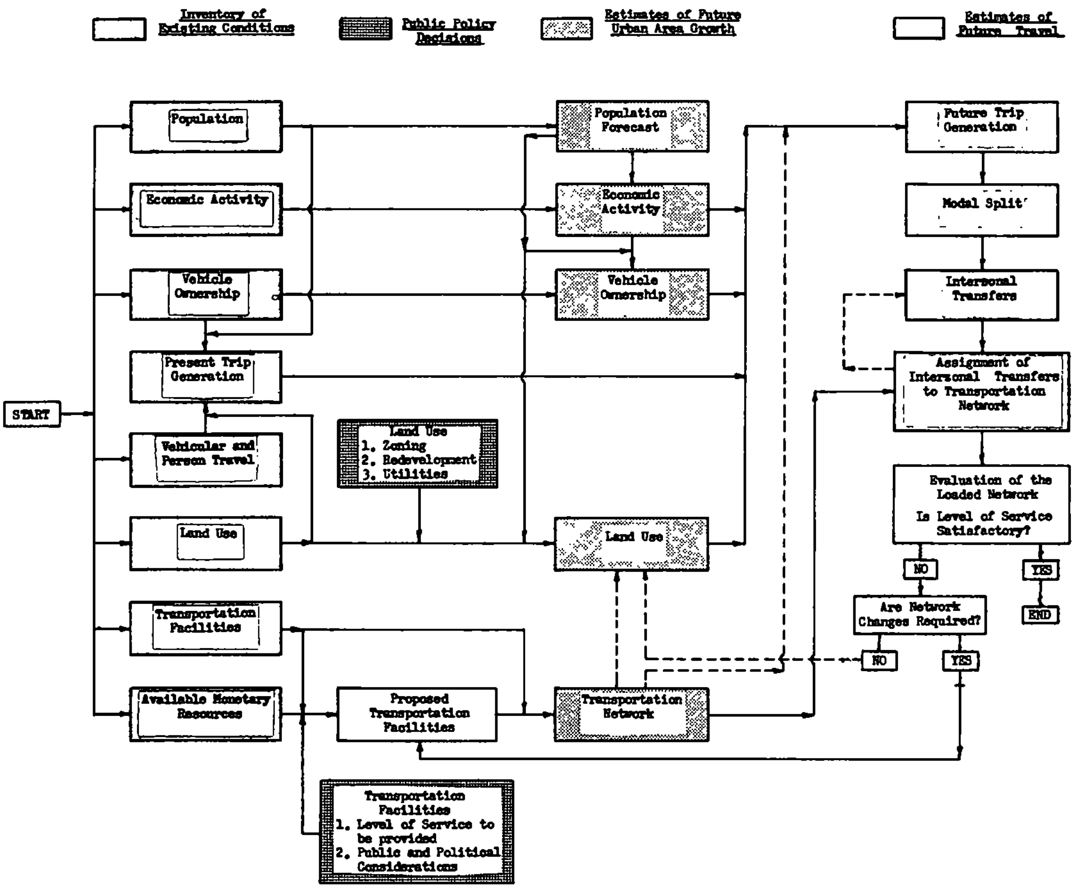


Figure 1. The total transportation planning process.

TABLE 1

METHODS, PROCEDURES, AND PRINCIPAL DATA OF THE TOTAL TRANSPORTATION PLANNING PROCESS

Phase	Method or Procedure Used to Determine Required Information	Data Required or Information Determined
1 Inventories of Existing Conditions		
a Land Use	1 Home Interview Origin and Destination Survey (Urban Area Transportation Study) 2 Planning Board, City Assessor etc Data	Kinds of Activity and Intensity of Site Usage Taking Place on Land
b Population	1 Decennial Census Tract Information (U S Bureau of the Census) 2 Home Interview Origin and Destination Survey (Urban Area Transportation Study)	Persons per Unit Area and Per Zone
c Vehicle Ownership	1 Home Interview Origin and Destination Survey (Urban Area Transportation Study) 2 State Motor Vehicle Registration Bureau	1 Automobiles (private commercial and taxis) 2 Trucks (light medium heavy) 3 Mass Transportation Vehicles (busses steetcars) per unit area and per zone)
d Vehicular and Person Travel	Origin and Destination Surveys (home interview cordon line truck taxi mass transportation and screen line)	Trips per person or vehicle per day
e Transportation Facilities	1 Survey of the Physical Characteristics of Transportation Facilities 2 Survey of the Operational Characteristics of Transportation Facilities	Miles of highway by class; travel times speeds and capacity by time of day
f Economic Activities	1 Economic Reports of Existing Urban Area Economic Study Groups 2 U S Bureau of Labor Statistics Employment Data 3 U S Bureau of the Census Budget Study Information	1 Employment 2 Per Capita Income
g Available Monetary Resources	1 Review of Present Expenditures for Transportation Facilities 2 Estimate of Future Income	Federal State County and Urban Area (city town etc) Funds Available for Expenditure on Transportation Facilities
h Present Trip Generation	Analysis of Trips by Trip Purpose Family Income Vehicle Ownership Land Use at Origin Distance from the CBD Length of Trip Mode Land Use at Destination and Time of Day	Trip Generation Characteristics and Rates (person and vehicle)
2 Public Policy Decisions		
a Land Use		1 Estimate of the Future Zoning 2 Public and Private Redevelopment and Urban Renewal Plans 3 Availability of Utilities and Community Services within the Urban Area
b Transportation Facilities		1 The Future Level of Service to be Provided 2 Political Considerations 3 Expressed Wishes of the General Public
c Proposed Transportation Facilities	1 Location of Present and Expected Future Deficiencies in Capacity 2 Theoretical Considerations on the Spacing of Transportation Facilities	Master Plan of Additional Transportation Facilities
3 Estimates of Future Urban Area Growth		
a Population Forecast	Methods developed by the U S Bureau of the Census	Persons per Unit Area and per Zone
b Economic Activity	1 Ratio of Employment to Population 2 Simple Trend Analysis 3 Expansion from Manufacturing Employment 4 Input-Output Model	1 Employment 2 Per Capita Income
c Vehicle Ownership	1 Automobiles: Budget Study Time Series and Combined Budget Study and Time Series 2 Trucks: Trend Analysis 3 Mass Transportation Vehicles: Assumed Constant	Number of Automobiles (private commercial and taxis) Trucks (light, medium and heavy) and Mass Transportation Vehicles (busses) per Unit Area and per Zone
d Land Use	1 Intuitive Judgement 2 Land Use Accounting 3 Combination of Intuitive Judgement and Land Use Accounting	Expected Future Zonal Uses of Presently Vacant Land Densities of Development and Quantity to be Absorbed into Urban Uses by a Specific Date (or Dates)
e Transportation Network	Combining the Proposed Transportation Facilities with the Present Transportation Facilities	Master Plan of the Future Transportation Network
4 Estimates of Future Travel		
a Future Trip Generation	Combining the Estimates of Future Economic Activity Vehicle Ownership and Land Use with Present Trip Generation Information	1 Future Trip Generation Characteristics 2 Future Zonal Estimates of Person and Vehicle Trips
b Modal Split	Trend Analysis	The Number of Person Trips Using Mass Transportation
c Interzonal Transfers	1 Growth Factor Methods (Uniform Factor Average Factor Fratar and Detroit) 2 Inter-Area Formula Methods (Gravity Model Interactance Model and Opportunity Model)	Estimate of the Future Number of Zone-to-Zone Vehicle Trips
d Assignment of Interzonal Transfers to Transportation Network	1 Without Capacity Restraint (Diverson Curve or All or Nothing" Assignment) 2 With Capacity Restraints (Proportional or All or Nothing Assignment)	Directional or Non-Directional Traffic Volumes Using Transportation Facilities
e Evaluation of the Loaded Network	1 Inspection of the Traffic Assignment Made 2 Determination of the Level of Service Provided 3 Economic Analysis of the Proposed Facilities to Determine Feasibility	1 Volume-Capacity Ratios 2 Vehicle Speeds by Time of Day 3 Economic Return (Benefit-Cost Ratios Rate of Return or Annual Cost)

ence often exerted by interest groups? The need to improve the public administration and functional organization of transportation planning is great, and must be done if this planning is to be removed from the political to the professional level.

It has long been recognized that transportation planning is only one phase of general urban planning. Numerous phases of planning are common to both transportation and urban planning. Specifically, what policies, plans, and programs are the primary concern of urban planning? What phases of the planning process can best be handled within the transportation study framework envisioned in this paper? What phases of transportation planning are separable, and what phases require coordination between transportation and urban planners? The area of delineating responsibilities, improving interagency communication channels, and creating adequate governmental machinery to help bring about desired urban goals is one of major importance. This area has a great potential for the development and application of new ideas, because the resulting form and character of urban areas are a direct reflection of the planning accomplished and control exercised over the policies and programs of all contributing individuals and groups.

2. Land Use.—In predicting the character and form of urban areas in the future, planners begin with land use. Land use refers to the activities taking place on the land, the density of persons, and rate of change of use. Land use is greatly affected by public policies, both now and in the future. What community land-use policies, evidenced by zoning ordinances, slum clearance and redevelopment projects, community industrial land use promotion, etc., are relatively stable with time? What policies are subject to gradual changes through local or regional political and economic processes? What is the nature of the broad changes expected in public policy towards urban land use in the future, indicated in part by the changes occurring during the past several decades? How do the socioeconomic characteristics of the local or regional population affect the resultant policy decisions relating to land use? Can public policy decisions towards future land use be predicted with a reasonable degree of certainty? What changes will be necessary in public policies towards land use densities in order to efficiently accommodate the estimated future urban population? While public policies are open to speculation as to their predictableness, research can indicate those policies that will most likely occur in the future, and over which the greatest amount of public control can be exercised.

3. Transportation Facilities.—The amount and service characteristics that various types of transportation facilities should provide are of vital concern, although specific answers are for the most part unknown. What level or quality of service should the facilities provide? What is quality of service, how can it be defined and measured? What variables influence quality of service, and in what manner and to what extent? In designing and planning for new facilities, what level of service should be selected? Is there a rational economic basis to the selection of an appropriate level of service? Should the future transportation network provide a higher, similar, or lower level of service as compared with the present? Research directed at answering these is essential because it points to a fundamental question: What quantity and quality of facilities is necessary and desirable to satisfy the demands placed on the transportation network?

Estimates of Future Urban Area Growth

1. Land Use.—Transportation planning is a major portion of general urban planning. As such it relies heavily on concepts of and plans for the urban area. Unfortunately, the fundamentals of urban planning are often elusive and are presently largely undefined, resulting in a considerable amount of confusion and controversy. What kind of cities are wanted in the future? What will be their form, characteristics, and functions? What will be their land-use requirements by types of activities, density of persons, and location of future development? To reshape present cities to those patterns and structures desired for the future gives rise to the question: What patterns of urban land-use development should be encouraged today? What are the alternative types of cities among which there is a possible choice? What groups will have a decisive role

in influencing the form and characteristics of these cities? This series of questions is basic and fundamental. Its importance becomes apparent when one realizes that decisions concerning urban goals must necessarily take precedence over transportation planning (although it will be influenced somewhat by transportation considerations).

Looking at the other side of the coin, how important is the transportation network in influencing the location, density, and timing of urban growth? How can this cause and effect relationship be recognized and evaluated? How should land-use and building controls be utilized to guide constructively, rather than hinder, this process of urban evolution? What techniques are available to test the effects that hypothesized transportation networks have on urban growth and change? How can these techniques be improved to indicate the consequences of transportation plans better? Although some research is currently in progress, much remains to be accomplished, especially in determining the precise impact that transportation facilties have on adjacent land uses.

Many factors underlie the observed changes taking place in urban land uses over time. How do such factors as the quality and capacity of a community's sewer and water facilities, building and subdivision controls, land cost and availability of suitably sized tracts for real estate development, community land use promotion, tax rates, and prestige affect the type and density of land use and its rate of change? Further research and development of land-use models for distributing future population and employment to small areas is a promising area of endeavor. The work done to date has been exploratory; refined land-use models will explicitly recognize and account for all variables that can be qualitatively identified as affecting urban area growth and change.

2. Transportation Network. —Observed urban travel patterns need questioning and the following propositions seriously pondered. How much of present urban travel is really necessary, or considering the regional or national economy, desirable or tolerable? Where is the separation between productive and nonproductive travel? At what point do rising costs associated with user's time, vehicle operation, and driver comfort and convenience become a serious detriment to travel within the urban area? What criteria must be used to establish a rational balance between minimum and maximum travel? Obviously too many transportation facilities are as economically wasteful as too few, because they encourage unnecessary personal expenditures on transportation and violate sound investment practices. Research can provide a clearer answer on the quantity of urban transportation that is really desirable.

The proper location of facilities directly affects the success of the transportation network in meeting the potential demand for transportation. Equally important is the operation of present facilities and their adaptability to changing operational demands. What can be done to insure that proposed transportation facilities are located to advance over-all community objectives? How can better use be made of existing facilities? How can flexibility in the present and proposed facilities be retained so that they can be more adaptable to changes brought about by technological developments? Proper location, efficient use, and flexibility (to prevent premature obsolescence) of transportation facilities are operating characteristics explicitly recognized today as being important. Unfortunately, the techniques necessary to insure proper recognition or preservation of these characteristics through time have not yet been perfected.

Transportation today consists of the loose grouping of different modes, industries, and individual efforts. It is this illogical grouping that has caused many existing problems. How can highway and mass transportation planning be better integrated to: (a) make advantageous and efficient use of existing facilities, to minimize the requirements for additional facilities; (b) eliminate various forms of destructive competition between different modes of transportation; and (c) provide efficient intermodal transfer facilities, thereby encouraging the continued use of public and private transportation for those portions of the trip where each is most advantageous? Comprehensive research aimed at developing new methods for the efficient and effective integration of all forms of urban transportation is vitally needed.

Estimates of Future Travel

1. Future Trip Generation. —Transportation planners have long sought to establish

definitive relationships between person or vehicle travel and land use. These trip generation factors are determined for observed conditions and used to predict the amount of travel occurring at some point in the future. Constancy of trip generation factors with time is often assumed. Do these trip generation factors, or rates, remain static over time? Results from repeat origin and destination surveys have indicated that this assumption is probably not true, and if assumed, can lead to large errors in future estimates. Ways of modifying present trip generation characteristics to reflect probable future conditions better need immediate development.

Today, urban transportation represents an unstable compromise between the large, partially unsatisfied, demand for transportation and the available supply of physical facilities. In most urban areas the transportation demand is to an appreciable extent "throttled" by lack of facilities. What trip generation rates would occur if an unlimited network of facilities was available? What retards this trip generation potential from being fully realized? How does the completion of a new facility affect adjacent land-use trip generation rates? Research is urgently needed to determine the probable magnitude and implications of trip generation potential under specified traffic and environmental conditions, and to determine the manner in which present facilities retard or advance trip making.

Present trip generation data are invariably based on empirical observations, and do not attempt to answer basic questions, such as: (a) why do people make trips at all; (b) what motivations are most significant in influencing all facets of trip generation; (c) what decisions does an individual make and what decision process does he use in determining whether to make a trip; (d) what criteria of selection or measures of effectiveness do individuals use in arriving at a resultant trip decision; and (e) what precise values do individuals place on trip purpose, time of day, route, mode, and terminal conditions? A great need is to uncover the basic motivations of trip makers. Research along this line will enable making more rational estimates of future trip generation.

Often trip generation is assumed to be independent of the quality of the transportation network, although this is incorrect. Occasionally, percentage modifications are made to account for facility-generated traffic. This traffic is referred to as induced traffic and can be readily observed on recently completed expressway-type facilities. What is induced traffic? On the completion of new transportation facilities, what factors make entirely new trips "now worthwhile?" What type of trips are induced; e.g., time of day, purpose, destination? Where are the person or vehicle trip ends of induced travel? Research can uncover the cause and effects underlying induced travel, and will assist in developing a satisfactory method for including this effect in the planning process.

2. Modal Split.—Perhaps one of the largest areas of uncertainty is the future division of trips between different modes. To a large extent the success of mass transportation planning depends on the accurate prediction of its potential riders. What factors cause people to shift from one mode of transportation to another—an effect which has occurred extensively in the past decade? What are the social and economic characteristics of those induced to shift modes? What are the precise characteristics of the captive mass transportation rider, of those who are able to choose between either personal or mass transportation, and of those who exclusively use private transportation? What values are placed on quality of service, travel time, vehicle and terminal comfort, esthetics and cleanliness, user convenience, route or time flexibility, and cost by users of different modes of transportation? Research in this area will develop the tools that transportation planners need to identify and quantify the dynamic relationships involved so that future predictions involving the use of different modes of transportation can be based on more than an extension of past trends.

3. Interzonal Transfers.—During the past two decades, various mathematical procedures have been developed for distributing generated trips between small areas, or zones. Various growth factor methods and inter-area travel formulas are currently available. Unfortunately little comparative information between different techniques exists. For each technique, what is the accuracy of the obtained results, as compared with observed results through time; the cost of securing the necessary imput data; the cost of computer distributive techniques; and the stability of the model attraction and

resistance parameters with time? These techniques are based on different concepts of travel. Therefore, research is needed to develop necessary comparative measures so that a qualitative and quantitative evaluation of existing interzonal transfer methods can be made.

Looking further at inter-area travel formulas, are there better attraction and resistance parameters available for use in interzonal transfer methods? An attraction parameter combining zonal and retail employment, sales volume, and general type of business might be a better measure of zonal attraction for commercial trips than one containing only retail employment. Likewise, a resistance parameter combining travel time, ground distance, and the general level or quality of service offered by applicable facilities would be a better measure of travel resistance than travel time or distance alone. There is a definite need for refined, representative parameters suitable for use in interzonal transfer models.

4. Assignment of Interzonal Transfers to Transportation Network. —Assignment of interzonal transfer trips to transportation facilities must eventually recognize the capacity limitations of the physical facilities and intersections between portions of the network. Obviously, no more traffic should be assigned to a facility than it is capable of handling. Capacity restraints are a tool used to prevent possible overassignment and maintain system balance. How should capacity restraints be used in the assignment process? How do capacity restraints affect interzonal transfers and trip generation? What modifications to existing assignment techniques are necessary to utilize fully the philosphy represented by capacity restraints? The inclusion of capacity restraints in a traffic assignment program is a relatively recent development, and further investigation is required to determine the extent of the feedback process (to the assignment, the interzonal transfer, or the future trip generation phases) and the most economical use of capacity restraints in the assignment program.

The assignment process today evolves around the use of electronic computers to perform the tedious process of distributing interzonal transfers. Nevertheless, many questions regarding the proper role and function of computers remain unanswered. How much of the existing network of transportation facilities should be coded for use in the computer assignment process? What are the costs involved, in terms of accuracy, representation, computer size, and required assignment time? More information on cost vs accuracy and capabilities of assignment programs would definitely aid future transportation studies in a better selection of both program and computer.

CONCLUSION

This paper has summarized the transportation planning process as developed to date (1961) by major urban area transportation studies. In addition, it has focused attention on a few of the areas where research will be useful and profitable.

The major advantage of the planning process is that it is a systematic, rational method for determining the need for improved or additional facilities and of allocating the amount, timing, and specific purpose of governmental expenditures on transportation facilities. It also gives a strong impetus to coordinating transportation and urban planning, so that the many conflicting goals involving the form, function, characteristics, and transportation in the city of the future can be minimized.

The planning process as presently practiced does have weaknesses. In the interest of expediency, methods are commonly applied that are in fact an oversimplification of the problem. Factors exhibiting a high degree of correlation with travel patterns are generally used, whereas, other factors of a more subjective nature, but of considerable importance, are neglected. Many studies tend to portray future urban travel as an extention of past trends. Such an assumption implies a perpetuation of current conditions and neglects the inevitable changes occurring in urban socio-economic characteristics, regional political, and governmental structure, and technology, which are sure to develop.

Imaginative, basic research offers the best potential means of providing the additional information and techniques required to achieve better advance transportation planning. This research must draw on the knowledge, talents, and disciplines of the social and physical sciences as well as those of transportation and city planning. Efforts should continually be increased to understand the interacting forces shaping cities and the resulting movements of persons and goods, for the decisions of today directly affect the quality of future cities.

REFERENCE

1. Martin, B.V., Memmott, F.W., and Bone, A.J., "Principles and Techniques of Predicting Future Demand for Urban Area Transportation." Joint Highway Research Project of the Department of Civil Engineering, M.I.T., and the Massachusetts Department of Public Works, Research Report 38 (June 1961).

Appendix

ANNOTATED BIBLIOGRAPHY ON TRAFFIC ESTIMATION AND ASSIGNMENT

Principal Categories of Traffic Estimation and Assignment	Bibliography Reference Numbers
Assignment programs	21-24, 28, 124, 126, 135, 154, 169
Assignment techniques	6, 23, 24, 30, 38, 45, 81, 88, 92, 101, 129, 141, 153, 168, 169
Diversion curves	6, 30, 31, 45, 114, 119, 126-129, 134, 137, 141, 153, 160, 168
Economic analysis	25, 27, 43, 62, 84, 86, 139, 143, 153
General	4, 7, 32, 35, 37, 40, 41, 47, 53, 56, 57, 61, 63, 94, 107, 110, 120, 125, 138, 141, 151, 153, 164
Interzonal transfer methods	8, 12, 17, 19, 20, 29, 36, 37, 43, 54, 58, 59, 79, 104, 108, 109, 116, 132, 141, 153, 159, 161-163, 165, 170, 172, 173, 177
Land use	5, 16, 25, 26, 27, 67, 70, 73-77, 93, 117, 118, 125, 140-145, 153, 166
Modal split	1, 2, 17, 89, 90, 125, 131, 141, 145, 147, 153
Origin and destination surveys	3, 33, 42, 83, 98, 111-113, 115, 120, 121, 125, 130, 138, 141, 155, 156, 174
Population forecasts	105, 106, 144
Transportation facilities	48-50, 95-97, 136, 153, 164, 170, 171, 174
Transportation studies (all categories)	18, 34, 44, 55, 80, 82, 152, 171
Travel time	60, 66, 93, 99, 125, 126, 136, 141, 160
Trip generation	9-11, 13-15, 39, 46, 51-53, 64, 65, 67-72, 78, 85, 87, 91, 98, 100, 102, 103, 108, 109, 117, 118, 122, 123, 125, 133, 141, 146, 148, 149, 150, 153, 157, 158, 167, 175, 176

1. Adams, W.T., "Factors Influencing Mass-Transit and Automobile Travel in Urban Areas." Public Roads, 30:256-260 (Dec. 1959).

An account of an investigation of the volume of public and private transport in urban areas and the factors affecting these two modes of travel. Surveys carried out in 1948 to 1953.

2. Adams, W.T., "Factors Influencing Transit and Automobile Use in Urban Areas." HRB Bull. 230, 101-111 (1959).

Essentially the same as reference 1.

3. Anderson, O.K., "Statistical Evaluation of Origin-Destination Data." Traffic Engineering, 22:183-187 (Feb. 1952).

Describes several statistical tests applicable in analysis of origin and destination data.

4. American Society of Civil Engineers, Committee on Urban Transportation, "Urban Transportation Problem." Proc., ASCE, 84:HW3, Paper 1801 (Oct. 1958).

Statement of the urban transportation problem, particularly in regard to the relation of different modes to each other and the city form.

5. Barnes, C.F., Jr., "Integrating Land Use and Traffic Forecasting." HRB Bull. 297, 1-13 (1961).

Discussion of procedures used and basic information obtained during development of a land-use analysis procedure for Hartford Area Transportation Study. A mathematical procedure that can be used to forecast the future zone-by-zone distribution of population and employment areas.

6. Barry, W.A., Jr., "Allocation of Traffic to the Hampton Roads Bridge-and-Tunnel System." HRB Proc., 34:530-540 (1955).

Outline of method used to assign traffic to new facility. Cost analysis of time and operation serves as basis for diversion of traffic from one route to another.

7. Bartelsmeyer, R.R., "Factual Data for Urban Transportation Planning." Proc., ASCE, 85:No.HW-4, pp. 55-60 (Dec. 1959).

Brief outline of some of the information that should be obtained to guide thinking and planning for future transportation systems.

8. Bevis, H.W., "Forecasting Zonal Traffic Volumes." Traffic Quarterly, 10:207-222 (April 1956).

Describes method of determining interzonal trip volumes used in Detroit Area Transportation Study. Method based on present volumes, relative attractiveness of zones, and travel friction between zones. Experience with method cited, giving details on iteration convergence, basic assumptions, and shortcomings.

9. Bevis, H.W., "Selected Comparisons of Average Trip Length for Detroit and Chicago." CATS Research News, 2:7-9 (March 14, 1958).

Average trip lengths, for Detroit and Chicago Area Transportation Studies are compared by trip purpose. Qualitative explanations offered for observed differences.

10. Bevis, H.W., "Trip Length Distributions for the Chicago Area." CATS Research News, 2:6-8 (April 25, 1958).

Trip length distribution by trip purpose, as determined from O-D data in the Chicago Area Transportation Study.

11. Bevis, H.W., "Trip Length by Mode of Travel in CATS Area." CATS Research News, 2:6-8 (June 27, 1958).

Distributions of trips by trip length and by mode of travel, from O-D data of the Chicago Area Transportation Study.

12. Bevis, H.W., "A Model for Predicting Urban Travel Patterns." Jour., Amer. Inst. of Planners, 25:87-89 (May 1959).

Describes traffic model developed and used by Chicago Area Transportation Study for predicting interzonal traffic volumes. Model essentially a gravity model combined with linear programming techniques.

13. Blake, G.W., "Trip Lengths." PATS Research Letter, 1:15-21 (Oct. 1959).

Summary of trip length distributions as determined from O-D data of Pittsburgh Area Transportation Study.

14. Blake, G.W., "First Work Trips." PATS Research Letter, 1:1-11 (Nov. 1959).

Summary of modal split, length of trip, car occupancy, and land use at destination for first work trips, as determined from O-D data of Pittsburgh Area Transportation Study.

15. Blake, G.W., "Trip Linking Rationale." PATS Research Letter, 1:12-16 (Dec. 1959).

Discussion of method used in Pittsburgh Area Transportation Study for combining change of mode or serve passenger trip purposes with more basic trip purposes.

16. Blumenfeld, H., "Are Land Use Patterns Predictable?" Jour., Amer. Insti. of Planners, 25:61-66 (May 1959).

Identification of some key variables affecting urban growth patterns. Distance and density patterns shown to follow concentric ring pattern and "crest of the wave" theory of urban growth.

17. Booth, J., and Morris, R., "Transit vs Auto Travel in the Future." Jour., Amer. Inst. of Planners, 25:90-95 (May 1959).

Description of mathematical model used to predict future traffic volumes that would occur on proposed highway system if specific mass transportation improvements were made. Model used for estimating and predicting future traffic patterns in Baltimore region.

18. Boston College Seminar on Urban Research, "Travel in the Boston Region 1959-1980." Vol. 1 (Jan. 1960); Vol. 2 (Feb. 1961); Vol. 3 (April 1961).

Vol. 1: Describes techniques and procedures used, and presents initial findings. Vol. 2: Describes in detail use of Gravity Model for determining geographical pattern of trips. Vol. 3: When published, will give final results of travel in region for 1980, and present consequent implications on need for future highway and transit improvements in Boston area by 1980.

19. Brokke, G.E., "Evaluating Trip Forecasting Methods with an Electronic Computer." HRB Bull. 203, 52-75 (1958).

Average Factor, Detroit, and Fratar methods of forecasting trip distribution were tested with aid of computer. Maximum accuracy reached in second approximation of Fratar method, but four or more approximations usually required with the other methods.

20. Brokke, G.E., and Mertz, W.L., "Evaluating Trip Forecasting Methods with an Electronic Computer." Public Roads, 30:77-87 (Oct. 1958).

    Essentially the same as reference 19.

21. Brokke, G.E., "Program for Assigning Traffic to a Highway Network." HRB Bull. 224, 89-97 (1959).

    Techniques used in Washington for estimating distribution of traffic among various routes are described. Nine-stage electronic programming system used can provide data on any given traffic situation and on effectiveness of new highway design. Program described uses Bureau of Public Roads time diversion curve, and is suitable for use on IBM 704 computer.

22. Brokke, G.E., "Assigning Traffic to a Highway Network." Public Roads, 30:227-233 (Oct. 1959).

    Essentially the same as reference 21.

23. Brown, J.H., and Wilson, J.S., "Traffic Assignment to a Highway Network by Minimum Path Method." Traffic Planning Seminar, Mass. Insti. of Tech., (Nov. 1960).

    Gives detailed description of techniques used in applying Bureau of Public Roads IBM 704 traffic assignment program to Washington Area Transportation Study.

24. Brown, R.M., and Weaver, H.H., "Traffic Assignment Using IBM Computations." HRB Bull. 130, 47-58 (1956).

    Presents probable distribution of traffic on arterial street systems of Lafayette and West Lafayette, Ind., after completion of construction of Wabash River Bridge.

25. Browning, C.E., "The Distribution of Available Industrial Land in the Chicago Area." CATS Research News, 2:11-16 (Jan. 17, 1958).

    Tabulation of available industrial land in Chicago area, showing spatial differences (ring and sector) between zoned industrial land and that currently available.

26. Browning, C.E., "Selected Relationships of Land Use and Distance from City Center." CATS Research News, 2:3-12 (Feb. 14, 1958).

    Discusses proportion of land developed or in use by distance from CBD; land-use proportions by distance from CBD; and distribution of area in different land uses by 1-mi distance rings.

27. Browning, C.E., "Industrial Worker Densities in the CATS Area." CATS Research News, 2:9-16 (April 25, 1958).

    Presentation of distribution of industrial worker densities in Chicago area. Constant and relatively even decline in industrial worker density found as distance from the CBD increases, although significant differences occurred from sector to sector and between districts.

28. Bureau of Public Roads, "Electronic Computer Program for Assignment of Traffic to Street and Freeway Systems." Bureau of Public Roads Program T6. Annotated description.

29. Calland, W.B., "Traffic Forecasting for Freeway Planning." Jour. Amer. Insti. of Planners, 25:82-86 (May 1959).

Discussion of gravity model used in San Diego area. Model relates trips between zones to total trips generated by each zone and distance between those zones.

30. Campbell, E.W., "A Mechanical Method for Assigning Traffic to Expressways." HRB Bull. 130, 27-46 (1956).

Coding techniques and machine procedures used in Detroit Area Study outlined, and obtained results analyzed.

31. Campbell, E.W., and McCarger, R.S., "Objective and Subjective Correlates of Expressway Use." HRB Bull. 119, 17-38 (1956).

To assist in assigning traffic to proposed expressway network, and to develop a family of diversion curves relating distance ratio and speed ratio to expressway usage, data were obtained from studies of diversion to five expressways. Relationships between expressway usage, objective measurements of time, distance and speed, and subjective processes involved in a driver's choice of route were studied.

32. Campbell, E.W., "Organizing a Continuing Agency for a Metropolitan Area Transportation Study." HRB Proc., 38:1-8 (1959).

Account of functions, staffing, activities, and organization of body which is to continue work of Chicago Area Transportation Study. Body to be called Urban Research Section and be a major part of Illinois Division of Highways Bureau of Research and Planning.

33. Carlisle, G., and Taylor, W.T., Jr., "Minimum Time Periods for Origin-Destination Surveys." HRB Proc., 28:340-347 (1948).

Discusses accuracy to be expected from short sampling time O-D surveys.

34. Carril, R.R., "Traffic Forecast Based on Anticipated Land Use and Current Travel Habits." HRB Proc., 31:386-410 (1952).

Method used for forecasting traffic in San Juan, Puerto Rico, Metropolitan Area on basis of anticipated land use and current travel habits is discussed.

35. Carroll, J.D., Jr., "Some Uses of Computers in O-D Studies." Proc., Insti. of Traffic Engineers, pp. 57-63 (1957).

Description of two special types of electronic data processing machines used at CATS, and experimental work done developing a network analog computer.

36. Carroll, J.D., Jr., "Future Traffic Predictions for the Detroit Area." HRB Proc., 36:680-685 (1957).

Procedure developed for forecasting probable travel movements between zones in 1980, based on forecasts of population, land usage, economic activity, and relation of traffic to population.

37. Carroll, J.D., Jr., and Bevis, H.W., "Predicting Local Travel in Urban Regions." Regional Science Association Papers and Proc., 3:183-197 (1957).

Discussion of urban transportation forecasting including prediction of future levels of personal automobile travel. Some current methods used by transportation studies discussed, and conceptual traffic prediction model presented. Reference to work done by Detroit Area Transportation Study.

38. Carroll, J.D., Jr., "A Method of Traffic Assignment to an Urban Network." HRB Bull. 224, 64-71 (1959).

Illustrated description of electronic computing technique used to determine traffic flow on different parts of road network in urban area of Chicago. Programming method, which allows for all possible route combinations, based on research by E.F. Moore on systematic and economical method of finding shortest path through a maze.

39. Carroll, J.D., Jr., "Trip Length Frequency Distribution and Its Effect on Highway Planning." CATS Research News, 3:No. 4 (Nov. 13, 1959).

Description of significance of "trip length" in measuring demand for highways.

40. Carroll, J.D., Jr., and Creighton, R.L., "Planning and Urban Area Transportation Studies." HRB Proc., 36:1-7 (1957).

Need for integrated transportation planning process discussed. Individual steps of process described, and "feedback" links, which need to be incorporated in future planning methods, indicated.

41. Cherniack, N., "Passenger Data for Urban Transportation Planning." Proc., ASCE, 85:No. HW4, pp. 37-54 (Dec. 1959).

General description of what urban area transportation is, including the varied demands made on it, and physical types of urban transportation available. Using travel across Hudson River in metropolitan New York area as example, variation of travel demands and services with time is discussed.

42. Cherniack, N., Campbell, E.W., Lynch, J.T., Steele, C.A., and Howe, R.T., "Critique of Home Interview Type O-D Surveys in Urban Areas." HRB Bull. 253, 166-188 (1960).

A searching review of current home interview origin and destination survey procedures is made. Various basic improvements to present techniques and philosophy are proposed.

43. Cherniack, N., "Effects of Travel Impedance Costs." HRB Special Report 56, 99-108 (1959).

Discussion on how travel impedance costs may be used in mathematical formulas to determine traffic generation and distribution in an urban area.

44. Cherniack, N., "Chicago Area Transportation Study." Vol. 1 (1959), Vol. 2 (1960), Vol. 3 (to be published).

Vol. 1: Detailed basic information needed for long-term planning. Data presented in three sections—description of region: measured quantities for the base year, 1956: and indications of reliability of basic information. Vol. 2: Concerned with estimation of amount, kind, and location of travel likely to take place in 1980 in Chicago area. Vol. 3: To set forth criteria for planning. Plans will be developed and tested, benefits weighed against costs. Finally, a staging of work for construction of new transportation facilities.

45. Conner, M.A., Hiller, S.H., "Mechanical Methods of Traffic Assignment." HRB Bull. 130, 69-75 (1956).

Description of use made of digital and analog computers in traffic engineering by Florida State Highway Department.

46. Gorman, D.A., and Hitchcock, S.T., "Characteristics of Traffic Entering and Leaving the CBD." Public Roads, 30:213-220 (Aug. 1959).

Description of general patterns of vehicle travel into and out of CBDs of a large number of cities.

47. Creighton, R. L., "Comprehensive Transportation Planning." Proc., ASCE, 84:No. HW3 (Oct. 1958).

Discusses methods to be used in Chicago Area Transportation Study.

48. Creighton, R. L., Hoch, I., and Schneider, M., "Estimating Efficient Spacing for Arterials and Expressways." HRB Bull. 253, 1-43 (1960).

Details of study made to determine optimal spacing of arterials and expressways as function of construction cost and user cost. Relationships obtained mathematically, and appropriate data for Chicago area used in obtaining final results.

49. Creighton, R. L., and Schneider, M., "The Optimal Spacing of Arterials and Expressways." CATS Research News, 2, 10-16 (Nov. 1958).

Summary of reference 48.

50. Creighton, R. L., and Hock, I., "The Optimum Spacing of Arterials and of Expressways." Traffic Quarterly, 13:477-494 (Oct. 1959).

Essentially the same as reference 48.

51. Creighton, R. L., "Linked Home Interview Travel Data." CATS Research News, 2:3-9 (Feb. 28, 1958).

Difference in number and purpose of trips shown to be function of accounting technique used to classify trips using more than one mode of travel.

52. Creighton, R. L., "Length of Travel." CATS Research News, 3:1-7 (Feb. 20, 1959).

Statistics giving length of person-trips and vehicle-trips, and miles of person and vehicle travel for the Chicago area, presented.

53. Curran, F. B., and Stegmaier, J. T., "Travel Patterns in 50 Cities." HRB Bull. 203, 99-130 (1958).

Results of investigation by Bureau of Public Roads on purpose and mode of travel of trips made by inhabitants of 50 cities. In most cases, volume of daily trips compared to number of persons, dwelling units, and cars in particular city.

54. Davidson, R. G., "Developing a Traffic Model with a Small Sample." HRB Bull. 297, 106-108 (1961).

Describes Boston College Urban Transportation Research Program, using gravity model, with a small home interview O-D survey, to develop traffic model for metropolitan Boston area.

55. Davidson, R.G., "Detroit Area Traffic Study 1956." Vol. 1 and 2.

Vol. 1: Data Summary and Interpretation. Account of study procedure, results of inventories, and analysis of survey data. Vol. 2: Future Traffic and a Long Range Expressway Plan. Extension of trends leading to estimate of future travel desires. Methods necessary to plan adequate (in location and supply) transportation facilities for present and future traffic demands presented.

56. Fagin, H., "Fundamental Philosphy and Concepts." HRB Bull. 293, 33-36 (1961).

Discussion of fundamental principles of metropolitan area transportation planning, as applied in Penn-Jersey Transportation Study.

57. Fleisher, A., "On Prediction and Urban Traffic." Meeting, Regional Science Assoc. (Dec. 1960).

    Discusses predictability of traffic in urban area.

58. Fratar, T.J., "Vehicular Trip Distribution by Successive Approximations." Traffic Quarterly, 8:53-65 (Jan. 1954).

    Describes method of successive approximations useful in estimating distribution of trips between zones in urban area. Numerical example of proposed method and comparison with average factor method also included.

59. Fratar, T.J., "Forecasting Distribution of Interzonal Vehicular Trips by Successive Approximations." HRB Proc., 33:376-385 (1954).

    More detailed presentation of material in reference 58.

60. Gardner, E.L., "Evaluation of Friction Measures." CATS Research News, 2:10-13 (March 14, 1958).

    Results of tests to determine value of travel time as friction measure.

61. Gittens, M.J., "Methodology or Planning." HRB Bull. 293, 36-39 (1961).

    General methodology of Penn-Jersey Transportation Study in terms of a single, unifying concept linking urban development, transportation movement, and growth of a metropolitan region presented.

62. Glanville, W., "Economic and Traffic Studies for Long-Birmingham Motorway." Proc., Inst. of Civil Engineers, Vol. 15 (April 1960).

    Review of traffic and economic study completed before construction of London-Birmingham Motorway.

63. Hall, E.M., "Metropolitan Area Transportation Studies." Proc., Inst. of Traffic Engineers, pp. 51-62 (1956).

    Describes organization and specific projects of San Diego Metropolitan Area Transportation Study.

64. Hall, E.M., "Travel Characteristics of Two San Diego Subdivision Developments." HRB Bull. 203, 1-19 (1958).

    Relationships between land use and traffic generation for two San Diego subdivision developments, indicating orientation of generated traffic are developed. Standard home interview and cordon line origin and destination survey was made.

65. Hall, E.M., "Traffic Generator Studies in San Diego." Traffic Engineering, 30: 13-16 (Feb. 1960).

    Essentially the same as reference 64.

66. Hall, E.M., and George, S., Jr., "Travel Time—An Effective Measure of Congestion and Level of Service." HRB Proc., 38:511-529 (1959).

    Value of travel time as measure of "level of service" discussed with particular reference to San Diego Metropolitan Area Transportation Study.

67. Hamburg, J.R., "Selected Land Use and Trip Purpose Comparisons—Detroit and Chicago." CATS Research News, 2:17-20 (Feb. 28, 1958).

Trip purpose distributions within selected generated land-use categories compared for Chicago and Detroit: Comparisons revealed high degree of similarity between the two cities.

68. Hamburg, J.R., "'Walk to Work' Trips in the CATS Area." CATS Research News, 2:3-5 (April 25, 1958).

    Shows absolute and percentage walk-to-work trips of total first work trips for Chicago and Detroit. Tendency for residents to walk to work maximized in central area and minimized in suburban areas.

69. Hamburg, J.R., "Summary Comparison of Trip Generation for Chicago and Detroit." CATS Research News, 2:3-5 (June 27, 1958).

    Comparison of trips generated per acre of land in various uses for Detroit and Chicago. Definition and data collection differences made comparison difficult, although general similarities were noticed in both cities.

70. Hamburg, J.R., "A Comparison of Vehicle and Person Destinations by Land Use." CATS Research News, 2:12-16 (Sept. 5, 1958).

    Examines trip destinations by vehicle type. Significant differences in proportions of trips generated by different land-use activities recorded for resident, taxi, and truck trips in Chicago Area Transportation Study.

71. Hamburg, J.R., "A Comparison of Car Ownership and Density-Chicago and Detroit." CATS Research News, 2:3-7 (Oct. 3, 1958).

    Shows that pattern of car ownership is practically the same in both Chicago and Detroit, even though physical structure of the two cities is considerably different (density, available mass transportation, size, etc.).

72. Hamburg, J.R., "Car Ownership and Trip Making in the CATS Area." CATS Research News, 3:8-12 (Feb. 20, 1959).

    Review of present and predicted future car ownership and trip making in CATS area.

73. Hamburg, J.R., "Land Use Projection for Predicting Future Traffic." HRB Bull. 224, 72-84 (1959).

    Forecasting procedure used for predicting land development in Chicago up to 1980 reviewed. Relationships developed between land use and trafffic used for predicting future travel.

74. Hamburg, J.R., and Creighton, R.L., "Predicting Chicago's Land Use Pattern." Jour. Amer. Insti. of Planners, 25:67-72 (May 1959).

    Procedure whereby area-wide estimates of future population and economic activity can be distributed to small subareas, so that measures of local land requirements may be obtained.

75. Hansen, W.G., "How Accessibility Shapes Land Use." Jour. Amer. Inst. of Planners, 25:73-76 (May 1959).

    Suggests method for determining accessibility patterns within metropolitan areas. Although model presented not yet sufficiently well refined for estimating purposes, concept and approach may be potentially useful tools for metropolitan planning purposes.

76. Hansen, W.G., "Land Use Forecasting for Transportation Planning." HRB Bull. 253, 145-151 (1960).

    Essentially the same as reference 75.

77. Hansen, W.G., "Hartford Transportation Study Procedures." Highway Planning Seminar, Mass. Insti. of Tech. (Nov. 1960).

Land-use model and traffic forecasting procedure used in Hartford Area Transportation Study discussed. Model incorporates a number of unique features not previously quantified.

78. Harper, B.C.S., and Edwards, H.M., "Generation of Person Trips by Areas Within the Central Business District." HRB Bull. 253, 44-61 (1960).

Description of method developed to measure attraction of person-trips to CBD. Results of both origin-destination and categorized floor-space surveys are used.

79. Heald, K.L., "Discussion of Iowa Gravity Model Traffic Distribution Program." Computing Center, Iowa State Highway Commission (March 1960).

Complete description of gravity model and associated computer program used in seven Iowa cities' transportation study.

80. Hillier, J.A., and Whiting, P.D., "Oxford Traffic Survey: An Assessment of the Traffic Consequences of Some Proposed Road Layouts." Dep. of Scientific and Industrial Research, Road Research Laboratory, RN/3537/JAH (July 1959).

Account of techniques used in Oxford (England) Traffic Survey, 1957.

81. Hillier, J.A., "The Assessment of the Effect of Relief Roads on Traffic." Institution of Highway Engineers, Portsmouth, England (Jan. 1961).

Assessment of current techniques of traffic estimation and assignment in Great Britain as developed by Road Research Laboratory.

82. Hillier, J.A., and Whiting, P.D., "Lagos Traffic Survey 1958." Dept. of Scientific and Industrial Research, Road Research Laboratory, RN/3508/JAH, PDW (June 1959).

Account of techniques used in Lagos (Nigeria) traffic survey, 1958.

83. Hitchcock, S.T., "Continuous Origin and Destination Traffic Surveys." Proc., ASCE, 84:No. HW2, Paper 1625 (May 1958).

Advantages of continuous O-D surveys discussed, and reference made to continuous sampling program planned by New York Port Authority.

84. Hoch, I., "Forecasting Economic Activity for the Chicago Region." HRB Proc., 38:9-25 (1959).

Economic forecast for years up to 1980 made by Chicago Area Transportation Study, with a view to forecasting employment, predicting numbers of vehicles registered, and gaining some insight into effects of expanded highway facilities on the economy. Electronic computer used for most of the calculations, account being taken of increase in population, real incomes, and shift in type and location of industry. A regional input-output model employed.

85. Hoch, I., "Forecasts of Automobile Registration for the CATS Study Area." CATS Research News, 2:3-9 (June 6, 1958).

Projections of automobile registration for Chicago area made using budget-study data on consumer expenditures, and time-series data on U.S. automobile registration.

86. Hoch, I., "The CATS Employment Forecast." CATS Research News, 2:4-9 (Nov. 28, 1958).

Procedure used to determine employment forecast, and results obtained for the Chicago area.

87. Hoch, I., "Auto Registration Forecasts Revisited." CATS Research News, 3:13-20 (Feb. 20, 1959).

Final forecast of auto registration for Chicago area, obtained by combining time-series and budget-study data.

88. Hooper, C.J., "The Need for Further Research on Traffic Assignment." HRB Bull. 61, 66-70 (1952).

Summary of trends in traffic growth, with areas for further research suggested.

89. Howe, J.J., "Modal Split of CBD Trips." CATS Research News, 2:3-10 (Aug. 22, 1958).

Modal split of trips starting or ending within CBD discussed for Chicago area.

90. Howe, J.J., "Modal Split of CBD Trips." CATS Research News, 2:3-10 (Aug. 22, 1958).

Describes modal split of trips starting or ending within CBD.

91. Howe, J.J., "A Theoretical Prediction of Work-Trip Patterns." HRB Bull. 253, 155-165 (1960).

Describes theoretical model of movement of people in response to varying land uses, based on principles of electrostatics. Although predictions given by model have not been field tested, it appears capable of predicting work-trip patterns in a metropolitan area within useable limits of accuracy.

92. Irwin, N.A., Dodd, N., and Von Cube, H.G., "Capacity Restraint in Assignment Programs." HRB Bull. 297, 109-127 (1961).

Complete description of methods used to include capacity restraints in future planning of highway facilities for Toronto metropolitan area. Method includes iteration procedure to obtain system equilibrium. Results of the programs compared with observed field data.

93. Johnston, W.W., "Travel Time and Planning." Traffic Quarterly, 10:67-78 (Jan. 1956).

Discussion of travel time and its affect on development of a region, particularly land use adjacent to new highways.

94. Kanwit, E.L., and Steele, C.A., "Need We Fail in Forecasting?" HRB Bull. 257, 1-35 (1960).

Appreciation of forecasting techniques. Concerned mainly with national and state-wide forecasts of vehicle registration and usage. A "yardstick" for assessing success of a forecast is suggested, and bases of forecasts made since 1950 are reviewed.

95. Keefer, L.E., "Reporting the Results of the CATS Speed-Volume Study." CATS Research News, 2:10-16 (June 6, 1958).

Presents major findings of speed-volume relationships for various classes of roads in Chicago area.

96. Keefer, L.E., "Reporting the Results of CATS' Intersection Capacity Study." CATS Research News, 2:12-16 (Sept. 19, 1958).

Report of major findings in Chicago Area Transportation Study to determine a prediction equation for capacity of an intersection which could be used in an assignment procedure.

97. Keefer, L.E., "The Arterial Street Inventory." PATS Research Letter, 1:1-5 (March 1959).

Describes inventory methods used at PATS for measuring traffic-carrying ability and quality of service provided by major streets (arterials) within study area.

98. Keefer, L.E., "Home Interview Survey-Summary Trip Data." PATS Research Letter, 1:12-17 (Nov. 1959).

Presents some over-all trip totals from home interview survey in Pittsburgh. Comparisons made with similar data from Chicago and Detroit.

99. Keefer, L.E., "Traffic Assignment Travel Times." PATS Research Letter, 1: 1-5 (July 1959).

Discussion of various aspects of using travel time in assignment procedures.

100. Keefer, L.E., "Central Business District—Summary Trip Data." PATS Research Letter, 1:1-8 (Dec. 1959).

Presents some over-all trip totals for CBD-orientated person and vehicle travel in Pittsburgh.

101. Keefer, L.E., "Traffic Assignment—What It Is." PATS Research Letter, 2:1-9 (Feb. 1960).

General discussion of principal procedures involved in making assignments of traffic to networks.

102. Keefer, L.E., "Alternate Approaches to Trip Generation." PATS Research Letter, 2:11-21 (May 1960).

Synopsis of current approaches to trip generation.

103. Keefer, L.E., "Some Factors Influencing Average Car Loading Factors." PATS Research Letter, 2:12-16 (Sept. 1960).

Presents basic data on car loadings, as affected by different variables, based on findings in Pittsburgh Area Transportation Study.

104. Killin, E.L., "Highway-Traffic Estimation by Linear Programming." Proc., ASCE, 85:No. HW-1, Pt 1, pp. 17-33 (Jan. 1959).

Application of linear programming to traffic estimation. Linear programming considered to have the following advantages over other procedures: (a) traffic movements in final solution will automatically behave with flow into interchange; (b) judgment can likely be applied with greater degree of confidence; (c) easily applicable to computer processing.

105. Kramer, C., "Population Density Patterns." CATS Research News, 2:3-10 (Jan. 31, 1958).

Derivation of residential density distribution described for future land-use structure in Chicago area. Units used are series of rings centered around CBD.

106. Kramer, C., "The Estimation of Future Population Densities." CATS Research News, 2:9-16 (June 27, 1958).

Method used in Chicago Area Transportation Study to prepare population density estimates outlined and discussed.

107. Lapin, H.S., "Transportation Analysis in the Philadelphia Metropolitan Region." Regional Science Association Papers and Proc., 3:198-206 (1957).

Discusses some concepts, principles, and applications derived from work done by Urban Traffic and Transportation Board of the City of Philadelphia. Group was given task of preparing "an integrated plan useful over an extended period for the elimination of urban transportation congestion."

108. Lapin, H.S., "Analysis of Work Trips Based on Mathematical Relationships and Variances." Institute for Urban Studies, Univ. of Pennsylvania (1956).

Presents results of analyses of work-trip generation between residential and employment concentrations in Philadelphia. Includes mathematical equation describing inverse relationship between interzonal trip volumes and respective time-distances for peak period travel.

109. Lapin, H.S., "The Analysis of Work-Trip Data." Traffic Quarterly, 11:278-292 (April 1957).

Details of analysis of work-trip generation between residential and industrial and business districts where level of employment is high. Equation given for evaluating interzonal trip volumes for peak periods.

110. Lapin, H.S., "Report on Analysis of Urban Work Trips." HRB Bull. 224, 51-63 (1959).

Analytical techniques used in study of peak-hour urban traffic flow reviewed, and methods of improving traffic forecasts discussed. Attention drawn to kind of information likely to permit realistic forecast of traffic patterns in time as well as direction.

111. Lovejoy, W.B., "Continuous Sampling Method of Conducting Origin-Destination Surveys." HRB Bull. 224, 41-50 (1959).

Results of first year's operation by New York Port Authority of continuous sampling program at Hudson River bridges and tunnels in New York Metropolitan Area. Statistical sample described, and advantages and future application of procedure discussed.

112. Lovejoy, W.B., "Trans-Hudson River Vehicular Origin and Destination Survey." Public Roads, 31:86-99 (Oct. 1960).

Essentially the same as reference 111.

113. Lovejoy, W.B., "New York Port Authority's 1958 O-D Survey Using Continuous Sampling." HRB Bull. 253, 152-154 (1960).

Essentially the same as reference 111.

114. Lynch, J.T., "Traffic Diversion to Toll Roads." Proc., ASCE, 81:Separate No. 702 (June 1955).

Growth, generation, and diversion of traffic since 1947 discussed with special reference to Maine Turnpike. Use of turnpike by trucks also discussed.

115. Lynch, J.T., "Home-Interview Traffic Surveys and Related Research Activities." Public Roads, 30:185-186 (June 1959). Also in HRB Bull. 224, 85-88 (1959).

Review of survey methods and traffic studies includes reference to origin-and-destination formulas and electronic computer techniques being developed by Bureau of Public Roads.

115. Lynch, J.T., Brokke, G.E., Voorhees, A.M., and Schneider, M., "Panel Discussion on Inter-Area Travel Formulas." HRB Bull. 253, 128-138 (1960).

A review of interzonal travel formulas, principally Fratar method, gravity model, and opportunity model.

117. McGrath, W.R., "Land Use in Traffic Generation." HRB Bull. 224, 132-135 (1959).

Essential requirements for practical and effective method of relating land development to traffic generation. Recommendations made based on work carried out in New Haven, Conn. in connection with planning of Interstate Highway System.

118. McGrath, W.R., "Land Use Planning Related to Traffic Generation and Estimation." Proc., Inst. of Traffic Engineers, pp. 66-77 (1958).

Essentially the same as reference 117.

119. May, A.D., Jr., and Michael, H.L., "Allocation of Traffic to Bypasses." HRB Bull. 61, 38-58 (1952).

Time ratio, distance ratio, and cost index methods for diverting traffic compared to known diversion of traffic using two by-passes in Indiana. Cost index method shown to give best fit in these two cases.

120. Mayer, A.J., and Smock, R.B., "The Continuing Traffic Study: Methods of Keeping O-D Data Up-To-Date." HRB Bull. 253, 109-113 (1960).

Describes the continuing organization and its activities created as follow-up to Detroit Area Origin and Destination Survey of 1953.

121. Mayer, A.J., "Obtaining O-D Data at the Time of Driver's License Renewal." Preprint HRB Annual Meeting (Jan. 9-13, 1961).

Describes continuous sampling origin-destination survey proposed for use at time of driver's license renewal.

122. Mertz, W.L., Hamner, L.B., "A Study of Factors Related to Urban Travel." Public Roads, 29:170-174 (April 1957).

Analysis of effect of car ownership, population density, distance from CBD, and family income on number of vehicular trips made by residents of Washington, D.C.

123. Mertz, W.L., "A Study of Traffic Characteristics in Suburban Residential Areas." Public Roads, 29:208-212 (Aug. 1957).

Discusses effect that different types of suburban residential development has on traffic generation in Washington, D.C. area, using garden-type apartment development and subdivision of single family homes as basis for comparison.

124. Mertz, W.L., "Review and Evaluation of Electronic Computer Traffic Assignment Programs." HRB Bull. 297, 94-105 (1961).

Brief discussion of different assignment programs for electronic computers. Type of assignment, network size, and other factors appropriate to each program are listed.

125. Mitchell, R.B., and Rapikin, C., "Urban Traffic, A Function of Land Use." Columbia Univ. Press. (1954).

Study of relationships between land use and movement of persons, goods, and vehicles. Concepts formulated as basis for analytical framework for investigation of traffic and land use. Also briefly considered the investigation development, and testing of techniques and procedures for securing data. Suggestions for further study in limited segments of the problem.

126. Mladinov, J.K., and Hansen, R.J., "A Mechanized Procedure for Assignment of Traffic to a New Route." HRB Bull. 130, 59-68 (1956).

Machine methods of assigning traffic by travel time to proposed new route reviewed with special reference to their application in State of Washington.

127. Mortimer, W.J., "Transportation Usage Study." HRB Bull. 203, 47-51 (1958).

Objective of paper to present information aiding in assignment of traffic to arterial streets, expressways, and mass transportation facilities. Study designed to probe directly into attitudes and personal reasons involved in choice of mode of travel.

128. Mortimer, W.J., "Trends in Traffic Diversion on Edens Expressway." HRB Bull. 119, 1-38 (1956).

Diversion effects of Edens Expressway deduced by comparing screen line data obtained both before and after opening of expressway.

129. Moskowitz, K., "California Method of Assigning Diverted Traffic to Proposed Freeways." HRB Bull. 130, 1-26 (1956).

Curves indicating percentage of traffic using freeway as function of time and distance differentials, curves tested against Shirley Highway data.

130. Murray, F.J., "A Comparative Study of Origin and Destination Data Obtained by Home Interview and Controlled Post Card Methods." HRB Proc., 36:669-679 (1957).

Responses to same questions compared when home interview and post card sampling method used. Sources of error outlined and discussed.

131. Plummer, A.V., Wilkie, L.G., and Gran, R.F., "Median Strip Mass Transit and Related Traffic Charcteristics on Congress Expressway. HRB 224, 124-131 (1959).

Tabulated analysis of results of survey conducted by Cook County Highway Department to determine effect of new public transport service operating on central reserve of Congress Expressway.

132. Pollard, W.S., Jr., "Forecasting Traffic with a Modified Growth Factor Procedure." HRB Bull. 297, 86-93 (1961).

Comparison of Fratar, average factor, and "Judgement Applied Factor" interzonal transfer methods used in Memphis, Tenn., area.

133. Pyers, C.E., "A Trend in Car Loading Factors." PATS Research Letter, 2:7-11 (Sept. 1960).

Describes current trends in car loading as function of car ownership, based on findings from Pittsburgh Area Transportation Study.

134. Quinby, H.D., "Traffic Distribution Forecasts—Highway and Transit." Traffic Engineering, 31:22-29 (Feb. 1961).

Describes development of suitable diversion curves for predicting future transit passengers on proposed San Francisco rapid transit system. Trips classified by time (peak and nonpeak hour), direction, and origin-destination (CBD or non-CBD oriented).

135. Rivard, L.A., "Electronic Traffic Projection and Assignment." American Highways, 39:5, 14-16 (July 1960).

General discussion of role of electronic computer in Washington Metropolitan Area Transportation Study.

136. Rothrock, C.A., and Keefer, L.E., "Measurement of Urban Traffic Congestion." HRB Bull. 156, 1-13 (1957).

Describes measurements made of progress of all vehicles, in a lane of traffic, through a test section subject to congestion. Results reveal characteristics used as measurement of degree of congestion.

137. Rothrock, C.A., and Campbell, W., "Comparative Traffic Usage of Kanawha Boulevard and Alternate City Arterials at Charlestown, West Virginia." HRB Bull. 61, 1-7 (1952).

Study compares usage of Kanawha Boulevard against usage of city streets for rush hour and non-rush hour periods. Diversion curves of time and distance are shown. Effect of trip length also indicated.

138. Row, A.T., "An Approach to O-D Data Analysis." Traffic Quarterly, 9:105-122 (Jan. 1955).

Analysis sequence used in Detroit Metropolitan Area Traffic Study, proceeding from compilation of origin-destination data, through several phases of analysis, to creation of metropolitan area highway plan.

139. Row, A.T., and Jurkat, E., "The Economic Forces Shaping Land Use Patterns." Jour. Amer. Inst. of Planners, 25:77-81 (May 1959).

Urban land-use model, based on population, economic composition, household incomes, business incomes, and input-output patterns of business is presented, suitable for use in generalized land-use projection. Model based on thesis that all activities in urban areas depend on convenient proximity to certain other activities.

140. Row, A.T., "Land Use Planning Related to Traffic Generation and Estimation." Proc., Inst. of Traffic Engineers, pp. 62-65 (1958).

Implications between traffic generation and land-use planning.

141. Schmidt, R.E., and Campbell, M.E., "Highway Traffic Estimation." Eno Foundation for Highway Traffic Control (1956).

Primarily concerned with three aspects of traffic estimating. (a) Traffic generating characteristics of major urban land areas; (b) relative attractiveness of various types of routes serving traffic between zones of origin and destination; and (c) growth of traffic resulting from increases in population, vehicle ownership, vehicle use, and other factors. Appraisals of specific facilities related to their environments in terms of significant economic and sociological data.

142. Schwartz, A., "Generalized Land Use." PATS Research Letter, 1:18-27 (1959).

Preliminary tabulations of land uses in Pittsburgh area. Comparison with Detroit and Chicago also made.

143. Schwartz, A., "Industrial Land Forecast." PATS Research Letter, 2:10-17 (Feb. 1960).

Procedures used in Pittsburgh Area Transportation Study to estimate requirements for future industrial land (both manufacturing and non-manufacturing) discussed.

144. Schwartz, A., "Net Residential Densities." PATS Research Letter, 2:10-16 (March 1960).

Procedures used in Pittsburgh Area Transportation Study to estimate requirements for future residential land (through residential densities).

145. Sharkey, R.H., "A Comparison of the Modal Stratification of Trips by Distance from the CBD." CATS Research News, 2:14-20 (March 14, 1958).

Modal split, as function of distance from CBD and land use, presented for Chicago area (within selected land-use categories).

146. Sharkey, R.H., "Trip Origins by Type of Land Use in the Chicago Area." CATS Research News, 2:13-20 (August 22, 1958).

Results of Chicago area transportation study home interview survey concerning generation of trip origins among detailed list of land-use activities.

147. Sharkey, R.H., "The Effect of Land Use and Other Variables on Mass Transit Usage in Chicago Area." CATS Research News, 3:3-10 (Jan. 9, 1959).

Analysis of factors found to affect mass transit usage, based on findings of Chicago Area Transportation Study.

148. Sharpe, G.B., Hansen, W.G., and Hamner, L.B., "Factors Affecting Trip Generation of Residential Land-Use Areas." Public Roads, 30:88-99 (Oct. 1958) Also in HRB Bull. 203, 20-36 (1958).

Methods for estimating potential generation and production of person-trips in urban residential developments. Results of an analysis showing what effect differences in population, car ownership, household income, and distance from CBD had on number of person trips attracted to and generated by residential land.

149. Silver, J., "Trends in Travel to the CBD by Residents of Washington, D.C. Metropolitan Area, 1948 and 1955." HRB Bull. 224, 1-40 (1959). Also in Public Roads, 30:153-176 (April 1959).

Analysis of changes that have taken place between 1948 and 1955 in travel between the CBD and other zones in Washington, D.C., metropolitan area.

150. Silver, J., and Hansen, W.G., "Characteristics of Travel to a Regional Shopping Center." Public Roads, 31:101-108 (Dec. 1960).

Describes many characteristics of travel to shopping center having regional market area.

151. Smith, W.S., "Analyzing and Projecting Travel Data." Proc. ASCE, 86:No. HW2 pp. 1-14 (June 1960).

Application of new techniques in recently completed traffic survey of Washington, D.C., Metropolitan Area. Purpose of survey to determine information needed for planning transportation system for that area.

152. Smith, Wilbur and Associates, "Mass Transportation Survey: National Capital Region, 1958."

Complete account of techniques, procedures, and results of transportation study of capitol region.

153. Smith, Wilbur and Associates, "Future Highways and Urban Growth." Report for Automobile Manufacturers Association (April 1961).

Comprehensive study of National System of Interstate Highways as it relates to future national transportation needs and changing shape of metropolitan America.

154. Sosslau, A.B., "IBM 704 Traffic Assignment Program." Highway Planning Seminar, Mass. Inst. of Tech. (Nov. 1960).

Detailed account of network coding for Bureau of Public Roads IBM 704 traffic assignment program.

155. Sosslau, A.B., and Brokke, G.E., "Appraisal of O-D Survey Sample Size." Public Roads, 31:114-119 (Dec. 1960).

Relationship between home interview type of O-D survey sampling rates and error to be expected in volumes accumulated from such a survey.

156. Sosslau, A.B., and Brokke, G.E., "Appraisal of Sample Size Based on Phoenix O-D Survey Data." HRB Bull. 253, 114-127 (1960).

Essentially the same as reference 155.

157. Thabit, W., and Lobe, N., "Shopper Origins and Destinations." Traffic Quarterly, 11:30-53 (Jan. 1957).

Study of inner and outer city shopper movements, using available data and statistics of sales and incomes.

158. Thompson, J.T., and Stegmaier, J.T., "The Effect of Building Space on Traffic Generation and Parking Demand." HRB Proc., 28:320-339 (1948).

Method for using urban origin and destination survey material for information concerning the power of buildings of various types to attract traffic and create parking demand.

159. Tomazinis, A.R., "Spatial Parameters Affecting Urban Traffic." Preprint HRB Annual Meeting (Jan. 9-13, 1961).

Analysis of factors affecting magnitude and pattern of interchange in urban areas. An indication of where current techniques need improving is given and mention made of investigations currently in progress by Penn-Jersey Transportation Study.

160. Trueblood, D.L., "The Effect of Travel Time and Distance on Freeway Usage." Public Roads, 26:241-250 (Feb. 1952). Also in HRB Bull. 61, 18-37 (1952).

Usage of Shirley Highway into Washington, D.C., studied, and diversion curves presented for time ratio, distance ratio, and time differential.

161. Voorhees, A.M., "A General Theory of Traffic Movement." Proc., Insti. of Traffic Engineers, pp. 46-56 (1955).

Factors affecting traffic movement in urban areas discussed. Information presented on purpose of trips, effect of distance and size of "attraction" on travel patterns. Example given of how theory can be applied to measure traffic movements.

162. Voorhees, A.M., "Forecasting Peak Hours of Travel." HRB Bull. 203, 37-46 (1958).

Existing origin and destination techniques shown to be inadequate for forecasting peak-hour travel. Improvement based on a mathematical model suggested.

163. Voorhees, A.M., and Morris, R., "Estimating and Forecasting Travel for Baltimore by Use of a Mathematical Model." HRB Bull. 224, 105-114 (1959).

Method developed by Baltimore Regional Planning Council based on mathematical analysis of information on trip frequency, car ownership, travel time, and choice of route and transport. Method found to have an accuracy comparable with estimates based on a percent home-interview study.

164. Voorhees, A.M., Booth, J.W., "Application of O-D Data in the Baltimore Region." HRB Bull. 224, 115-123 (1959).

Methods of determining where new main highways will be needed in Baltimore region reviewed, and illustrated account given of planning facilities for 1980.

165. Voorheees, A.M., "Use of Mathmatical Models in Estimating Travel." Proc., ASCE, 85:No. HW-4, pp. 129-142 (Dec. 1959).

Essentially the same as reference 163.

166. Voorhees, A.M., "Development Patterns in American Cities." HRB Bull. 293, 1-8 (1961).

Discussion of new techniques used to analyze growth characteristics of urban areas. Techniques developed to provide better basis for land-use projection.

167. Voorhees, A.M., Sharpe, G.B., and Stegmaier, J.T., "Shopping Habits and Travel Patterns." HRB Special Report 11-B (1955).

Relates shopper behavior to subjective quantities such as convenience, range of merchandise, selection, and services offered at various shopping areas. Patterns, such as time of shopping, frequency of shopping trips, mode of travel utilized and particular shopping area visited, are identified. Method has been developed whereby destination and frequency of auto and transit shopping trips from any residential area can be predicted.

168. Von Cube, H.B., Desjardine, R.J., and Dodd, N., "Assignment of Passengers to Transit Systems." Traffic Engineering, 28:12-14 -Aug. 1958).

Results of O-D transit survey, along with methods of assigning these trips to hypothetical transit systems. Diversion curves for time and distance developed, and other factors mentioned which were shown to affect choice of route by passenger.

169. Whiting, P.D., "Computer Programs for Allocating Traffic by the Quickest Route Method." Dept. of Scientific and Industrial Research, Road Research Laboratory, Research Note RN/3829/PDW.

Write-up of two complementary programs for Pegosus II computer. Program may be used for minimum time, distance, or cost. Assignments made to network for different vehicle classes in first program and second program sums results.

170. Wiant, R.H., "A Simplified Method for Forecasting Urban Traffic." HRB Bull. 297, 128-145 (1961).

Discusses simplified gravity model procedures used to forecast 1980 traffic volumes in seven Iowa cities. Application of data in selecting arterial street systems also included.

171. Wingo, L., "Measurement of Congestion in Transportation Systems." HRB Bull. 221, 1-28 (1959).

Using ingression analysis, article constructs mathematical model to describe congestion losses in transportation systems.

172. Witheford, D.D., "Zonal Interchange Reviewed." PATS Research Letter, 2:1-10 (May 1960).

Review of basic zonal interchange estimating methods, with particular emphasis on method used in Pittsburgh Area Transportation Study.

173. Witheford, D.D., "Comparison of Trip Distribution by Opportunity Model and Gravity Model." Preprint, HRB Annual Meeting (Jan. 9-13, 1961).

Reviews to mathematical concepts currently used to describe trip distribution, and compares accuracy of results obtained by both methods.

174. Wright, J.E., "Technique for Bringing O-D Data Up-To Date." Preprint, HRB Annual Meeting (Jan. 9-13, 1961).

Discusses method used to update and extend origin and destination data for Houston, Texas, area in order to assign vehicle trips for 1980 to proposed freeway system.

175. Wynn, F.H., "Intracity Traffic Movements." HRB Bull. 119, 53-68 (1956).

Summary of investigations on passenger car traffic within urban areas. Data from past home-interview origin and destination studies used.

176. Wynn, F.H., "Studies of Trip Generation in the Nation's Capital, 1956-58." HRB Bull. 230, 1-52 (1959).

Evaluation of past and present travel characteristics in relation to expansion of Washington Metropolitan Area, 1948-1955. Analysis techniques and formulas presented. Traffic volumes and modes of travel related to numbers, wealth, and geographic distribution of population.

177. Wynn, F.H., and Linder, C.E., "Tests of Interactance Formulas Derived from O-D Data." HRB Bull. 253, 62-85 (1960).

Describes use of synthetic inter-area travel projections in O-D studies recently completed in St. Louis, Mo.; Kansas City, Mo; and Charlotte, N.C.

178. Farmer, J.F., "Forecasting Travel Patterns." Traffic Engineering, 31:24-28 (April 1961).

179. Osofsky, S., "The Multiple Regression Method of Forecasting Traffic Volumes." Traffic Quarterly, 13:423-45 (July 1959).

THE NATIONAL ACADEMY OF SCIENCES—NATIONAL RESEARCH COUNCIL is a private, nonprofit organization of scientists, dedicated to the furtherance of science and to its use for the general welfare. The ACADEMY itself was established in 1863 under a congressional charter signed by President Lincoln. Empowered to provide for all activities appropriate to academies of science, it was also required by its charter to act as an adviser to the federal government in scientific matters. This provision accounts for the close ties that have always existed between the ACADEMY and the government, although the ACADEMY is not a governmental agency.

The NATIONAL RESEARCH COUNCIL was established by the ACADEMY in 1916, at the request of President Wilson, to enable scientists generally to associate their efforts with those of the limited membership of the ACADEMY in service to the nation, to society, and to science at home and abroad. Members of the NATIONAL RESEARCH COUNCIL receive their appointments from the president of the ACADEMY. They include representatives nominated by the major scientific and technical societies, representatives of the federal government, and a number of members at large. In addition, several thousand scientists and engineers take part in the activities of the research council through membership on its various boards and committees.

Receiving funds from both public and private sources, by contribution, grant, or contract, the ACADEMY and its RESEARCH COUNCIL thus work to stimulate research and its applications, to survey the broad possibilities of science, to promote effective utilization of the scientific and technical resources of the country, to serve the government, and to further the general interests of science.

The HIGHWAY RESEARCH BOARD was organized November 11, 1920, as an agency of the Division of Engineering and Industrial Research, one of the eight functional divisions of the NATIONAL RESEARCH COUNCIL. The BOARD is a cooperative organization of the highway technologists of America operating under the auspices of the ACADEMY–COUNCIL and with the support of the several highway departments, the Bureau of Public Roads, and many other organizations interested in the development of highway transportation. The purposes of the BOARD are to encourage research and to provide a national clearinghouse and correlation service for research activities and information on highway administration and technology.