Predicting Future Demand for Urban Area Transportation

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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.

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 in­
sure a specified level or levels of quality of service in speed and convenience of move­
ment between or within all portions of the urban area. This implies that adequate fa­
cilities, satisfying the demand for trips concentrated in time during the day and in geo­
graphic 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 consider­
ing 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 in­
dustrial 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 vehic­
ular speeds, personal safety, comfort, and convenience.

The extent to which these objectives may be achieved will depend on resources avail­
able 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 ex­
pected future economic and social development of the area. Because urban transporta­
tion 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 ma­
jority of the cause-and-effect variations encountered when studying phase interrela­tion­
ships 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 transpor­
tation 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 trial 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.
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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 facilities 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 input 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 philosophy 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 extension 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


Appendix

ANNOTATED BIBLIOGRAPHY ON TRAFFIC ESTIMATION AND ASSIGNMENT

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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.


Essentially the same as reference 1.


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


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


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.


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.


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


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.


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

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


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


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.


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


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.


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


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.


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.


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.


Essentially the same as reference 19.


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.


Essentially the same as reference 21.


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


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


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


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.


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.

   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.

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

   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.

   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.

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

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

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

   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.

   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.

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.


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


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.


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.


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


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


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.


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

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

Discusses methods to be used in Chicago Area Transportation Study.

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.

Summary of reference 48.

Essentially the same as reference 48.

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.

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

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.

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.


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

   Discusses predictability of traffic in urban area.

   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.

   More detailed presentation of material in reference 58.

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

   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.

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

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

   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.

   Essentially the same as reference 64.

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

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


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.


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.


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.


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.).


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


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


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.


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.


Essentially the same as reference 75.
Land-use model and traffic forecasting procedure used in Hartford Area Transportation Study discussed. Model incorporates a number of unique features not previously quantified.

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

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


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

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

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

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.

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

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


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


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


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


Describes modal split of trips starting or ending within CBD.


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 usable limits of accuracy.


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.


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


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.


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

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.


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


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


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


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


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


Synopsis of current approaches to trip generation.


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


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.


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

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


Discussion 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."


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.


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.


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.


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.


Essentially the same as reference 111.


Essentially the same as reference 111.


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

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.

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

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.

Essentially the same as reference 117.

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.

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

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

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.

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.

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

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.


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


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.


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


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


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


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.


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


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

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).


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


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.


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.


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.


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.


Implications between traffic generation and land-use planning.


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.


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

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


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


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


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


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


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.


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.


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


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.

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


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


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


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


Essentially the same as reference 155.


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


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.


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.


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


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.

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


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.


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


Essentially the same as reference 163.


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


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.


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 Pegasus II computer. Programs 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.


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.


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


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


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


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.


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


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.
