NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM REPORT **62**

URBAN TRAVEL PATTERNS FOR HOSPITALS, UNIVERSITIES, OFFICE BUILDINGS, AND CAPITOLS

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- URBAN LAND USE
- URBAN TRANSPORTATION SYSTEMS

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Bureau of Public Roads, United States Department of Transportation.

The Highway Research Board of the National Academy of Sciences-National Research Council was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as: it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state, and local governmental agencies, universities, and industry; its relationship to its parent organization, the National Academy of Sciences, a private, nonprofit institution, is an insurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

The program is developed on the basis of research needs identified by chief administrators of the highway departments and by committees of AASHO. Each year, specific areas of research needs to be included in the program are proposed to the Academy and the Board by the American Association of State Highway Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are responsibilities of the Academy and its Highway Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

This report is one of a series of reports issued from a continuing research program conducted under a three-way agreement entered into in June 1962 by and among the National Academy of Sciences-National Research Council, the American Association of State Highway Officials, and the U. S. Bureau of Public Roads. Individual fiscal agreements are executed annually by the Academy-Research Council, the Bureau of Public Roads, and participating state highway departments, members of the American Association of State Highway Officials.

This report was prepared by the contracting research agency. It has been reviewed by the appropriate Advisory Panel for clarity, documentation, and fulfillment of the contract. It has been accepted by the Highway Research Board and published in the interest of an effectual dissemination of findings and their application in the formulation of policies, procedures, and practices in the subject problem area.

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FOREWORD

By Staff

Highway Research Board

This report will be of particular interest to highway planners, traffic engineers, and highway design engineers, who are concerned with the traffic and transportation problems which are influenced by various land uses. Travel patterns have been studied for hospitals, colleges and universities, office buildings, and state capitol complexes. The analyses include trip generation, trip distribution, and general trip characteristics such as trip purpose and mode of travel. The report results should provide valuable insight information for understanding existing traffic and transportation problems related to the four types of land use, as well as determining the problems which may be created by newly planned facilities and the proposed expansion of existing establishments.

It is recognized that all trips must have an origin and a destination and that all forms of transportation are developed to serve the movement of both people and goods. The origins and destinations of these movements must be spacially located and related to some form of land use. Traffic problems develop because our transportation systems have limited capacities and the travel demands for service on portions of particular transportation systems periodically approach and surpass their design volumes. To derive a rational solution for these problems it is necessary to understand the trip generation characteristics for various forms of land use and the resulting travel patterns. It also is essential to know the influence of land-use types on travel if potential traffic problems are to be avoided in the planning, design, and construction of urban areas.

To study the travel characteristics for specific land uses, the authors of this report searched for the best and most complete data available. The data were obtained from many origin-and-destination studies conducted during recent years for urban transportation planning processes. Instead of studying a complete urban area, which is the function of the various transportation planning agencies that have been formed, the researchers studied only trips to and from specific types of land use. They illustrate, however, how these trips relate to the surrounding urban area.

The studies for each land-use facility include information on travel purpose, time, and trip distribution characteristics; modes of transportation used; competition between similar trip generators; socioeconomic characteristics of the trip makers; and the size, density, and degree of development of contributary areas. The trip generation characteristics are related to various quantifiable factors for each specific land use through the use of multiple regression analyses. The regression coefficients and the standard errors derived from the multiple regression computations are presented to indicate the variablility of the data involved and the range of confidence one may place in using the regression equation for predictive purposes.

This report presents trip characteristics for four specific uses of land. The travel information on hospitals has been derived from the study of data for 77 hospitals located in 16 different metropolitan areas. The findings for college and university travel were developed from 38 institutions located in 16 metropolitan areas. Travel patterns for six state capitol complexes are presented. The trip characteristics for 20 office buildings located in 9 cities comprise the fourth type of land use studied and reported in this document.

It is expected that the information presented in this report will be most useful for the traffic engineer in understanding existing traffic problems located in and around these large traffic generating facilities. The knowledge of why and how people and goods travel to and from a specific land-use type which seems to be causing traffic congestion may lead the engineer to the formulation of a practical method of solving the problem. The traffic generation prediction equations derived from the muliple regression analyses should provide the transportation planner and traffic analyst with a valuable tool when he must consider the traffic effects which will result from a proposed development or the expansion of an existing institution.

This report is the product of NCHRP Project 7-1, entitled "The Influence of Land Use on Urban Travel Patterns." A previous report emanating from this project was published as *NCHRP Report 24,* "Urban Travel Patterns for Airports, Shopping Centers, and Industrial Plants." The two reports from this project complement each other in the development of information for further understanding the travel patterns for specific land-use types.

CONTENTS

ACKNOWLEDGMENTS

The research reported herein was performed as the second phase of NCHRP Project 7-1 by Louis E. Keefer, Transportation Planning Consultant, with Mr. Keefer and David K. Witheford, Transportation Planning Consultant, as co-principal investigators. The latter participated throughout the project and prepared the material on colleges and universities and office buildings.

This report has been made possible through the continuing cooperation of a long list of participants. In most instances, contributions were freely made not only by the participants named in the following, but also by members of their staffs. Whether named or not, grateful appreciation is expressed to all who helped.

Basic origin-destination and supporting transportation study data were provided by Leland S. Veal, State Highway Planning Engineer, Georgia State Highway Department, for the Atlanta Area Transportation Study; H. H. Cooper, Director, Traffic Division, Michigan Department of State Highways, for the Ann Arbor Study; Roger L. Creighton, Director, Subdivision of Transportation Planning and Programming, and John R. Hamburg, Director, Bureau of Planning, New York Department of Public Works, for the Niagara Frontier Transportation Study; George Wey, Director, Bureau of Transportation Planning and Development, Massachusetts Department of Public Works, and Houston Wynn, Wilbur Smith & Associates, for the Eastern Massachusetts Regional Planning Project; James S. Burch, Planning Engineer, North Carolina State Highway Commission, and C. E. Vick, Jr., Harland Bartholomew & Associates, for the Durham and Raleigh Studies; Frank E. Ester, Engineer of Urban Planning, Indiana State Highway Commission, and George W. Barton, President, Barton-Aschman Associates, for the Indianapolis Regional Transportation and Development Study; D. F. Haist, Deputy Director for Planning and Research, State Highway Commission of Wisconsin, for the Madison Area Transportation Study; Floyd B. Bowen, Chairman, Florida State Road Department, and Mel Conner, President, Mel Conner & Associates, for the Miami Urban Area Transportation Study; Johann Nygaard, Planning Research Engineer, Minnesota Department of Highways, for the Twin Cities Area Transportation Study: Grady Carlisle, Traffic and Planning Engineer, Louisiana Department of Highways, for the New Orleans Metropolitan Area Transportation Study; Robert Kochanowski, Director, Pittsburgh Area Transportation Study; Richard J. Bouchard, Director, Rhode Island Statewide Comprehensive Transportation and Land Use Planning Program; Gerald Matthews, Transportation and Research Engineer, Utah State Department of Highways, for the Salt Lake Area Transportation Study; John D. McNeal, Engineer of Planning and Research, State Highway Commission of Kansas, for the Wichita Area Transportation Study; John K. Mladinov, Director, Puget Sound Regional Transportation Study; William G. Ealy, Manager, Tucson Area Transportation Planning Agency; and George V. Wickstrom, Program Director, New Castle County Program, and Ernest A. Davidson, Director of Operations, Delaware State Highway Department, for the Wilmington Study data.

Thanks also are owing to more than 100 hospital administrators, college and university officials, and office building managers or management agencies, who completed and returned questionnaires.

Particular thanks are due the American Hospital Association for making available certain unpublished data for the sample hospitals. Helpful information was also given by officials of several metropolitan hospital planning councils, city and regional planning agencies, city engineering departments, chambers of commerce, newspapers, and other institutions, pertaining to the particular cities in the cross section.

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URBAN TRAVEL PATTERNS FOR HOSPITALS, UNIVERSITIES, OFFICE BUILDINGS, AND CAPITOLS

SUMMARY

The information in this report was developed from a literature search and an extensive examination of statistical data dealt with in transportation studies already conducted. The advantage of this approach is that the data give an opportunity to compare developing trends in a wide variety of locations. A new study involving initial research within the scope of the project budget would seriously limit the data source.

A first-phase report was published as *NCHRP Report 24,* "Urban Travel Patterns for Airports, Shopping Centers, and Industrial Plants."

For this second-phase study, travel data were assembled from 17 studies representing 78 hospitals, 38 universities and colleges, 20 major office buildings, and six state capitol complexes. Various socio-economic, land-use, and street system data were also obtained to develop the required relationships.

Chapter Two lists the major findings in concise statements. The successive chapters and appendices deal with the subject matter in considerable detail.

Hospitals

Large hospitals are major trip generators, most of which involve the use of automobiles either by drivers or by passengers. Of the 78 hospitals in the study, eight have more than 9,000 person trips (to or from) per day. Two of the medical centers embracing a complex of hospitals at one location exceed 20,000 person trips per day. Up to one-half of the trips are made by staff or visiting physicians. About 25% are made by patients, and another 18% by visitors. The use of transit is strongly related to size of the city, location of the hospital, and such other factors as tripmaker sex, race, occupation, and car ownership. The use of taxis is surprisingly light. Because most hospital trips start from home, distribution of trip origins tends to follow distribution of population, but this may vary from hospital to hospital. Although trip origins may be scattered, the traffic converging on the hospital may require a large portion of the capacity of main access roads. Shortage of parking space often aggravates the situation and creates problems for both traffic officials and hospital administrators.

Colleges and Universities

Trips to and from the 38 cross-section institutions range from 1,000 to 87,000 daily person trips; from 500 to 57,000 daily vehicle trips. Major universities are virtually cities in themselves. The kind and amount of travel attracted is more variable than might be expected on the basis of size alone. Each campus seems to be unique in terms of its proportion of resident students, its acreage and building layout, its regulations on student car use, its faculty-to-student ratio, and other

individual characteristics. This study shows that travel is highly auto-oriented. About 90% of all nonwalking trips are by drivers or passengers. Less than 10% are by transit, and the use of taxis is practically nil.

University travel impact on the highway network is related to size of both the university and the community. Large institutions, depending on their location and on the adequacy of the adjacent highway network, may create critical capacity problems not only for campus-bound traffic but also for all traffic. Providing campus parking may be the primary concern of many university officials, but this is only a part of the larger transportation impact problem.

State Capitol Complexes

Tripmaking to the selected state capitol complexes, as designated for this study, is surprisingly light. Daily two-way vehicular trip generation ranges up to only 8,000 trips. Peak hours are sharp, however, and suggest the possibility of local traffic engineering problems—particularly where parking spaces are in short supply.

With the expected rapid growth in state government, many states are preparing master plans to expand their capitol centers. The trip generation resulting from this consolidation and expansion of existing state services could begin to have significant impact on the highway system.

Office Buildings

Most city dwellers are well aware of the office building boom, although it is often associated with New York City where one-half of the office space in the United States is located. But almost all metropolitan areas have participated in it. The postwar demand for new buildings has stemmed from several factors—continued growth of population and employment, the increased share of employment housed in office buildings, increased amount of floor space per worker, and the functional obsolescence of many older buildings.

Twenty major office buildings, located in nine urban areas with from 100,000 to 1,500,000 population, were selected for this study. They were often the biggest or otherwise most outstanding in their communities. Person trips to and from these buildings ranged from 3,200 to more than 11,000 daily. Beside other land areas examined in this study, such volumes seem small. But because office buildings cluster together in small land areas, they may be collectively responsible for more traffic congestion than any other single land-use category.

Travel to office buildings by trucks and taxis accounts for almost 10% of daily vehicle trips. At owner-tenanted buildings as much as one-third of the daily person movement may take place in a single peak hour. For all buildings during the highest peak hour, 18% of the daily total travel occurs in the morning. The evening peak is slightly lower. During these peak hours, an office building may require more than 15% of the nearby street capacity. The fact that trip lengths will increase as the population decentralizes to the suburbs emphasizes the importance of downtown tripmaking impact on the highway network.

CHAPTER ONE

INTRODUCTION AND RESEARCH APPROACH

PURPOSE OF THE STUDY

The following paragraphs from the project statement describing the first phase of this research effectively summarize the purpose of the study:

> The development of shopping centers, auditoriums, airports, industrial plants, and other large generators of urban travel increases traffic volumes and changes traffic patterns on the street networks which serve most traffic generators.
>
> It is desirable to determine criteria or values which establish the travel patterns created by these major traffic generators. Such information would be useful in forecasting the effect of various land uses on existing street networks; in providing a better basis for the design of new facilities; and in providing better criteria for the control of land use of this type.

The objective is:

1. Travel time characteristics and other measurers of the adequacy of the street network serving the generator.
2. Time distribution characteristics of generated traffic.
3. Characteristics of the traffic generator, including location, size, type, and intensity of land use.
4. Modes of travel of generated traffic.
5. Competition of similar generators for the same street network.
6. Socio-economic characteristics of the contributory area.
7. Size, density, and degree of development of the contributory area.

The resulting first-phase report was published as *NCHRP Report 24,* "Urban Travel Patterns for Airports, Shopping Centers, and Industrial Plants." This second-phase report considers hospitals, universities and colleges, major office buildings, and state capitol "complexes."

STUDY DESIGN

The design of the study was determined by its expected application. Consistent with the project statement, emphasis is placed on examining factors useful to highway planners and highway designers. In this context, the most important factors are time and place: when travel occurs and where. Factors related to tripmaker and service area socio-economic characteristics help explain the "when and where." Trends are considered because planning and design must look ahead. Thus, the study has a specific focus—the interrelationships of selected land uses and the travel they create—and is not intended as a general treatise on the selected land uses themselves.

It was felt that many factors bearing not only on highway design problems with respect to the generators considered, but also on forecasting and controlling their effect on highway development, could be developed from existing transportation study data. For this second-phase study, travel data from 17 studies were assembled, representing 78 hospitals, 38 universities and colleges, 20 major office buildings, and 6 state capitol complexes. Various socio-economic, land-use, and street system data were also obtained to develop the required relationships.

Meetings were held with each transportation study, or sponsoring highway department and/or consulting firm conducting the study, to discuss the project and to seek help in identifying trip generators for which trips could be successfully isolated. This was often possible by selecting generators which themselves represented an entire traffic zone or subzone, or by selecting generators which could be separated from different generators in the same traffic zone or subzone by utilizing unique two-digit "land-use" trip end coding. The generators were field-inspected to confirm their locations and appropriateness. Reproduced home interview, truck-taxi, and roadside interview survey trip cards (or sometimes whole trip survey "tapes"), and the other necessary study data, were then requested. The next step was to obtain full-record listings of the trip cards and to delete any trips which did not start or end at the selected generator sites. Finally, the "clean" trip cards were tabulated in various special sequences for the analyses. During this task, nearly one-half million punch cards were processed by the researchers.

Using transportation study data had both advantages and disadvantages. The advantages are, first, that there is no other way to acquire so many data so quickly, and at so little cost. The data represent about 70,000 sample hospital trips, about 50,000 university and college trips, about 40,000 office building trips, and about 8,000 state capitol complex trips. Expanded, these samples represent well over a million trips. The cost was less than $6,000, about one-half for the collective cost to the transportation studies of extracting the selective travel data from the areawide travel data, the other half for subsequent processing at a local service center. To have collected, coded, and processed new travel data within the funds available for this project would have yielded an extremely limited data base.

Second, because survey techniques tend to be standardized, transportation study data are highly comparable from city to city. This cannot be said of the many studies of subject generators made by planning and engineering consultants; state, county, and city engineering departments; and other interested agencies. To have assembled data from these latter sources would have yielded separate analyses from which comparisons would be difficult or impossible.

Third, and having considerable practicality, similar data will become increasingly available as a result of the 1962 Highway Act, which makes further federal aid for highway construction contingent upon the development of a continuing transportation planning process. This research may suggest that such data can be utilized more fully for selective trip generation studies than is normally the case. This would appear particularly advantageous to many not already familiar with the application of such data.

The disadvantages are:

(1) The travel surveys are based on samples, and it is impossible to measure exactly the sampling variability that may exist in particular data stratifications; (2) Saturday and Sunday travel is not recorded; (3) The travel survey period seldom exceeds six months duration, failing to reflect all possible seasonal variations in travel; (4) There are random errors in data translation; (5) Travel is never completely recorded.

Additionally, the use of transportation study data imposes restraints on the selection of a representative cross section of subject generators. The cross-section distribution by geographic area and size of metropolitan area is considered by the researchers as very good (see Appendix A). However, the cross section does not purport to be a scientific sample. Rather, it attempts to draw together the experience at subject generators covering a range of sizes and designs reasonably representative of all similar generators in metropolitan areas ranging from about 100,000 to 1,500,000 population.

This approach was necessary, first, because the number of transportation studies from which data could be obtained was restricted—data could not be thoroughly assimilated for a larger number of studies. Second, because within the study areas chosen, there were generally a limited number of the major generators sought (smaller generators were avoided because of higher sampling variability in the origin-destination data). Finally, the mechanics of trip-end coding meant that only generators whose trips could be definitely isolated from surrounding development could be considered.

Having reached a reasonable cross section, three levels of analyses were undertaken: (1) that concerning each trip generator separately, (2) that comparing similar generators in the same city, and (3) that comparing similar generators in all cities. Except in the case of state capitol complexes, only the second and third levels of analyses are provided in this report; although necessary to complete the composite analyses, space limitations prohibit reporting the results of all separate analyses. They are, however, reserved in the materials submitted to the NCHRP as part of this final report.

REPORT ORGANIZATION

Following the body of the report, successive appendices deal separately with each subject generator. Each is self-contained and can be read without reference to the others. Also included is an annotated bibliography.

CHAPTER TWO

FINDINGS

The information in this report was developed from a literature search and examination of statistical data already collected which dealt with the subject material. For this reason, the summary of findings in this chapter is quantitative rather than qualitative. The advantage of this approach is that the data give opportunity to compare developing trends in a wide variety of locations. A new study involving initial research within the scope of the project budget would seriously limit the data source.

In general, transportation study data are subject to various degrees of sampling variability. But they can be used effectively to study the many characteristics of travel to specific major generator sites. The findings reflect the occasional difficulty of using floor space or acreages as single variables to predict trip generation at specific sites. This, however, is not meant to detract from the effectiveness of the trip generation process at the traffic zone, district, ring, or sector level, where the aggregation of trips and land areas or floor space for a number of like land uses can produce meaningful indicators of trip generation.

The nature of this report is to explore relationships between hospitals, colleges and universities, office buildings, and state capitols. This chapter attempts to recount the major findings in concise statements. Related findings are given throughout successive chapters and appendices.

HOSPITALS

The following findings are associated with 78 hospitals in 16 metropolitan areas. The sample represents a variety of characteristics—in hospital types and sizes, administrative controls, locations within the metropolitan areas, ages, services available, and so forth. Therefore, in most cases, the following findings tend to be generalized.

1. Among the 58 short-stay general hospitals in the cross section, two-way travel ranges up to 25,000 person trips on a typical weekday. Among the 4 additional short-stay hospitals which are part of major university campuses, two-way travel ranges up to 20,000 person trips on a typical weekday.

2. Among the 11 long-stay Veterans Administration hospitals in the cross section, two-way travel ranges up to 6,000 person trips on a typical weekday. Among the 4

long-stay mental hospitals, two-way travel ranges up to 3,000 person trips on a typical weekday.

3. Relative trip generation varies by hospital type: university hospitals average 8.5 daily trips per bed; other general hospitals, 5.8; VA hospitals, 2.7; and mental hospitals, 0.4 daily person trips per bed. However, since long-stay hospitals tend to be larger than short-stay hospitals, they can be major travel generators, also.

4. Trips to work account for about 47 percent of all trips to university hospitals, and about 42 percent of all trips to other general hospitals. University hospitals also attract a high percentage of trips "to school" by medical students. Thus, trips by patients and visitors account for only about 27 percent of all trips to university hospitals, as against 44 percent of all trips to other general hospitals.

5. By contrast, VA hospitals attract 53 percent work trips, and mental hospitals attract 74 percent work trips. Trips by patients and visitors account for 36 percent of all trips to VA hospitals, as against only about 19 percent of all trips to mental hospitals.

6. About 85 percent of all trips to university, VA, and mental hospitals are by automobile. About 77 percent of all trips to other general hospitals are by automobile. About 10 percent of all trips to university, VA, and mental hospitals, and about 17 percent of all trips to other general hospitals, are by transit. Taxis generally account for less than 2 percent. "Walk-to-work" trips—the only type of walking trip considered throughout this report—generally accounted for between 3-5 percent.

7. Transit use is higher at hospitals located nearest central business districts, and lower at hospitals with suburban locations; is higher at hospitals in large cities, and lower at hospitals in small cities. This is partly because transit service tends to be best toward the center of large cities.

8. Transit use is least likely among males, licensed drivers, and professional and technical workers. In terms of tripmaker attributes, however, car ownership is the key determinant of modal choice: persons without cars are by far the most likely to use transit.

9. Hospitals are not major generators of truck trips—trucks accounting for only 5-6 percent of the daily vehicular tripmaking. About half are made by pickup and panel trucks. (Ambulance tripmaking is not identifiable in the typical truck-taxi survey, nor was it meant to be a major concern of this study.)

10. Except for a dip in November and December, hospital travel is fairly constant throughout the year. Day of the week patterns vary, usually with many admissions early in the week, and many discharges late in the week.

11. Hospital travel peaks three times a day: between 7-9 AM, between 2-4 PM, and again between 7-8 PM. In general, doctors come and go all day, nurses work three shifts, and other employees work a single daytime shift. Inpatients are discharged in the morning, and admitted in the afternoon. Outpatients arrive and depart all day. Peak visiting hours are in the early afternoon and the early evening.

12. Trip lengths vary with city size and hospital type, but, on the average, are quite short: 3-4 airline miles, or 15-20 minutes. Trips to VA and university hospitals are slightly longer, and trips to mental hospitals slightly shorter than trips to other general hospitals.

13. Even the largest hospitals generate less than 1 percent of total urban area travel. Nevertheless, they can have significant local impact on the highway system—examples requiring up to two-thirds of the capacity of the main access road during peak hours.

14. Local congestion because of insufficient parking facilities is probably the most critical hospital traffic problem. Thirty-seven out of 45 hospital administrators indicate that on-street parking is poor to very inadequate. Although most hospital tripmakers report parking free, many hospitals do not provide off-street parking.

15. The average car loading for work trips is 1.1 persons per car: regular car pools are found to be virtually nonexistent. Trips by patients and visitors average 1.5 to 1.6 persons per car; trips by all others, principally drivers picking up or dropping off passengers, average 1.7 to 1.8 persons per car.

16. The number of beds is a good indicator, and the number of hospital personnel an even better indicator, of trip generation at general hospitals. Stratification of tripmaking into work and nonwork trip purposes slightly improves both results. Separate consideration must, of course, be given to the clinic or outpatient services provided. However, neither site acreage nor floor space, as single variables, will produce consistent trip generation estimates.

17. Multiple regression equations incorporating from 5 to 12 "predictor" variables produced the best estimates of trip generation at general hospitals. Nevertheless, though multiple coefficients of determination (R^2) ranged from 0.76 to 0.92, standard errors of the estimate (S_E) were all more than 25 percent of the dependent variable means.

18. Trip rates per thousand population tend to decrease regularly with increasing distance or time. Work trip rates decrease more quickly than trip rates for patients and visitors. In fact, where one hospital principally serves a specific economic, religious, or ethnic group, drawing its patients from a wide geographic area, service areas may significantly overlap.

19. The proportion of trip origins in the major travel corridors converging on a particular hospital can be established reasonably well by applying trip rate curves to the population corridor on either a distance or travel time basis.

20. In a sense, hospitals compete for patients with other hospitals and with medical offices. Since they tend to be fully utilized, however, travel characteristics for any particular hospital can be reasonably predicted for highway design purposes without the elaboration of modeling entire urban areas to account for competitive effects.

21. Examination of all medical-dental trips in two metropolitan areas showed that about one-half are to hospitals, one-half to medical-dental offices. Suburban families had the greater propensity to drive to suburban-oriented medical offices; city families had the greater propensity to ride public transit to city-oriented hospitals.

22. Hospital use has trebled in the last thirty years. This is because of shorter stays per patient, and more hospital personnel per bed, meaning that the daily generation

of patient, visitor, and work trips has increased. With Medicare, and with the role of the hospital in community health problems still expanding, hospital trip generation is likely to continue to grow still more rapidly.

COLLEGE AND UNIVERSITY TRAVEL

The following findings are drawn from travel data associated with 38 colleges and universities in 16 metropolitan areas. The sample represents a broad range of characteristics—in campus sizes and locations, student enrollments, proportions of resident students, administrative controls, and so forth.

1. Colleges are major traffic generators. Daily travel volumes at the selected institutions range from only 500 to over 80,000 person trips. Eight of the sample attract over 10,000 daily vehicle trips. Three experience peak parking accumulations of over 5,000 vehicles, equivalent to that of downtown areas in many major cities.

2. Trips to school account for 45 percent of daily tripmaking, while work trips are only 21 percent. The remaining one-third of daily travel to colleges is made up of mainly social-recreation and serve passenger trips, or trips to home.

3. Auto drivers and passengers make up 84 percent of all the daily trips. Fully 95 percent of all nonwalking trips to work by professional and technical personnel are made by automobile.

4. Transit trips make up 13 percent of daily tripmaking, but are only 3 percent at colleges in cities with less than 100,000 population. In cities of over 1,000,000 population, transit trips average 14 percent of daily college travel.

5. Other factors influencing or related to choice of travel mode are student auto use regulations, household car ownership, and tripmaker characteristics such as sex, race, income, age, and occupation.

6. Colleges attract only 50 truck trips and only 5 taxi trips daily for every 1,000 daily auto driver trips. During peak hours, the proportion of truck trips is typically even less.

7. No seasonal variations during the course of the academic year could be observed from the data, although summer travel is clearly lower than that during the remainder of the year. According to other sources, day of the week variations are slight.

8. Hourly travel patterns at colleges differ from those of most land uses mainly in the higher volumes generated between 6 PM and midnight, when 20 percent of the auto driver trip arrivals and 27 percent of the departures occur.

9. Peak arrival hours are invariably between 7 and 9 AM, and the proportion of daily arrivals in the highest hour varies inversely with the proportion of resident students. The peak departure hours occur at various times during the afternoon, but almost uniformly average 16 percent of the daily departures.

10. The peak-hour two-way flow as a proportion of daily two-way volume varies according to campus population, from 17 percent at the smallest to 10 percent at the largest universities. Other design-hour factors include an 80-20 directional imbalance and truck trip average of 1 percent during the peak.

11. Travel times and trip lengths increase with increasing size of communities. The range in values is wider for auto driver trips than for transit trips, but transit trips in every community take longer than the counterpart auto driver trips.

12. By trip purpose, school trips are longest at 4.0 miles, compared with the over-all average of 3.6 miles. Work trips average 3.5 miles, and the remaining trips are shortest at 3.2 miles.

13. Parking provisions are highly variable from one institution to another. Off-street parking accommodates 86 percent of all work trips, but only 60 percent of all other trips. The proportions of paid parking rise with increasing campus population.

14. Car occupancy for both work and school trips is 1.2 persons per auto. All other trips, weighted by serve passenger and social-recreation purposes, average 1.7 persons per auto to give an over-all car loading of 1.4 persons.

15. Relationships between trip categories and single measures of college characteristics do not provide a sound basis for trip generation analysis. For example, a high correlation is found between person trips to work and faculty-staff employment, but the standard error is almost one-half the mean value of the data.

16. Multiple linear regression incorporating both university and community variables provides higher correlations than does simple regression, but standard errors are still large. Person trips to work appear most amenable to sound prediction.

17. The distribution of college trip origins at various distances or travel times can be described by trip rate curves based on trips per thousand population. All trip rates decline nonlinearly with increasing time or distance, but slight variations exist by trip purpose.

18. Beyond the unique influences of immediate residential or other surrounding, the orientation of trip origins by sector can be predicted from trip rate curves and population data. Distribution of volumes on access highways, therefore, can be assessed reliably for analysis of college impacts on highway systems.

19. Predicted distributions of trip origins by sector can be improved by adjusting for the higher than normal trip rates associated first with central business districts and second with those areas having less accessibility to all colleges than other areas at equal travel time from the institution.

20. Several factors may synergistically affect the growth rate for automobile trips generated by colleges and universities. These include increasing car ownership levels, growing college enrollments, decreasing or static proportions of resident to nonresident students, and the need by new institutions for suburban or outlying locations. The automobile, under such circumstances, must attract an increasingly dominant share of total tripmaking.

STATE CAPITOL COMPLEXES

The following findings are based on state capitol complexes in six states. In two cases, only the original capitol buildings are included; in the others, from two to four major buildings make up the complex. The principal differences among them are in the number and variety of state agencies involved.

1. Tripmaking to the selected state capitol complexes is surprisingly light, ranging up to about 11,000 two-way person trips and 8,000 two-way vehicle trips a day.

2. About 61 percent of all trips are as auto drivers, 22 percent as auto passengers, 13 percent as transit passengers, 3 percent as "walk-to-work," and 1 percent as taxi passengers. Since the capitols are centrally located, specific transit use relates very much to areawide transit use.

3. About two-thirds of all trips are to work, 19 percent for personal business, 10 percent to drop off or pick up passengers, and 4 percent for social-recreation. Although during the season capitols may attract many tourists, during the regular work week they are primarily work places.

4. The predominance of work trips creates sharp morning and afternoon travel peaks. Almost 60 percent of all person trips arrive between 7 and 9 AM; about 55 percent depart between 4 and 6 PM. Transit travel is typically more peaked than automobile travel.

5. Average airline trip lengths are most directly related to the size of the capital city. Work trips are slightly longer than trips for other purposes, mainly because more of the latter are nonhome based.

6. Only about one out of six auto driver trips to the cross-section capitols required paid parking. Most auto drivers used free, off-street spaces at convenient distances. Car pooling is infrequent: car loading for work trips averaging 1.2 persons, and for nonwork trips, about 1.6 persons.

7. On the average, vehicular traffic is composed of 89 percent passenger cars, 6 percent light trucks, 4 percent medium and heavy trucks, and 1 percent taxies. At peak hours, passenger car units account for over 98 percent of the vehicle trips arriving or departing.

8. Although recurrent out-of-town assignments create higher than average absentee rates, there are about 0.9 daily person trips to work per employee. On the average, there are about 0.5 daily person nonwork trips per work trip.

9. State capitol complexes often combine new buildings with old together housing many separate departments, each of which may provide different amounts of floor space per employee, and attract different levels of visitor tripmaking. Thus, floor space trip generation rates are inconsistent.

10. Trip rates per thousand population decrease with increasing distance or travel time from the capitols. Trip origins tend to be directionally distributed according to the population distribution. Combined, these relationships provide a convenient method for estimating the proportion of traffic volumes approaching from designated travel corridors.

11. State capitol complexes seldom account for all state office employment in the capital cities. Where comprehensive plans call for consolidating scattered employment, the resulting trip generation would be much higher than indicated in this report.

12. In the future, regular office functions may more often be separated from legislative and judicial functions, and relocated in more spacious suburban surroundings. This can be one means of accommodating the surging growth of employment in government, and the resulting increase in trip generation and travel impact on the highway system.

OFFICE BUILDING TRAVEL

These findings are based on travel data for 20 office buildings, usually the largest or otherwise most outstanding in the nine cities represented. They range up to a million sq ft of floor space, and from 4 to 44 stories.

1. Public buildings average 6,000 two-way daily person trips, while private buildings average 5,700 trips. Two-way vehicle volumes range between 1,500 and 9,000 trips daily for public buildings; between 800 and 5,500 trips daily for private buildings.

2. Two-thirds of all trips are to work—slightly more for private buildings, slightly less for public buildings. Personal business trips account for over a quarter of the total trips to public buildings, but only 20 percent of the total for all buildings.

3. Three-fourths of all office building trips are by automobile (10 percent higher for owner-tenanted buildings). About 20 percent of all trips are by transit. The remainder consist of walk-to-work and taxi trips.

4. Factors relating to variable levels of transit tripmaking include: over-all central business district transit trip proportions, and tripmaker race, sex, occupation, and car ownership.

5. There are 8 truck trips for every 100 auto driver trips to office buildings (a figure surprisingly higher than for any other land use studied). Less than 2 percent of all vehicle trips are by taxis.

6. Seasonal or day-of-week travel variations could not be found in the study data. However, some public buildings clearly attract periodic peak volumes due to vehicle registration schedules, court sessions, elections and other special events.

7. Two-way peak-hour travel at private buildings is 20 percent of the daily travel. The public building peak hour is only 18 percent, because more public building trips occur in mid-day.

8. The average length of stay per tripmaker is 6.5 hours at private buildings. It is an hour less at public buildings because of the more numerous short personal business trips. Length of stay for auto driver trips is less than for auto or transit passenger trips.

9. Reported travel times and trip lengths, which range from 2.3 to 5.4 airline miles, both increase with increasing size of the urban area.

10. On-street parking is used by a third of all public building auto driver trips, but by only a sixth of those to private buildings. Almost one-quarter of all auto driver work trips parked on-street.

11. The maximum accumulation varies by building type. For owner-tenanted buildings, it averages 61 percent of the daily auto arrivals; for multi-tenanted and public buildings, respectively, it averages 36 and 42 percent.

12. Car occupancy for office building auto driver trips

is 1.3 persons per car—lowest of the land uses studied. Work trips average 1.2 persons, and all other trips, 1.6 persons.

13. Employment and trip generation are highly related. However, floor space is also a good indicator of office building trip activity. Private building trips can be more reliably estimated than public building trips.

14. Trip rates per thousand population decline regularly with increasing time or distance from the building. The distribution of office building trips to access routes can be approximated by applying such trip rate curves to population data grouped by travel corridor.

15. More precise distribution estimates should take into account the variability in trip rates associated with accessibility and income differentials with the urban areas. All other things being equal, higher trip rates to office buildings occur in areas with higher income and lower accessibility characteristics.

16. Office building auto driver trip rates are likely to increase as time passes. Though person trip rates related to floor space may hold steady, increased car ownership and decreased transit service prompt more auto use. Trends toward suburban office park construction will further support growth in automobile travel to office buildings.

CHAPTER THREE

APPRAISAL AND APPLICATION

This chapter is intended to answer such questions as what do the findings mean—how can they be used in standards, specifications, policies, and procedures? What do they add to our understanding? What effect do they have on economy, safety, amenities, convenience, or other desirable attributes of transportation? It is intended, also, to appraise —in retrospect—the reliability and completeness of the findings themselves.

APPRAISAL OF FINDINGS

The findings are subject to the advantages and disadvantages inherent in transportation study data. Some were mentioned by way of introduction. Others will have become apparent throughout the succeeding appendices. It is felt, all things considered, that selected types of major traffic generators can be examined successfully by using transportation study data. Curiously, this approach was first taken some 20 years ago, but never rigorously followed up. The precursor report concluded:

> It can only be said that the results hang together with remarkable consistency. The data show that . . . . [people] . . . . travel when they are believed to do so, in the proper order of numbers, and by the presumed modes of transportation. These encouraging conformities lead one to believe that the suggested method, when applied to a number of other generators in various localities, will yield results from which generalizations may be drawn.

Thanks to experience and computer processing, transportation study data today are more complete and more accurate than in 1948. They have been used for many purposes other than the preparation of long-range transportation plans. The present use—to describe the major characteristics of travel to specific sites—represents but another logical application which has been too seldom made. But problems arising from sampling variability remain. Although conventional reporting calls for treating the data as if they were exact, and although percentages, ratios, and other relationships may show several decimal places, the reader should understand that interpretive judgment is required. Generalizations may safely be drawn from the results, but they should be considered approximate.

Such results also leave certain gaps, as follows:

1. The transportation study data represent single points in time (that is, typical travel weekdays in particular years) and these are different for each of the different studies.
2. In representing the typical weekday over a span of 2 to 12 months, study data tend to average out the peaks and valleys of travel on different days. This is perhaps more an advantage than a disadvantage—certainly it is unlike dealing with data produced by travel interviews or traffic counts for a given day, or for several days, as customary in most travel surveys.
3. Weekend travel can only be surmised, it is not surveyed by the transportation studies.
4. Walking trips, other than to work, are not accounted for. This might explain difficulties in predicting trip generation at land uses such as downtown office buildings, which attract highly variable numbers of walk-in trips.

Yet many aspects of tripmaking to the subject generators have been shown for the first time. Perspective is provided —documentation of differences and likenesses as they exist from city to city—to augment previous knowledge based on scattered sources of data inconsistently collected and variously analyzed. In presenting diverse findings, simplification has been the rule; much detailed analysis appears finally in highly summarized form. The objective throughout has been to present simple relationships which can be applied to a variety of real situations.

APPLICATION OF FINDINGS

State highway departments, and other transportation agencies, are often confronted with the need to provide improved highway access to a new or existing hospital, college, or office building (and, of course, any number of other land uses). Requests by developers may be predicated on little more than a guess at vehicular trip generation, its distribution in time and space, and its impact on the adjacent highway system. Even where traffic estimates have been made by the developer's consultants, the prudent highway department will typically review those estimates for reasonableness. The factors and relationships presented in this report should provide additional guidance to traffic planning engineers faced with making such reviews for highway design purposes.

Where the generators are public rather than private enterprises, there should be fewer problems of communication between developers and transportation agencies. Yet the literature suggests that even public developers do not make extensive studies of the impact of their proposals on the adjacent highway system. Instead they rely on the transportation agencies to do so, in many cases after site plans are well advanced. This report suggests the desirability of bridging such gaps between site planning and traffic planning.

The traffic impact of highly concentrated trip generators may suggest the need for various means of controlling land-use development to maintain efficient traffic flow. It might be logical to rule, for example, that no additional traffic generator, whatever its type, be permitted access to a highway already operating at or near its capacity unless the benefits to the public as a whole are demonstrably greater than the costs of enlarging the highway's capacity. For those who might not share this view, the traffic consequences of permitting or prohibiting extremes of urban development might be pointed up, in part, from the ranges of trip generation established in this report and its predecessor (*NCHRP Report 24*, "Urban Travel Patterns for Airports, Shopping Centers, and Industrial Plants").

The findings may also have utility for transportation study analysts. Seldom do they have the opportunity of looking closely at specific major traffic generators. They are concerned, rather, with patterns of land-use types through entire metropolitan areas. Specific generators should sometimes have close scrutiny, however, because they can create as many trips as most entire traffic zones. This is clearly recognized in the new U.S. Bureau of Public Roads publication, "Guidelines for Trip Generation Analysis." Values presented here may be suggestive of the traffic growth potential at subject generator types—a basic ingredient of long-range planning.

Transportation studies in the future will probably concentrate more attention on specific major generators. One reviewer of the draft of this report, involved in the preparation of a prospectus for a new study in his city, said that it had provided him with certain ideas for adapting his study design toward better coverage of major generators, particularly where standard home interview techniques could be improved for the purpose. The report may be similarly suggestive to state highway department planning divisions and others active in the design and supervision of new transportation studies.

Traffic divisions may find applications in the hourly and directional traffic data ranges provided. Although precise traffic counts are not available in this report, various percentages have been presented, and these should have an acceptable accuracy for problem-scaling purposes. City-to-city comparisons show that many traffic patterns are much the same, consistent with the differences in the metropolitan areas themselves. Citation of such patterns might counter the frequent claim that "our situation is so different and special" that an extraordinary remedial treatment is required.

In summary, however, the principal application of the findings of this report might be thought of as informational. There were no physical problems concerning structures or materials to be settled. There were no geometric design problems concerning cross sections or interchanges to be solved. Rather, the objective was to explore the relationships between travel to four specific types of land uses and the various factors that influence such travel. The resulting relationships should have a variety of applications.

CHAPTER FOUR

CONCLUSIONS AND SUGGESTED RESEARCH

The application of transportation study data in an examination of land use-travel relationships for specific major traffic generators is perhaps unusual. The approach takes advantage of vast amounts of data already available, always an attractive concept. The data are more complete in many respects than those obtainable through parking lot interviews or various return postcard techniques. Treatment provides broad perspectives about different parts of the trip generation-trip distribution problem, ranging from tripmaker attributes to actual traffic on the highways.

Transportation study data were not, however, designed for this type of examination. As a result, there are gaps in the sequence of relationships—unknowns left to be puzzled over. Where significant questions cannot be answered from other sources, they merit identification as topics for further research. By way of supplementing previously presented conclusions, the remainder of this chapter sets forth suggestions for continued research.

HOSPITAL TRIPMAKING

Continuous Counter Installations

There are no known installations of continuous, road-tube-actuated traffic counters at hospitals. Mechanical counts, supplemented occasionally with manual classification counts, offer ready means of directly relating traffic to hospital activity in terms of inpatients, outpatients, visitors, and staff. Taken through a full year, at several major hospitals each having a limited number of vehicular access points, such counts would help establish monthly, daily, and hourly traffic factors useful for highway design purposes. Although this information might have limited application for any single state highway department, there are sufficient new hospitals being built in suburban locations throughout the United States that some research effort in this direction seems warranted. Similar effort, where continuous counting is physically feasible, might be worthwhile for a whole range of major land uses.

Tripmaking Separated by Health Care Function

With the role of the community general hospital now embracing family planning services, home care programs, rehabilitation services, mental health, and so forth, trip generation at hospitals is increasing, but cannot be readily related to the number of hospital beds or hospital personnel. At major hospital centers, particularly, it would seem useful to establish travel parameters for such separate functions. This cannot be done with transportation study data due to lack of more detailed trip-end land use or trip purpose coding (such coding simply indicates a "hospital" land use or a "medical-dental" trip purpose). Further, for a more complete knowledge of all travel for health purposes, various non-hospital health care centers—such as nursing homes and other extended-care facilities—also merit separate attention (they were excluded from the present work). Special, on-site studies would appear appropriate for both purposes.

Hospital Parking Problems

The shortage of parking space at center-city hospitals appears to be a chronic problem that the hospitals alone cannot solve. Convenient parking would, of course, help to relieve one of the many natural anxieties of hospital tripmaking, and would also smooth the flow of through traffic. It is suggested that a study group be commissioned to assess the magnitude of the parking problem, along with access requirements generally, at public and private hospitals throughout the country; to study the full range of possible solutions in terms of costs, financing, and legal requirements for action; and to make recommendations. The study group might logically include not only hospital administrators, but also federal, state, and local officials from both health and highway agencies. So far as is known, such a study has never been made.

Hospital Travel Trends

Will total hospital travel be reduced through technological advances which will allow adequate treatment short of hospital confinement? Answering this question means asking others: What degree of substitution can exist between hospitals and medical office buildings? Can the latter assume more of the diagnostic role of hospitals? For that matter, can patients be tested at home by medical technicians "wiring" them into diagnostic machines at remote hospitals? By way of exploration, hospital planners might usefully look at all trips reported for "medical-dental" purposes (in transportation study data) for a national cross section of urban areas. Such work should help explain the present comparative "service areas" of hospitals vs medical office buildings vs individual doctor's and dentist's offices, and should shed further light on the possible travel implications of alternate locations for planned hospitals.

COLLEGE AND UNIVERSITY TRIPMAKING

Trip Generation Refinements

Various refinements needed for making better estimates of college and university trip generation can readily be suggested. Most cannot be examined by using transportation study data. For example, in this report whole campuses were considered; problems associated with sampling variability militated against the disaggregation of tripmaking by campus activity (that is, the separation of trips to administrative buildings, regular classrooms, athletic stadia, dormitories, etc.) and subsequent comparisons with matching values of floor space, desks, seats, employment, etc. Likewise, problems associated with tripmaker age and occupation coding made it impossible to segregate undergraduate and graduate students, academic staff, and other staff, even though secondary sources suggest marked differences in their daily travel activity. This meant, too, that because student class could not be established, the effect of campus car registration policies could not be related to tripmaking by individual students. Refinements such as these—and others which the reader will recognize—should by virtue of further study significantly improve trip generation estimates.

Trip Distribution Refinements

Although trip rate curves depicting trip origins per 1,000 population can be used with population data to provide acceptable directional distributions of trip origins, the average trip rates developed from transportation study data often mask tripmaking variations within subareas at equal times or distances from the institution. Differences in average family income and travel accessibility factors appear primarily responsible for these variations. Related differences in age-sex-race distributions by subarea may also have some effect. The direction and magnitude of the CBD-institution trip interchange is another complicating factor. Further study of these influences for several urban areas which combine large trip samples for a number of different institutions with accessibility measures, family income, and related population attributes, should lead to improvements in predicting the directional distribution of trips.

Cooperative Transportation Planning

Central business districts are commonly accepted as focal points in the preparation of areawide transportation plans. Both external approaches and internal circulation systems are matters of public concern. Planning tends to be highly cooperative. Because major universities generate as many trips as some central business districts, and create similar internal and external travel requirements, the planning of associated transportation facilities should be equally cooperative as a matter of public concern. This seems however, not always to be the case. Sometimes, even where through traffic routes bisect the campus, major universities seem free to plan for internal circulation as though they were not part of the larger community. The reverse situation, where universities have too little control over planning and operating through traffic routes on campus, also occurs. To alleviate some of the resulting problems, it would seem desirable that guidelines for stronger cooperative planning be established, not only locally but also at the state and federal levels. Research aimed at disclosing variations in existing planning policies should make a good beginning.

CAPITOL COMPLEX TRIPMAKING

Transportation Implications of "Complexes"

Studies-in-depth of travel to *all* state government offices in the capital city should be part of master planning for State Capitol development. In view of expanding governmental services, two main questions relating to transportation planning can be raised: First, will it be necessary for the States to plan enlarged, consolidated complexes, or would a policy of decentralized offices be better? Second, if consolidated complexes are favored, what location would be most effective—central city or suburban? The alternatives could have significant influence on areawide transportation plans. Centralized complexes could create more transit demand, whereas suburban complexes, or no complex at all, could create more highway demand. It is suspected that current State Capitol master plans do not always fully account for such transportation implications.

OFFICE BUILDING TRIPMAKING

Trip Generation by Establishment

The broad range in trip rates per 1,000 sq ft of office building floor space is probably a consequence of the unique array of activities associated with some buildings. More accurate trip generation data might be obtained by aggregating separate trip estimates based on individual establishments. The problem of small trip samples to particular activities within buildings might be overcome by assembling all the trips for a given central business district by detailed types of office building activities. The resulting activity trip rates might then be evaluated by comparing actual trips to selected buildings with predicted trips built up from estimates for the individual establishments therein. The principal needs of sufficiently detailed land-use classification, floor space measurements, and travel data could probably be met by many recent urban transportation studies.

Improving Trip Distribution Techniques

Although the directional orientation of office building trip origins can be estimated from population data and composite trip rate curves, actual trip rates are known to vary as between areas at equal times or distances from downtown. These variations seem related, as they were for colleges and universities, to accessibility factors, family income, and other population attributes. Consideration of trips to *all* office buildings within some selected central business district would permit the more complete investigation of these influences, by providing sufficient samples for trip stratification, not only by types of office building activity and by trip purpose, but also by smaller time or distance increments for sectors of varying income or accessibility levels. Such further refinement of the trip distribution technique, if sucessful, could provide a valuable tool not only for treating individual office buildings, but also for treating a significant portion of central business tripmaking as a whole.

Office Buildings and Peak-Hour Travel

Staggered office hours are often suggested as a way to reduce downtown street congestion. Whether significant results can be achieved is usually speculative. Transportation study data could provide a starting point: examination of trip arrivals and departures by type of office activity, by block, or, where possible, by individual building, by 6-min intervals, would show what degree of staggering presently exists (it may be more than commonly supposed), and maximum and minimum trip rates within the peak periods could be assessed. Other factors of timing must also be considered; that required to park or unpark automobiles, that required to walk to and from office buildings, the waiting time at elevators, even the time required to thread through the central business district before parking or unparking. Further consideration of these additional aspects of staggered hours at particular buildings might end speculation about the results.

APPENDIX A

INFORMATION ON TRANSPORTATION STUDIES FURNISHING BASIC TRAVEL DATA

STUDY	HOME INTERVIEW		SCREEN-LINE CHECK (%)	STUDY AREA DATA		NO. OF SAMPLE SITES ANALYZED [a]			
	DATES	SAMPLE SIZE (%)		AREA (SQ MI)	POP. (MIL.)	HOS.	UN.	CAP.	OFF.
Atlanta Area Transportation Study [b]	2/61-7/61	5	95	200	0.6	5	3	1	2
Ann Arbor Metropolitan Area Traffic Study	4/60-6/60	8.33	77 [c]	45	0.1	2	1	—	—
Durham Urban Area Transportation Study	9/64-1/65	12.5	80	98	0.1	3	2	—	—
Indianapolis Regional Trans. and Devel. Study	8/64-11/64	5	91	493	0.7	6	2	1	—
Madison Area Transportation Study	4/62-8/62	10	93 [c]	129	0.2	5	1	1	1
Miami Area Transportation Study	3/64-4/64	5	87 [c]	400	1.1	5	2	—	3
New Castle County Planning Program	9/64-11/64	6.67	92	437	0.4	5	1	—	3
New Orleans Metropolitan Area Trans. Study	5/60-10/60	5 and 10	83	250	0.9	7	3	—	1
Niagara Frontier Transportation Study	6/62-8/62	4	96	810	1.3	12	2	—	—
Pittsburgh Area Transportation Study	9/58-11/58	4	90	420	1.5	4	3	—	3
Puget Sound Regional Transportation Study	7/61-11/61	4 and 10	95	1269	1.5	5	5	—	4
Raleigh Urban Area Transportation Study	9/64-1/65	12.5	75	154	0.1	3	4	1	—
Rhode Island Statewide Traffic Survey [d]	1/61-8/61	5 and 10	82 [c]	295	0.8	—	—	1	—
Salt Lake Area Transportation Study	10/59-9/60	6.67 and 10	91	350	0.4	1	2	1	1
Tucson Area Transportation Study	12/59-5/60	10 and 20	87	612	0.2	3	1	—	—
Twin Cities Area Transportation Study	7/58-11/58	5	84 [c]	890	1.4	10	4	1	2
Wichita Area Transportation Study	5/60-10/60	8.33	88	410	0.3	2	2	—	—
All						78	38	7	20

[a] Hos. = hospitals; Un. = universities; Cap. = capitols; Off. = office buildings.
[b] Home interview and truck-taxi travel data only.
[c] Home interview travel data subsequently factored up.
[d] Home interview travel data only.

APPENDIX B

HOSPITALS

Hospitals constitute one of the nation's largest industries. About 7,200 hospitals employ nearly 2 million people and meet an annual payroll of $8.5 billion. Total annual operating expenses are about $13 billion. More than 1.7 million beds serve 30 million patients a year.

Hospitals have increasingly diverse purposes in addition to caring for the sick. They also dispense charity, serve religious aims, protect the public by confining those who are insane or suffer contagious diseases, and promote the public health through research and education. As a result, hospitals are often major travel generators.

This appendix presents factors and relationships by which transportation planners, traffic engineers, and highway designers can be guided in providing effective highway service to hospitals. Travel to and from 78 sample hospitals has been analyzed from the results of area-wide transportation studies in 16 urban areas (see Appendix A). Except for walking trips other than to work, tripmaking by all travel modes for all purposes has been considered. Such tripmaking represents an average weekday, excluding Saturdays and Sundays, for the typical three- to six-month origin-and-destination survey. Total hospital sites are considered, including, for example, clinics, medical schools, and nurses homes, where they are clearly an integral part of the hospital complex. Although sometimes it may have been impossible to separate some trips to peripheral development, this is deemed a minor problem.

The distribution of sample hospitals by administrative control by number of beds is given in Table B-1. Generally speaking, most of the sample hospitals are very large—that is, the average number of beds by administrative group is greater than the national average. This was a deliberate selection in order to minimize the sampling variability in reported tripmaking. For example, the average number of beds for the sample groups for "church related or operated" and "other non-profit" hospitals is 375 and 385 beds, respectively; the 1960 national averages (the median year of the trip data) were 155 and 124 beds, respectively. The average number of beds for all nonfederal short-stay hospitals in the sample is 470; the 1960 national average was only 118 beds (*1*).

In Table B-1, four of the six state-administered hospitals are long-term mental institutions, one is part of a "medical center" in a large southern city, and one is part of another "medical center" in a large midwestern city (incorporating a university-affiliated medical school, a Veterans Administration hospital, and both city and county hospitals). Three of the four university hospitals are integral parts of "Big Ten" university campuses, and the fourth is an integral part of a large southern university campus. All provide service to the public at large. One of the eleven Veterans Administration (VA) hospitals is a tuberculosis hospital; the remainder are general hospitals. Except for one "childrens" hospital in the "other non-profit" group, all other hospitals

TABLE B-1

SAMPLE HOSPITALS BY ADMINISTRATIVE CONTROL BY NUMBER OF BEDS

ADMINISTRATIVE CONTROL	NO. OF HOSPITALS WITH UNDER 300 BEDS	300-399 BEDS	400-499 BEDS	500-599 BEDS	600-999 BEDS	1,000 BEDS PLUS	TOTAL
State	—	—	—	—	—	6	6
County	1	1	—	1	2	1	6
City	—	—	1	—	—	—	1
City-county	—	—	—	—	1	—	1
Church related or operated	8	8	5	—	3	—	24
Other non-profit	2	16	3	2	1	—	24
Public Health Service	—	—	1	—	—	—	1
Veterans Administration	—	3	5	1	1	1	11
University	—	—	1	—	3	—	4
All	11	28	16	4	11	8	78

Source: *Hospitals* (Guide Issue). Amer. Hosp. Assn. (var. years).

in the cross section are general hospitals. For most analytical purposes, the 78 hospitals are grouped functionally: 59 general, 11 VA, 4 university, and 4 mental. Subsequent reporting will show that there are significant travel differences for these functional groupings, particularly when general hospitals are further grouped by number of beds.

Generally, no attempt has been made to account for the different services provided by the different hospitals. Although services are not exactly alike for all the general hospitals in the cross section, they appear sufficiently alike to be discounted as major factors in explaining trip generation differences. Possibly this results from having selected the largest hospitals for each urban area considered. Comparison of services provided, from *Hospitals* (Guide Issues), shows that most offer the same essential facilities (Table B-2).

TABLE B-2

PERCENTAGE OF NONFEDERAL SHORT-STAY GENERAL AND OTHER SPECIAL HOSPITALS REPORTING SELECTED FACILITIES AND SERVICES

FACILITIES AND SERVICES PROVIDED	NATIONAL AVG., 1965 (%)	CROSS-SECTION HOSPITALS, SURVEY YEARS (%)
X-Ray, diagnostic	98.4	100.0
Clinical laboratory	97.6	100.0
Operating room	97.5	100.0
Emergency department	92.8	98.3
Delivery room	89.6	100.0
Organized hospital auxiliary	70.4	66.1
Postoperative recovery room	69.0	94.9
Blood bank	61.4	89.8
Premature nursery	59.9	98.3
Pharmacy	58.5	98.3
Pathology laboratory	56.6	81.3
Physical therapy department	51.7	93.2
Chapel or prayer room	46.6	67.8
Outpatient department	39.4	81.3
Established chaplaincy service	38.5	—[a]
X-Ray, therapeutic	37.1	93.2
X-Ray, admission (chest)	34.9	50.8
Dental facilities	32.6	55.9
Radium therapy	32.0	—[a]
Radioactive isotype facility	30.1	88.1
Electroencephalography	27.7	71.1
Intensive care unit	26.7	39.0
Social work department	17.3	—[a]
Psychiatric inpatient unit	13.3	11.9
Occupational therapy department	11.2	42.4
Cobalt therapy	10.5	—[a]
Rehabilitation unit	7.1	15.2
Home care program	5.0	10.2
Family planning service	4.8	3.4

[a] Definition not used, or not consistently used, in the earlier (trip) survey years.

Source: *Hospitals* (Guide Issue) (var. years). Amer. Hosp. Assn.

GENERAL TRIP CHARACTERISTICS

Mode and Purpose of Person Travel

MODE, BY TRIP PURPOSE

Table B-3 shows the dominant dependence upon the automobile in getting to the hospital. (In this report "to" means literally trips to the subject generator from nongenerator origins; "from" means literally trips from the subject generator to nongenerator destinations.) About 54% of all trips to general hospitals are as auto drivers, 23% as auto passengers, 17% as transit passengers, 1% as taxi passengers, and 4% as "walk-to-work" (the only walking trips considered in this report). About three out of four person trips, then, are by automobile. It should be noted that the percentage travel mode distribution is much the same regardless of hospital size, with two exceptions: the groups with 500 to 599 beds, and over 1,000 beds, each contain a hospital with a sufficiently high proportion of transit tripmakers to reduce the "normal" proportion of automobile tripmakers.

At veterans, mental, and university hospitals, the dependence on the automobile is still more pronounced. The combined proportion of auto drivers and auto passengers consistently runs about 85%. The proportion of transit passengers consistently runs about 10%. Taxi tripmaking is minimal and walk-to-work trips run 3 to 5%.

Part of the apparent difference in travel mode distribution between the different types of hospitals may be traced to their differing functions. At long-stay veterans and mental hospitals, there is less patient and visitor tripmaking, and staff workers represent a higher proportion of the daily trip activity than at short-stay hospitals. As will be shown, staff workers are more likely to drive than are patients and visitors.

Despite the regularity of the averages in Table B-3, there is much variation when hospitals are considered individually. Auto driver trips to general hospitals, for example, range from 27 to 84%; transit passenger trips range from 1 to 53%. There is also significant variation city by city. For all general hospitals in New Orleans, for example, auto drivers represent only 40% of all tripmakers; in Pittsburgh this figure is 43%, in the Twin Cities 53%, in Atlanta 54%, Tucson is the highest at 71%, with the remaining nine cross-section cities having percentages in the 60's. There are corresponding differences in the percentage of transit tripmakers, ranging from less than 2% in Tucson to 39% in New Orleans.

The variation in modal split and other hospital travel characteristics from city to city relates, of course, to variations in total study area travel characteristics, as given in Table B-4. For example, New Orleans has not only the highest percentage of hospital trips by transit, but also of all trips by transit. (It also has the lowest number of cars per dwelling unit.) Table B-4 may be referenced to other chapters and appendices of this report for similar comparison purposes.

In general, from Table B-5 it appears that the larger the city, the greater will be the proportion of trips by transit and the lesser will be the proportion of trips by auto drivers

TABLE B-3

PERCENTAGE TRAVEL MODE DISTRIBUTION, HOME INTERVIEW PERSON TRIPS TO SELECTED HOSPITALS, ALL PURPOSES

		MODE OF TRAVEL [b]					
HOSPITAL TYPE	NO. OF HOSP. [a]	AUTO DRIVER	AUTO PASS.	TRANSIT PASS.	TAXI PASS.	WALK TO WORK	ALL
General:							
Under 300 beds	11	59.0	24.5	12.4	1.1	3.0	100.0
300-399 beds	24	58.1	24.4	10.9	0.9	5.7	100.0
400-499 beds	11	57.5	20.2	16.9	2.8	2.6	100.0
500-599 beds	3	47.7	22.6	21.6	1.8	6.3	100.0
600-999 beds	7	51.6	24.8	17.4	2.2	4.0	100.0
1,000 and over	3	46.5	21.0	26.9	2.3	3.3	100.0
Average	*59*	*54.3*	*23.0*	*16.8*	*1.8*	*4.1*	*100.0*
Veterans	11	64.9	20.8	10.5	0.7	3.1	100.0
Mental	4	64.4	20.1	10.5	—	5.0	100.0
University	4	60.4	25.0	9.5	1.2	3.9	100.0

[a] Unless otherwise specified, this number of hospitals is represented in all subsequent tables.
[b] Throughout this report "auto drivers" includes drivers of rental and company-owned cars, "auto passengers" includes truck passengers, and "transit passengers" includes all forms of public transit.

Source: Transportation study data for various urban areas. (Unless otherwise specifically shown, all subsequent tables are understood to have this same source.)

(general hospitals only). Although the detailed results of a multiple regression analysis are provided later, note that study area population and the percent of transit trips per hospital correlate at $r = 0.55$, and study area population and the number of transit trips per hospital correlate at $r = 0.36$—low values reflecting the considerable variation that exists even within the same city ($N = 57$ general hospitals only).

TABLE B-4

SELECTED TRAVEL CHARACTERISTICS IN STUDY AREAS CONTAINING SAMPLE TRAVEL GENERATORS

	PERSONS TRANSIT TRIPS (%)				PROPORTION OF VEHICLE TRIPS (%)	
STUDY AREA	TOTAL STUDY AREA	CENTRAL BUSINESS DISTRICT	SAMPLE GENERAL HOSPITALS	CARS PER DWELLING UNIT	TRUCKS	TAXIS
Ann Arbor, Mich.	5.1	1.8	— [b]	0.83	5.0	NA [d]
Atlanta, Ga.	9.6	28.4	19.3	0.97	13.3	2.4
Buffalo, N. Y.	10.0	30.8	18.9	1.00	12.1	1.0
Durham, N. C.	6.0	9.8	4.8	0.97	16.1	2.4
Indianapolis, Ind.	8.3	20.0	7.5	1.22	18.2	
Madison, Wis.	7.3	15.8	7.5	1.05	12.8	1.6
Miami, Fla.	8.3	NA	14.5	1.01	NA	NA
Minneapolis-St. Paul	12.4	29.6 [c]	18.6	1.07	15.1	1.5
New Orleans, La.	26.5	50.8	38.5	0.77	26.2	4.3
Pittsburgh, Pa.	20.3	50.8	26.5	0.88	15.2	1.9
Providence, R. I.	7.7	13.1	— [b]	1.01	16.0	1.1
Raleigh, N. C.	3.0	4.5	3.9	1.27	12.4	2.3
Salt Lake City, Utah	5.5	11.4	8.5	1.22	18.0	1.0
Seattle, Wash.	6.0	30.0	10.5	1.19	12.8	
Tucson, Ariz.	4.7	9.0	1.9	1.22	12.9	0.5
Wichita, Kans.	2.3	7.9	2.2	1.13	11.7	
Wilmington, Del.	8.2	13.8	8.8	1.21	19.1	0.6

[a] For strict comparability among all urban areas includes trips by school bus; percentages may be somewhat higher, therefore, than in other published sources.
[b] No sample hospitals in urban area.
[c] Minneapolis CBD (St. Paul CBD = 25.9%).
[d] Not available.

TABLE B-5

PERCENTAGE TRAVEL MODE DISTRIBUTION, HOME INTERVIEW PERSON TRIPS TO SELECTED GENERAL HOSPITALS, ALL PURPOSES, BY STUDY AREA POPULATION GROUP

		MODE OF TRAVEL					
STUDY AREA POPULATION	NO. OF HOSP.	AUTO DRIVER	AUTO PASS.	TRANSIT PASS.	TAXI PASS.	WALK TO WORK	ALL
Up to 250,000	8	67.2	24.2	4.5	1.3	2.8	100.0
250,000-499,000	6	61.7	24.6	4.8	1.6	7.3	100.0
500,000-749,000	9	58.7	23.9	11.0	1.7	4.7	100.0
750,000-999,000	6[a]	39.8	18.1	38.1	3.0	1.0	100.0
1,000,000-1,249,000	14	57.1	22.7	1.2	1.2	2.3	100.0
1,250,000 and over	16	48.6	25.0	19.1	2.0	5.3	100.0
Average	*59*	*54.3*	*23.0*	*16.8*	*1.8*	*4.1*	*100.0*

[a] Includes New Orleans urban area hospitals only; every other group includes hospitals in two or more urban areas.

Throughout this and subsequent discussions, the travel mode distribution for trips from hospitals is basically the same as for trips to hospitals.

MODE, WORK TRIPS

In considering the purpose of hospital trips, it has proved useful to combine the ten more or less standard origin-destination survey trip purposes into four groups: (1) work trips; (2) medical-dental and personal business trips, generally indicating trips by patients or by family and friends providing transportation for patients; (3) social-recreation, eat meal, and ride trips, generally indicating trips by visitors; and (4) serve passenger, shop, school, and home trips. Judging from purpose definitions published by each transportation study, and from comparisons of trip data by purpose, grouped results are reasonably comparable. Hereafter, for convenience, the four groups are called simply work, medical, visitor, and other.

Table B-6 shows that the modal distribution for trips to work is different than for all trips (compare Table B-3). Although there are about the same proportions of auto drivers, there are fewer auto passengers (reflecting lower car loading factors) and taxi passengers, but more transit passengers. Naturally, walk-to-work trips show up as a higher proportion of work trips than of all trips.

About one-half of all work trips to general hospitals with more than 500 beds are as auto drivers, and 22% as transit passengers; to those with less than 500 beds the comparable figures are 57% and 17%, respectively. The proportions of the other modes are generally alike. Considering individual general hospitals, however, work trips by auto drivers range from 24 to 80%; work trips by transit passengers range from less than 2 to 51%.

MODE, MEDICAL TRIPS

Table B-7 shows that trips to general hospitals for medical purposes are more likely to be as passengers in autos, taxis, or transit than as auto drivers. The proportion of auto

TABLE B-6

PERCENTAGE TRAVEL MODE DISTRIBUTION, HOME INTERVIEW PERSON TRIPS TO SELECTED HOSPITALS, TO WORK

	MODE OF TRAVEL					
HOSPITAL TYPE	AUTO DRIVER	AUTO PASS.	TRANSIT PASS.	TAXI PASS.	WALK TO WORK	ALL
General:						
Under 300 beds	56.1	18.6	16.1	1.4	7.8	100.0
300-399 beds	55.5	16.7	15.9	0.3	11.6	100.0
400-499 beds	62.3	11.3	18.3	1.4	6.7	100.0
500-599 beds	42.5	16.8	28.9	—	11.8	100.0
600-999 beds	52.7	19.3	17.3	1.0	9.7	100.0
1,000 and over	50.7	17.9	23.2	0.6	7.6	100.0
Average	*54.5*	*16.6*	*18.7*	*0.8*	*9.4*	*100.0*
Veterans	68.2	17.3	8.4	—	6.1	100.0
Mental	61.6	20.3	11.2	—	6.9	100.0
University	54.2	22.2	13.7	1.3	8.6	100.0

TABLE B-7

PERCENTAGE TRAVEL MODE DISTRIBUTION, HOME INTERVIEW PERSON TRIPS TO SELECTED HOSPITALS, MEDICAL PURPOSES

	MODE OF TRAVEL				
HOSPITAL TYPE	AUTO DRIVER	AUTO PASS.	TRANSIT PASS.	TAXI PASS.	ALL
General:					
Under 300 beds	57.2	28.9	12.0	1.9	100.0
300-399 beds	46.7	37.6	12.9	2.8	100.0
400-499 beds	47.8	24.5	21.2	6.5	100.0
500-599 beds	34.3	35.2	24.5	6.0	100.0
600-999 beds	36.0	33.3	24.6	6.1	100.0
1,000 and over	22.7	25.4	46.1	5.8	100.0
Average	*40.1*	*31.3*	*23.9*	*4.7*	*100.0*
Veterans	55.7	25.3	15.3	3.7	100.0
Mental	79.3	12.6	8.1	—	100.0
University	49.2	37.0	11.4	2.4	100.0

drivers, moreover, decreases systematically with increasing hospital size, whereas the proportion of transit passengers increases. Scanning through individual hospital percentages, the range of auto driver trips is from 6 to 80%; the range of transit passenger trips is from 0 to 68%. Medical trips to university hospitals favor the automobile slightly more than trips to general hospitals. Medical trips to VA and mental hospitals, however, favor the automobile much more heavily.

MODE, VISITOR TRIPS

Table B-8 shows that a high proportion of visitor trips to any hospital type are by auto passengers. This is not unexpected, inasmuch as visiting confined friends or relatives tends to involve whole families traveling together. Again, the data show considerable variation from hospital to hospital.

MODE, OTHER TRIPS

Table B-9 shows that a very high proportion of all remaining trips are by auto drivers. Three-fourths of these "other" trips are to serve passengers; that is, they are auto driver trips to pick up or drop off passengers. The drivers themselves are not hospital tripmakers. In measuring total trip generation, however, they should be considered, because they use street capacity (though generally not off-street parking facilities) just as though they were hospital tripmakers. It is rather remarkable, perhaps, that on the average two out of every ten auto driver trips to a hospital site are of this stop-and-go category.

PURPOSES OF PERSON TRAVEL, ALL MODES

Taking all modes together, Table B-10 shows that at general hospitals about 42% of all trips are to work, about 26%

TABLE B-8

PERCENTAGE TRAVEL MODE DISTRIBUTION, HOME INTERVIEW PERSON TRIPS TO SELECTED HOSPITALS, VISITOR PURPOSES

	MODE OF TRAVEL				
HOSPITAL TYPE	AUTO DRIVER	AUTO PASS.	TRANSIT PASS.	TAXI PASS.	ALL
General:					
Under 300 beds	51.8	34.3	13.4	0.5	100.0
300-399 beds	56.7	35.9	6.6	0.8	100.0
400-499 beds	48.3	34.4	14.6	2.7	100.0
500-599 beds	60.7	29.0	10.3	—	100.0
600-999 beds	52.0	36.9	10.2	0.9	100.0
1,000 and over	41.5	29.0	27.5	2.0	100.0
Average	*51.4*	*34.3*	*13.0*	*1.3*	*100.0*
Veterans	52.8	28.9	18.0	0.3	100.0
Mental	37.2	46.1	16.7	—	100.0
University	46.0	49.5	4.1	0.4	100.0

for medical care, 18% for social-recreation, and 14% for other purposes. The relative frequencies are fairly consistent regardless of hospital size. At university hospitals, there are far more "other" trips, a large share of which involve a "to school" purpose—perfectly in keeping with the function of these great teaching hospitals. At VA and mental hospitals, where length of patient stay is greater, and visitors less frequent, the proportion of work trips is naturally much higher. On the whole, the distribution by purpose varies less than the distribution by travel mode when individual hospitals or geographic regions are considered.

Note, however, that work trips may be slightly better reported in the home-interview O-D data than are trips for other purposes. The common experience of all transportation studies is that nonwork trips are not completely reported. Among the various tests to determine the degree of completeness is the screen line check—a comparison of expanded sample tripmaking across a line bisecting a study area, with actual traffic counts taken along the same line. Appendix A shows that although such checks ranged from 75 to 96%, only 5 of the 17 studies contributing data to this project imposed a correction factor. Thus, in some instances the home-interview trip data somewhat understate actual tripmaking.

Turning attention now to trips from hospitals, Table B-11 shows that more than two-thirds are to return home. A fairly high proportion is to shop or for social-recreation. This group probably includes not only patients and visitors who are continuing a multi-purpose trip before returning home, but also some nurses and other staff who may be resident at the hospital. The group going to work from the hospital would include doctors making further hospital or house calls, or returning to their offices. The "other" trips are a mixture of the remaining trip purposes, with none paramount.

TABLE B-9

PERCENTAGE TRAVEL MODE DISTRIBUTION, HOME INTERVIEW PERSON TRIPS TO SELECTED HOSPITALS, OTHER PURPOSES

	MODE OF TRAVEL				
HOSPITAL TYPE	AUTO DRIVER	AUTO PASS.	TRANSIT PASS.	TAXI PASS.	ALL
General:					
Under 300 beds	80.4	17.7	1.9	—	100.0
300-399 beds	92.0	7.9	—	0.1	100.0
400-499 beds	79.2	13.7	7.1	—	100.0
500-599 beds	90.2	9.8	—	—	100.0
600-999 beds	83.5	5.9	10.6	—	100.0
1,000 and over	80.3	15.1	3.3	1.3	100.0
Average	*84.5*	*11.5*	*3.6*	*0.4*	*100.0*
Veterans	83.3	16.7	—	—	100.0
Mental	100.0	—	—	—	100.0
University	83.6	12.3	3.6	0.5	100.0

TABLE B-10

PERCENTAGE PURPOSE DISTRIBUTION, HOME INTERVIEW PERSON TRIPS TO SELECTED HOSPITALS, ALL MODES

	TRIP PURPOSE TO				
HOSPITAL TYPE	WORK	MEDICAL	VISITOR	OTHER	ALL
General:					
Under 300 beds	38.6	22.3	24.0	15.1	100.0
300-399 beds	45.2	24.0	19.0	11.8	100.0
400-499 beds	40.4	24.8	22.9	11.9	100.0
500-599 beds	46.6	30.2	10.4	12.8	100.0
600-999 beds	39.8	29.5	17.8	12.9	100.0
1000 and over	42.7	27.4	13.1	16.8	100.0
Average	*42.3*	*25.7*	*18.4*	*13.6*	*100.0*
Veterans	53.3	18.0	18.2	10.5	100.0
Mental	73.6	10.2	8.3	7.9	100.0
University	46.9	14.2	12.7	26.3	100.0

TABLE B-11

PERCENTAGE PURPOSE DISTRIBUTION, HOME INTERVIEW PERSON TRIPS FROM SELECTED HOSPITALS, ALL MODES

HOSPITAL TYPE	TRIP PURPOSE TO HOME	WORK	SHOP OR SOC.-RECR.	OTHER	ALL
General:					
Under 300 beds	67.4	8.9	16.2	7.5	100.0
300-399 beds	69.9	8.6	13.0	8.5	100.0
400-499 beds	69.2	8.6	13.3	8.9	100.0
500-599 beds	69.0	8.0	9.4	13.6	100.0
600-999 beds	72.0	6.4	11.7	9.9	100.0
1000 and over	73.1	5.7	13.2	8.0	100.0
Average	*70.4*	*7.7*	*13.1*	*8.8*	*100.0*
Veterans	71.0	6.1	13.3	9.6	100.0
Mental	77.9	5.9	10.5	5.7	100.0
University	65.1	6.0	14.4	14.5	100.0

Factors Associated With Travel Mode

CAR OWNERSHIP

Table B-12 shows that family car ownership is a key determinant of modal choice. For 14 general hospitals in Buffalo and Pittsburgh, tripmakers from 0-car households average 64% of their trips as transit passengers, with the remainder divided about equally as auto passengers or as walkers. Tripmakers from 1-car households average only 14% of their trips as transit passengers, with 58% as auto drivers, 26% as auto passengers, and 2% as walkers. There is a further pronounced shift away from transit for tripmakers from multi-car households.

From the regression analysis it can also be shown that the number of transit trips correlates at $r = -0.55$ with autos owned per 1,000 population within a 3-mile radius of the general hospital. The percent of transit trips correlates at $r = -0.63$ with the same independent variable ($N = 57$). The related variable, total autos owned within a 3-mile radius, however, shows positive (instead of negative) correlations with transit tripmaking because it is more a measure of the density of urban development than a true measure of auto availability per potential tripmaker.

TRIPMAKER OCCUPATION

In looking at modal distribution and tripmaker occupation for work trips to all 59 general hospitals in the cross section, Table B-13 shows that, along with clerical staff, professional and technical personnel are the least likely to use transit. They are the most likely to drive. By all odds, laborers and service workers have the highest probability of requiring transit.

For the record, 56% of all trips to work at general hospitals are self-reported as having been made by professional or technical personnel, 15% by clerical staff, 7% by operatives, and 22% by laborers or service workers. This may explain why the professional group, although having the lowest probability of using transit, accounts for about one-half of all transit trips. The occupational breakdown at university and VA hospitals is reported as comparable to that given at general hospitals; at the mental hospitals, there are fewer professional or technical personnel, and more laborers and service workers.

TABLE B-12

PERCENTAGE TRAVEL MODE DISTRIBUTION, HOME INTERVIEW PERSON TRIPS TO FOURTEEN SELECTED GENERAL HOSPITALS IN BUFFALO AND PITTSBURGH, BY FAMILY CAR OWNERSHIP CLASS

TRAVEL MODE	0-CAR FAMILIES	1-CAR FAMILIES	2-CAR FAMILIES	ALL FAMILIES
Auto driver	—	58	70	51
Auto passenger	19	26	22	24
Transit passenger [a]	64	14	7	21
Walk to work	17	2	1	4
All	100	100	100	100

[a] Includes taxi passengers.

TABLE B-13

PERCENTAGE TRAVEL MODE DISTRIBUTION, HOME INTERVIEW PERSON TRIPS TO WORK AT SELECTED GENERAL HOSPITALS, BY TRIPMAKER OCCUPATION

	TRAVEL MODE [b]			
OCCUPATION [a] OF TRIPMAKER	AUTO DRIVER	AUTO PASS.	TRANSIT PASS.	ALL
Professional and technical	72	16	12	100
Clerical and salesworkers	66	22	12	100
Craftsmen and operatives	68	14	18	100
Laborers and service workers	34	22	44	100

[a] Consolidated from ten standard groupings used by the transportation studies by which exact occupations cannot be shown. Naturally there are few "salesworkers" or "operatives" at hospitals (an operative refers to anyone who runs a machine, not to operating room personnel); they are grouped with "clerical" and "craftsmen," respectively, only for consistency with other parts of the report.
[b] Excluding taxi passenger and walk-to-work trips.

TRIPMAKER SEX AND DRIVER LICENSING

Table B-14 shows that males who make trips to general hospitals are twice as likely to drive cars as are females. They are less than half as likely to take transit. In both groups, however, the probability of transit use increases with increasing hospital size. Males average 6% transit use to general hospitals with less than 500 beds, 19% to hospitals with more than 500 beds. Females average 15% and 41%, respectively. There are corresponding decreases in car use.

Transit use at veterans and mental hospitals, on the whole, averages about one-half that at general hospitals. But female transit use drops off more than male transit use, as Table B-14 shows. For that matter, total female tripmaking is less: at general hospitals it averages about 55%, almost regardless of hospital size; at veterans and mental hospitals it averages 41 and 48%, respectively.

By contrast, Table B-14 shows that transit use by both males and females at university hospitals is comparable to that at general hospitals. Large universities are high trip generators, and often have transit service as good as that enjoyed by general hospitals in central city locations. Total female tripmaking is 54%, almost the same as at general hospitals.

Table B-15 shows that transit use among male drivers averages 6%, and among female drivers 18% (based on 17 general hospitals in Buffalo, Pittsburgh, and Wilmington, the only studies in the sample where driver licensing is found in the trip records). However, transit use among male nondrivers averages 59%, and among female nondrivers 53%. In the present group, 54% of all tripmakers are female (almost the same as for all general hospitals) whereas 93% of all male tripmakers are licensed to drive, but only 75% of all female tripmakers.

POPULATION AND NET RESIDENTIAL DENSITY

Although transit tripmaking to general hospitals has been shown to relate with urban area population, there is a somewhat stronger relationship when only population within a 3-mile radius is considered. The correlation with percent of transit trips is $r = 0.68$; with number of transit trips, $r = 0.59$. This result is partly because the higher the gross population density within a 3-mile radius, the lower

TABLE B-14

PERCENTAGE TRAVEL MODE DISTRIBUTION, HOME INTERVIEW PERSON TRIPS TO SELECTED GENERAL HOSPITALS, BY TRIPMAKER SEX

		TRAVEL MODE [a]			
SEX OF TRIPMAKER	HOSPITAL TYPE	AUTO DRIVER	AUTO PASS.	TRANSIT PASS.	ALL
Male	General	79	11	10	100
	Veterans	80	12	8	100
	Mental	89	6	5	100
	University	81	12	7	100
Female	General	41	34	25	100
	Veterans	56	30	14	100
	Mental	51	38	11	100
	University	45	34	21	100

[a] Excluding taxi passenger and walk-to-work trips.

TABLE B-15

PERCENTAGE TRAVEL MODE DISTRIBUTION, HOME INTERVIEW PERSON TRIPS TO SEVENTEEN SELECTED GENERAL HOSPITALS IN BUFFALO, PITTSBURGH, AND WILMINGTON, BY TRIPMAKER SEX AND DRIVER LICENSING

		TRAVEL MODE [a]			
TRIPMAKER SEX	DRIVER LICENSING	AUTO DRIVER	AUTO PASS.	TRANSIT PASS.	ALL
Male	Drivers	87	7	6	100
	Nondrivers	—	41	59	100
Female	Drivers	47	35	18	100
	Nondrivers	—	47	53	100

[a] Excluding taxi passenger and walk-to-work trips.

the car ownership per 1,000 population ($r = -0.65$). However, it can be assumed, also, that the higher this density, the better the transit service.

Net residential density (NRD, or persons per acre of residential land) within a 3-mile radius might be expected to provide higher correlations with transit tripmakng, but does not. With percent of transit trips, $r = 0.61$; with number of transit trips, $r = 0.49$. However, both population and NRD enter into the multiple regression predictive equations for transit tripmaking described later.

TRANSIT SERVICE AND TYPE AREA

Transit service to most of the general (and university) hospitals in the cross section tends to be good, because these facilities are largely located near the centers of the urban areas considered. With relatively few exceptions, such hospitals are served by established bus routes oriented to the central business district. The VA and mental hospitals, however, are often located at or near the fringe of urban development, where transit service is poorer.

This is substantiated by questionnaire returns: of 45 responding general hospitals, 27 reported good to excellent transit service, 13 reported fair, and only 5 reported poor or inadequate (Fig. B-1 and Table B-16). Of 9 responding VA hospitals, 4 reported good transit service, 4 reported fair, and 1 reported poor. Of 3 responding mental hospitals, 2 reported good, and 1 reported poor. There was a strong relationship to the locational type area reported; that is, downtown- and intermediately-located hospitals most often reported good to excellent service, whereas suburban- and outlying-located hospitals most often reported fair to poor service.

Better proof is provided by Table B-17. When trips for all general hospitals are aggregated by type area in which they are located (definitions per 1950 edition of the Highway Capacity Manual (*28*)), and proportions by travel mode derived, downtown hospitals are seen to attract about 29% transit tripmaking; intermediate hospitals, 14%; suburban hospitals, 9%; and outlying hospitals, 5%. The proportions of taxi passenger and walk-to-work trips decrease, and the proportion of auto driver trips increases, in similar progression.

There is always the question of whether there would have been more transit trips had transit service been better. Possibly, yes. But transit service to specific sites is difficult, if not impossible, to measure quantitatively, and to relate to reported tripmaking. Moreover, because all of the hospitals in the cross section have some transit service, and 8 out of 10 report such service as at least fair, other variables seem the prime determinants of modal choice, as the multiple regression results will illustrate.

Truck Travel

There were 5,330 internal and about 300 external truck trips to the 59 general hospitals (external trips start outside the urban areas studied). VA, mental, and university hospitals attracted approximately 500, 200, and 650 truck trips, respectively, with about the same internal-external ratio. These figures indicate that hospitals, generally, are not major generators of truck trips.

Moreover, most trips are by light trucks—four-tired pickup or panel trucks which for highway design purposes are generally treated as passenger car equivalents (see subsequent section on "Highway Design Factors"). For all hospitals combined, there were only 1,860 medium or heavy truck trips. This averages to about 25 daily truck trips per hospital.

Table B-18 gives ratios of total internal truck trips to total internal person trips, and total internal auto driver trips. Both appear to be consistent indicators of the level of truck activity: for general and VA hospitals, from 3 to 4 truck trips per 100 person trips, or from 6 to 7 truck trips per 100 auto driver trips, would seem appropriate. For mental hospitals, somewhat higher ratios would be expected; for university hospitals, somewhat lower.

Taxi Travel

There are slightly fewer taxi trips than truck trips: approximately 4,860 to general hospitals, 310 to VA, 50 to mental, and 570 to university hospitals. For all hospitals combined, this averages to 75 daily taxi trips per hospital.

Table B-19 shows that neither person trip nor auto driver trips ratios are very consistent indicators of taxi trip ac-

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
Project 7-1/1
Data Needs at Generator Sites
HOSPITALS

SURVEY YEAR ____________

Name: ____

Address: ____

Location: Downtown___ Intermediate___ Suburban___ Outlying___

Immediate Vicinity: Residential___ Institutional___ Commercial___

Transit Service: Type______ Quality________

Ambulance Service: Affiliated___ Separate___

Associated With: Other Hospitals nearby___ Separate___
Medical School___ Nursing School___

Type of Hospital: Public___ Private___
Profit___ Nonprofit___
General___ Other___
Short stay___ Long stay___
Average length of Stay______

Number of Beds: Total________ Ward______ Private, Semi-Private_______

Number of Bassinets: Total_____ Births/Year________

Staff: Doctors_________ Other Total______

Special Facilities: (from Hospital Directory)____________________________

Special Free Services: X-rays or other Clinics___ Full Time___ Periodic______
____

Residential Accommodations for Staff:______________________________

Building Floor Space (square feet)____________ Site Acreage:________

Parking: Total OnSite____ Staff_____ Visitors________
Private OffSite____ Public OffSite______
Availability and Adequacy of Street Parking____________________

Visitor Policy: Hours______ Limitations____________________

Annual Report and Floor Plans Available:____________________________

Figure B-1. Hospital questionnaire.

TABLE B-16

HOSPITAL QUESTIONNAIRE RESULTS [a]

HOSPITAL NO.	CONTROL CODE [b]	TYPE OF AREA	QUALITY OF BUS SERVICE	RESIDENTIAL ACCOMMODATIONS FOR STAFF [d]	OFF-STREET PARKING SPACES (NO.): STAFF	OFF-STREET PARKING SPACES (NO.): VISITORS	AVAIL. AND ADEQUACY OF ON-STREET PARKING
1 [e]	23	I [f]	Fair [f]	Yes [f]	*	*	Inadequate [f]
2	23	I	Fair	Yes	100	50	Limited
3	21	I	Fair	Yes	44	200	Yes
4	23	I	Fair	Yes	*	*	Inadequate [f]
5	21	S	Inadequate	No	250	100	Inadequate [f]
6 [e]	23	S [f]	Fair [f]	No	*	*	Adequate [f]
7	13	I	Good	Yes	1000		Inadequate [f]
8	23	I	Good	Yes	96	946	None
9	45	S	Good	Yes	607		Metered
10	21	I	Good	Yes	246		Good

TABLE B-16 (*Continued*)

HOSPITAL NO.	CONTROL CODE [b]	TYPE OF AREA	QUALITY OF BUS SERVICE	RESIDENTIAL ACCOMMODATIONS FOR STAFF [d]	OFF-STREET PARKING SPACES (NO.) STAFF	VISITORS	AVAIL. AND ADEQUACY OF ON-STREET PARKING
11	12	I	Poor	Yes	*	*	None
12	23	O	Good	No	850		Not needed
13	21	I	Good	Yes	639	175	Very limited
14	12-13	I	Good	Yes	*	*	*
14A	21	S	Fair	No	80	200	*
14B	21	C	Good	No	67	213	Time limited
15	21	I	Poor [f]	Yes	494	112	Limited
16	21	I	Fair	Yes	600		Inadequate
17 [e]	21	I [f]	Good [f]	Yes [f]	*	*	Not good [f]
18	13	C	Excellent	Yes	600		Not adequate
19	21	C	Good	No	350	321	Limited
20	23	S	Excellent	Yes	232	242	No
21	45	S	Fine	Yes	329		None
22	23	I	Good	Yes	60	149	Limited
23	23	I	Fair	Yes	125	15	Inadequate
24	23	I	Good	No	54	52	Not adequate
25	12	S	Good	Yes	283	150	None
26	45	S	Fair	Yes	240	19	Good
27	23	S	Poor	No	*	*	Not needed [f]
28	21	S	Poor	Yes	*	*	Not needed [f]
29	45	O	Avg. to poor	No	300	359	Not needed [f]
30	45	O	None	Yes	349	75	Inadequate
31	12	C	Good	Yes	350	*	Inadequate [f]
32	21	C	Excellent	Yes	*	*	Poor
33	21	I	Fair	Yes	407		Crowded [f]
34	23	I	Fair [f]	Yes	*	*	Not good
35	23	I	Poor	No	100	500	None
36	44	I [f]	Fair [f]	Yes	160		Fair [f]
37	45	I	Good	Yes	123	0	Crowded [f]
38	23	I	Fair	Yes	400	100	Crowded
39	12	I	Good	Yes	300	150	Limited
40	23	I	Fair [f]	No	70	55	20-Min only
41	23	I	Fair	Yes	150	75	Adequate
42 [e]	21	I [f]	*	*	*	*	*
43	13	S	Poor [f]	No	850		Not needed [f]
44	23	I	Good	Yes	280		Poor
45	21	I	Excellent	No	*	*	Minimal
46	23	C	Good	Yes	100	0	*
47 [e]	21	C [f]	*	*	*	*	*
48	21	I	Good	Yes	*	*	Limited [f]
49	45	S	Good	Yes	659		Not needed [f]
50 [e]	15	I [f]	Fair [f]	Yes	*	*	*
51 [e]	21	I [f]	Fair [f]	*	*	*	*
52	14	C	Good [f]	Yes	None		50 spaces
53	23	C	Good [f]	*	*	*	Inadequate [f]
54	21	I	Fair	No	40	60	Fairly good
55	21	C	Good	No	200	50	Limited
56	21	I	Good	Yes	52	101	Inadequate
57	23	I	Good	Yes	135	0	Very inadequate
58	45	S	Fair	Yes	*	*	Not needed [f]
59	23	S	Adequate	Yes	191	232	All sides
60	45	S	Fair	Yes	365	0	Not enough
61	12	I	Good	Yes	*	*	Fair
62	23	S	Adequate	Yes	*	*	Limited
63	12	O	Fair	Yes	247	227	None
64	13	C	Good	Yes	170	0	Very limited
66 [e]	13	I [f]	Poor [f]	*	*	*	Not needed [f]
67	21	I	Good	Yes	— [g]		Adequate
69	45	S	Fair	Yes	170	122	Good
70	23	I	Good	No	50	270	Adequate
71	21	I	Good	Yes	*	*	Fair
72 [e]	21	I [f]	*	Yes	*	*	*
73 [e]	45	I [f]	*	Yes	*	*	*

* Not given and otherwise not known.

[a] See also Figure B-29 for additional hospital data.

[b] 12 = state; 13 = county; 14 = city; 15 = city-county; 21 = church related or operated; 23 = other non-profit; 44 = U. S. Public Health Service; 45 = Veterans Administration.

[c] C = central business district; I = intermediate; S = suburban; O = outlying.

[d] *Any* amount or type of residential accommodations available for staff indicated by "yes."

[e] No response to questionnaire.

[f] The researchers' judgment, based on hospital site inspection.

[g] 35,000 sq ft.

TABLE B-17

PERCENTAGE TRAVEL MODE DISTRIBUTION, HOME INTERVIEW PERSON TRIPS TO SELECTED GENERAL HOSPITALS, BY TYPE AREA IN WHICH HOSPITALS ARE LOCATED

AREA TYPE	MODE OF TRAVEL AUTO DRIVER	AUTO PASS.	TRANSIT PASS.	TAXI PASS.	WALK TO WORK	ALL
Cent. bus. dist.	44.3	20.7	28.7	3.2	3.1	100.0
Intermediate	55.6	23.8	14.4	1.5	4.7	100.0
Suburban	64.6	22.7	8.7	0.6	3.4	100.0
Outlying	65.9	26.0	4.9	0.3	2.9	100.0

TABLE B-18

RATIOS OF INTERNAL TRUCK TRIPS TO INTERNAL PERSON TRIPS, BY PURPOSE, AND TO INTERNAL AUTO DRIVER TRIPS, ALL PURPOSES

HOSPITAL TYPE	PER 100 PERSON TRIPS TO WORK	TO MEDICAL	TO ALL OTHER PURPOSES	TO ALL PURPOSES	PER 100 AUTO TRIPS (ALL PURPOSES)
General:					
Under 300 beds	10.0	17.9	10.2	3.94	6.75
300-399 beds	8.4	15.8	12.3	3.80	6.54
400-499 beds	8.9	14.5	10.3	3.58	6.23
500-599 beds	2.9	4.5	5.9	1.36	2.85
600-999 beds	8.2	11.1	10.6	3.27	6.33
1000 and over	7.4	11.5	10.6	3.16	6.79
Average	*8.1*	*13.4*	*10.9*	*3.45*	*6.37*
Veterans	7.0	20.6	12.9	3.71	5.72
Mental	6.3	45.5	28.7	4.63	7.19
University	6.2	20.6	7.5	2.92	4.84

tivity. For all except mental hospitals, a figure of 3 taxi trips per 100 person trips would seem most appropriate; for mental hospitals, about one-half that rate.

Variation in taxi use is difficult to explain in terms of any single factor. Differences in urban area taxi fleet sizes, and thus availability; fares; competitive transit service; family income and car ownership; and other factors, probably together account for the variation. Inasmuch as 69% of all taxi passenger trips are for medical purposes, 17% are to work, and 14% are for social-recreation purposes, most of the variation in taxi use seems related to how patients and those who accompany them elect to go to the hospital.

Time Patterns

MONTHLY

Hospital travel is somewhat seasonal (Fig. B-2). Plots of total admissions and total outpatient visits for all nonfederal, short-stay general, and other special hospitals in the United States illustrate this clearly. With monthly totals expressed as percentages of the average month, 8 of the 12 months are within ± 3% of the average, and the remaining 4 months are well within ± 8%. Assuming proportionate traffic generation, this degree of seasonality seems relatively slight—much less, for example, than that for traffic generation at airports or shopping centers.

DAILY

Hospital travel varies slightly through the week. A large number of admissions characteristically occur early in the week; a large number of discharges, late in the week. Various studies have demonstrated that hospital occupancy drops on weekends. A study of 14 Pennsylvania hospitals (*2*) showed the peak census days were Monday and Tuesday, with Saturday the low census day. A study of 12 California hospitals (*3*) showed the peak census days were Wednesday and Thursday, but with Saturday still the low census day. The Pennsylvania study concluded that, lacking evidence to show that serious illness regularly declined over weekends, the timing of admissions and discharges was the result of personal considerations of patients and their families, established work patterns of physicians, and various hospital routines. (The same study indicated that hospital occupancy dropped still more sharply at holidays. For

TABLE B-19

RATIOS OF INTERNAL TAXI TRIPS TO INTERNAL PERSON TRIPS, BY PURPOSE, AND TO INTERNAL AUTO DRIVER TRIPS, ALL PURPOSES

HOSPITAL TYPE	PER 100 PERSON TRIPS: TO WORK	TO MEDICAL	TO ALL OTHER PURPOSES	TO ALL PURPOSES	PER 100 AUTO TRIPS (ALL PURPOSES)
General:					
Under 300 beds	4.7	8.4	4.8	1.84	3.16
300-399 beds	5.0	9.5	7.4	2.28	3.93
400-499 beds	12.0	19.6	13.9	4.85	8.44
500-599 beds	8.2	12.7	16.6	3.84	8.05
600-999 beds	7.6	10.3	9.9	3.03	5.88
1000 and over	8.8	13.8	12.5	3.77	8.10
Average	*7.4*	*12.2*	*9.9*	*3.15*	*5.80*
Veterans	4.8	14.3	8.9	2.57	3.96
Mental	1.8	12.9	8.1	1.31	2.04
University	6.5	21.5	7.8	3.04	5.04

example, at Thanksgiving down 15%, at Christmas down 40%, and at New Year's down 18%. Depressed occupancy was not just for the holiday, but also for the days preceding and following.)

Consultant reports based on surveys of parking lot activity suggest considerable variation from hospital to hospital. One study of a 390-bed general hospital in Pasadena, Calif. (*4*), found that at the visitor's parking lot Tuesday was the most active and Thursday the least active weekday, with Saturday the least active of all. At the employees' lot, however, Friday was the most active and Monday the least active weekday, with Sunday the least active of all. Another study in Buffalo, N.Y. (*5*), considering visitors only, found that at one 650-bed general hospital both Saturday and Sunday tripmaking was about equal to average weekday tripmaking. At another 350-bed hospital, both Saturday and Sunday were about one-half again as much as the average weekday tripmaking; and at still another 530-bed general hospital, Saturday tripmaking was only one-half, and Sunday tripmaking only one-fifth, as much as the average weekday tripmaking.

Examination of transportation study data for daily patterns is made difficult by the unevenness of home interview surveys. Although an equal number of households are scheduled to be interviewed each day, this is seldom accomplished. Because only one study in the present cross section has published its interviewing "take" by day of the week, correction factors cannot be systematically applied. However, taking the travel data at face value, various summary tables indicate that total tripmaking on any given weekday seldom exceeds ± 15% of the average weekday, Saturdays and Sundays excluded.

HOURLY, PERSON TRIPS

Plots of hourly distributions of total person trips to individual hospitals, and to groups of hospitals by city, show remarkable consistency. Taken from them, Figure B-3 compares the composite distributions for general, VA, mental, and university hospitals. Morning peaks occur between 6-8 AM, afternoon peaks between 2-4 PM, and evening peaks between 7-8 PM. Figure B-4 shows the counterpart patterns of total person trip from the four hospital types.

Trip purpose variations in total person tripmaking are shown in Figure B-5 (trips to) and Figure B-6 (trips from). Work trips show clearly demarcated peaks during shift-change hours. Medical trips, however, tend to occur throughout the day (the evening peak probably reflects variation in trip purpose definitions; some personal business trips should perhaps have been reported as social-recreation or visitor trips). "Other" trips also occur throughout the day, with peaks at shift-change hours reflecting the dominant serve passenger component of this trip purpose catch-all. Visitor trips are the most sharply peaked, with evening activity nearly double mid-afternoon activity.

Such patterns confirm the general impression of daily hospital activity drawn from various nonstudy sources.

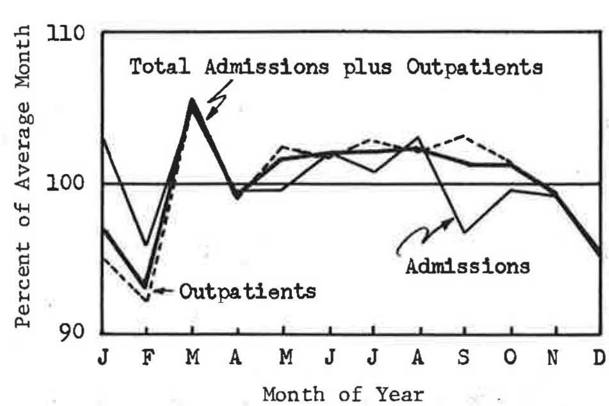

Figure B-2. Monthly variation in hospital admissions and outpatients in the United States, 1966. (From Hospitals, *Jour. Am. Hosp. Assn.)*

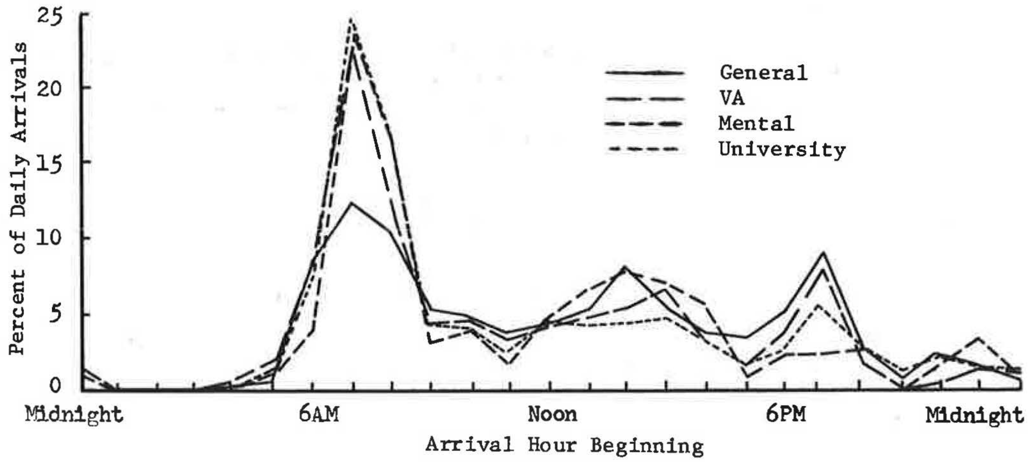

Figure B-3. Home interview person trips to hospitals, by hospital type.

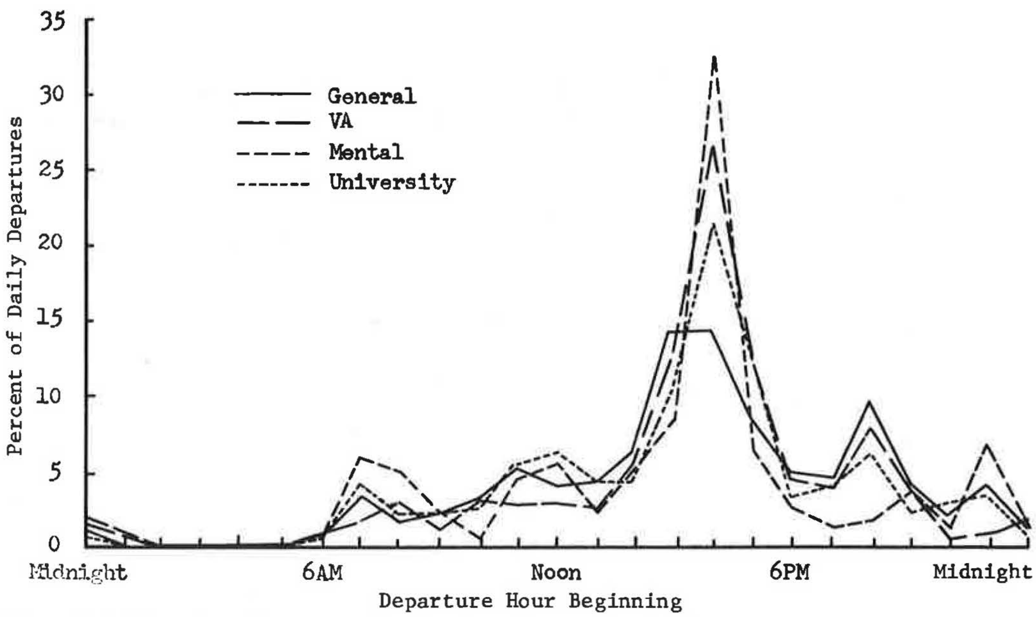

Figure B-4. Home interview person trips from hospitals, by hospital type.

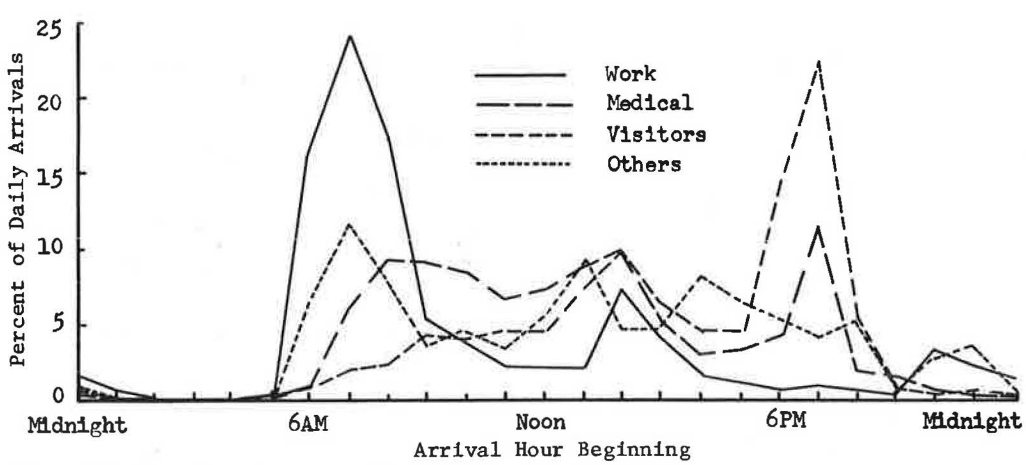

Figure B-5. Home interview person trips to general hospitals, by trip purpose.

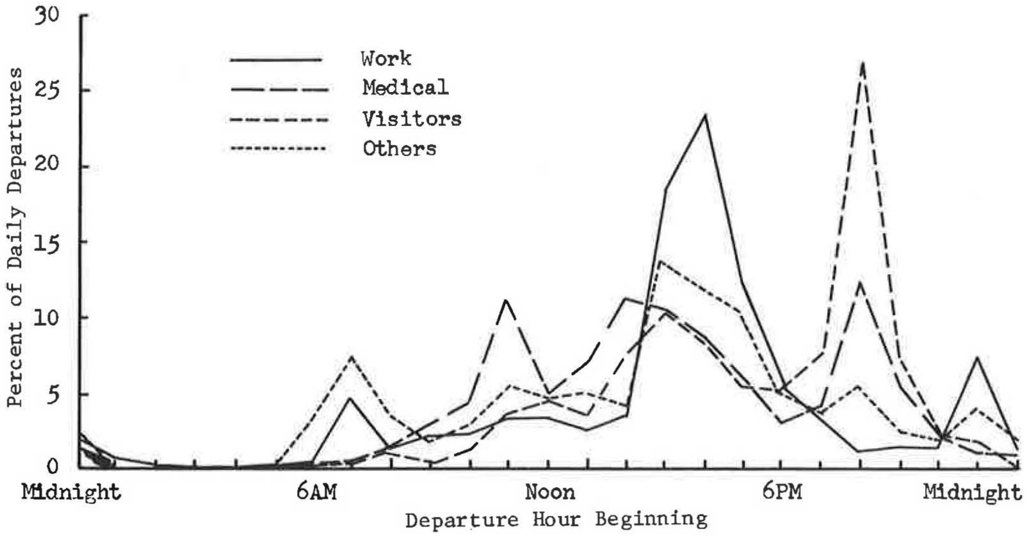

Figure B-6. Home interview person trips from general hospitals, by trip purpose.

Doctors come and go all day, with a concentration of visits in the morning. Nurses generally work three shifts: 7 AM-3:30 PM, 3 PM-11 PM, and 11 PM-7 AM. Most other employees work a single daytime shift, coming to work at various times, but generally between 7 and 9 AM, and leaving between 3:30 and 5:30 PM. Volunteer workers usually work only 3 to 4 hr. Inpatients are discharged primarily during the morning hours; admitted in the afternoon, beginning shortly after noontime. Outpatients arrive and depart throughout the day. Visiting hours vary from hospital to hospital, but peak activity occurs between 2 and 4 PM, and 6 and 8 PM.

HOURLY, AUTO DRIVER TRIPS

Figures B-7 and B-8 show the composite patterns of total auto driver trips to and from the four hospital types. The patterns are approximately the same as for total person trips. This is expected, as the great majority of tripmakers arrive either as drivers or as auto passengers.

HOURLY, TRANSIT PASSENGER TRIPS

Figure B-9 shows total transit passenger trips to and from general hospitals (other hospital types have too few trips to plot meaningfully). Both arrival and departure peaks are sharper than those for auto driver trips, particularly the mid-afternoon departures. The highest arrival hour accounts for about 17% of the daily arrivals; the highest departure hour accounts for about 21% of the daily departures.

HOURLY, TRUCK AND TAXI TRIPS

Figures B-10 and B-11 show truck and taxi trips to general hospitals in the Twin Cities, chosen for illustration because of the high survey sample rates used (50% for taxis and 10% for trucks). Taxi activity is fairly constant from early morning to about midnight. The highest arrival and departure hours each account for only about 10% of the daily totals. Truck activity is more concentrated during daylight hours. The highest arrival hour accounts for about 15% of the daily arrivals; the highest departure hour, about 18% of the daily departures.

ACCUMULATION CURVES, AUTOMOBILE TRIPS

The peak accumulation of auto driver trips occurs between 10 AM and 2 PM for all types of hospitals, and for all sizes of general hospitals, as shown by Figure B-12. (In constructing the accumulation curves, it was assumed that 5 AM would represent 20% of the peak. This value may be higher or lower without affecting the shape of the curves or the maximum accumulation hour.)

The morning increase is very rapid: 80 to 90% of the peak accumulation is achieved by 8 AM. The afternoon decrease is nearly as sharp: the number of parked automobiles drops to about 50% of the peak accumulation by 4 PM. Thereafter, there are interesting differences according to hospital type and size: at general hospitals, the influx of evening visitors, beginning around 7 PM, again increases the number of parked automobiles to between 40 and 70% of the peak accumulation—the smaller the hospital, the higher the percentage. This evening increase does not occur at the other hospital types.

Travel Times and Distances

Although they represent a rather specialized land use, hospitals do not generate particularly long average trip lengths. Table B-20 shows that auto driver trips to general hospitals vary from about 3.2 to 3.9 airline miles, depending on hospital size. On the average, the largest hospitals attract the longest trips, although the smallest (in the cross section) also attract relatively long trips. It might be supposed that the fewer the general hospitals in any urban area, the longer the average trip length would be. However, there was a very low correlation ($r = 0.30$) between the number of

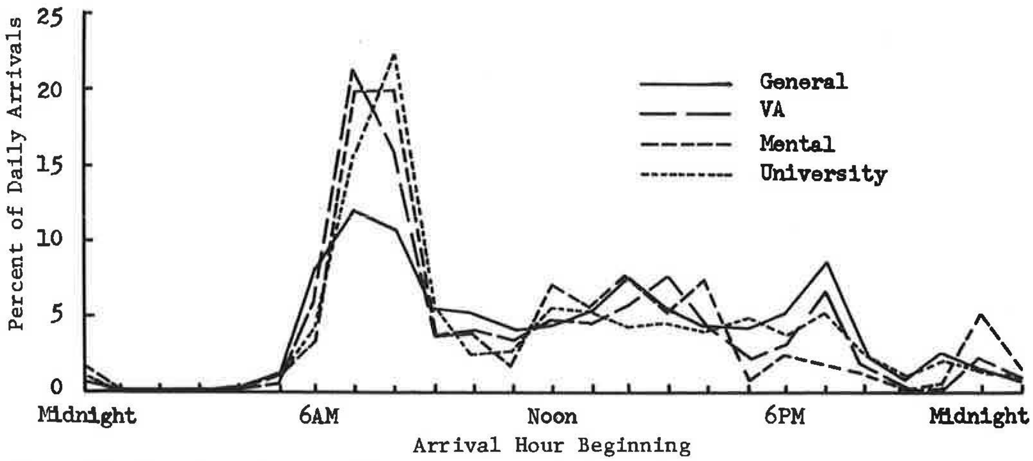

Figure B-7. Home interview auto driver trips to hospitals, by hospital type.

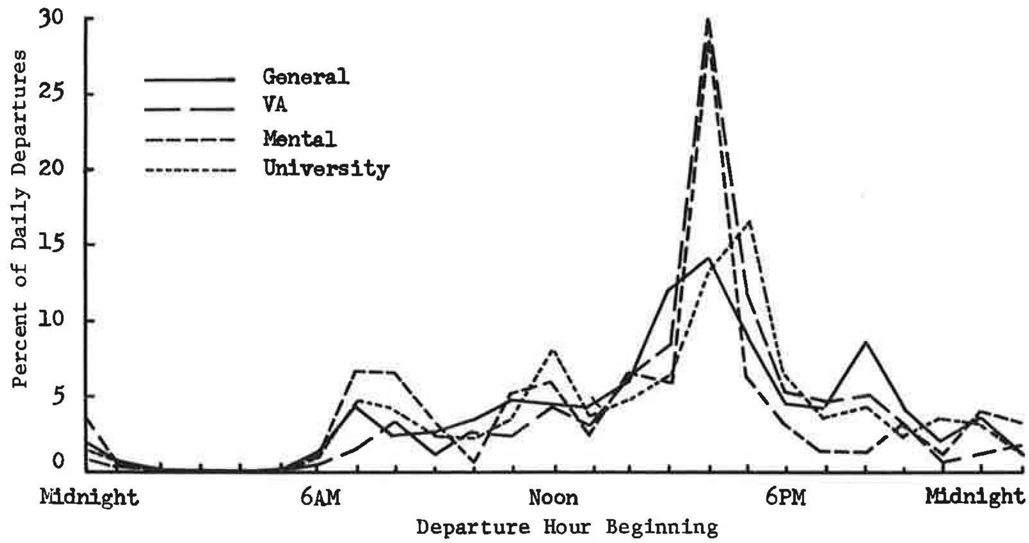

Figure B-8. Home interview auto driver trips from hospitals, by hospital type.

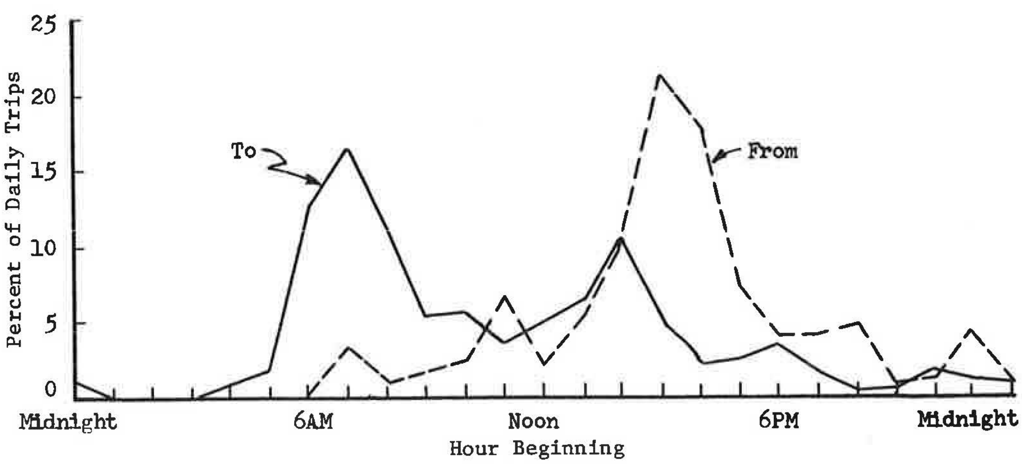

Figure B-9. Transit trips to and from general hospitals.

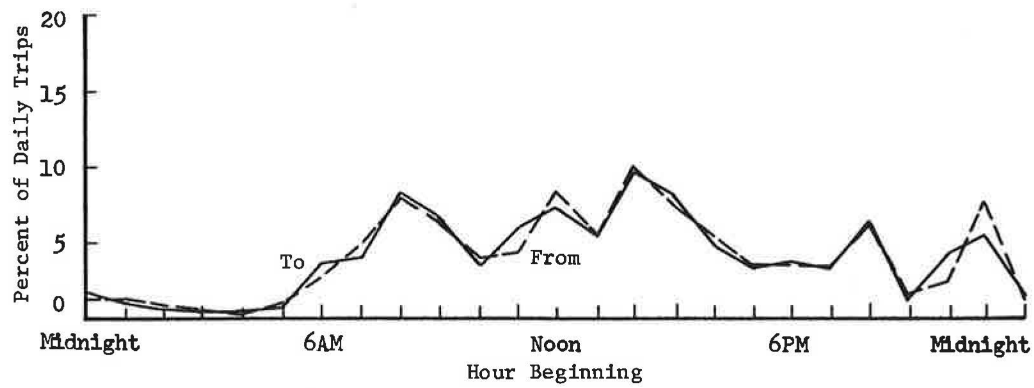

Figure B-10. Taxi trips to and from general hospitals.

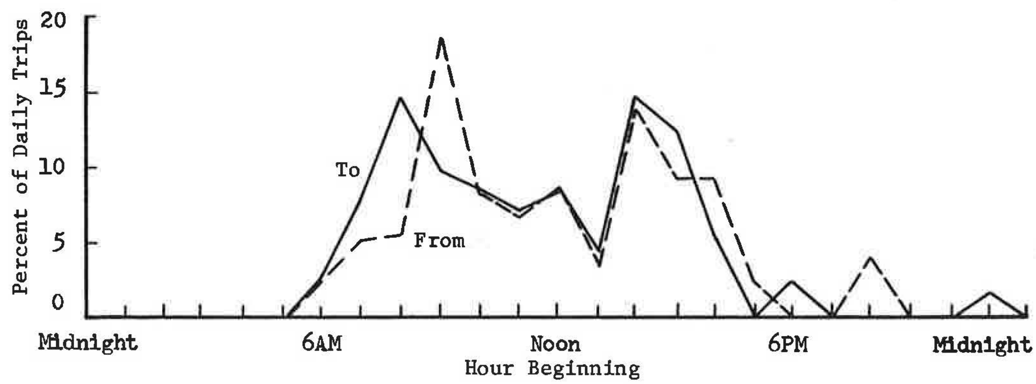

Figure B-11. Truck trips to and from general hospitals.

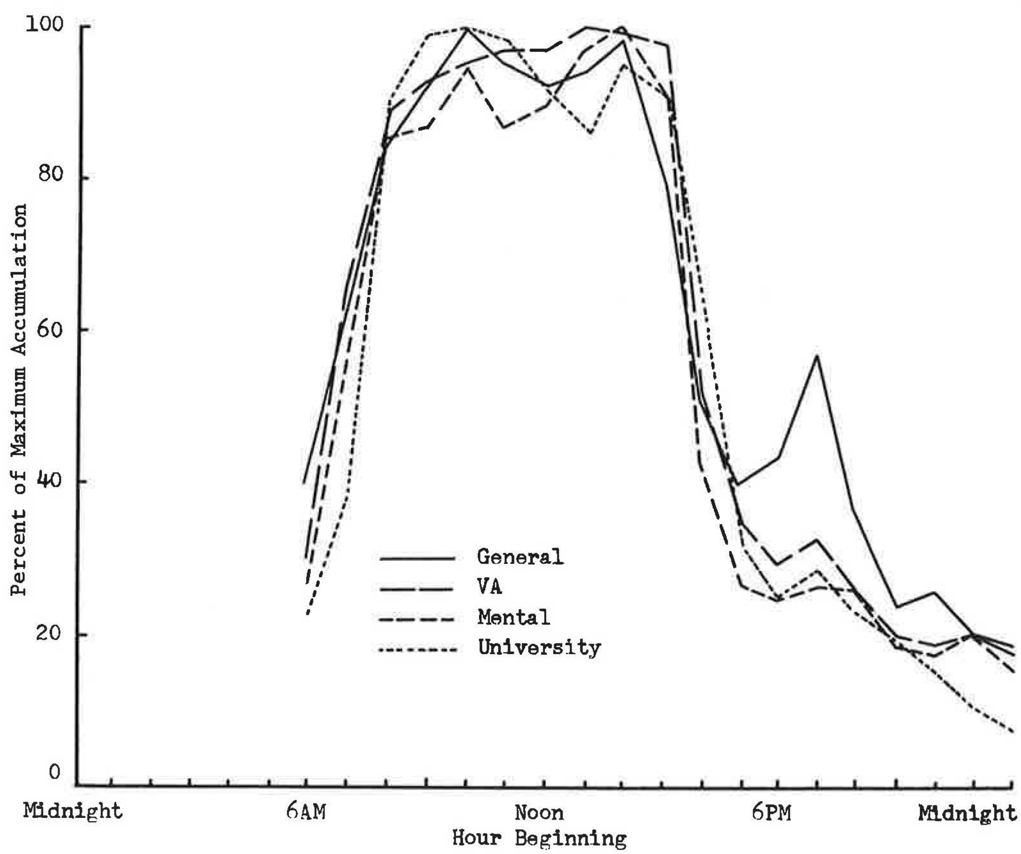

Figure B-12. Accumulation curves, auto driver trips to hospitals (assuming 20 percent residual accumulation at 5 AM).

TABLE B-20

HOME INTERVIEW AUTO DRIVER AIRLINE TRIP LENGTH (MILES) TO SELECTED HOSPITALS, BY TRIP PURPOSE

HOSPITAL TYPE	NO. OF HOSP.	TRIP PURPOSE TO WORK	MEDICAL	VISITOR	OTHER	ALL
General:						
Under 300 beds	8	3.65	3.57	4.36	3.25	3.71
300-399 beds	19	3.67	3.67	3.79	3.57	3.67
400-499 beds	10	3.26	3.21	3.08	3.04	3.18
500-599 beds	2	3.47	3.65	3.42	2.73	3.32
600-999 beds	7	3.53	3.74	3.46	2.67	3.39
1000 and over	3	4.27	4.10	4.42	3.10	3.91
Average	*49*	*3.69*	*3.64*	*3.92*	*3.20*	*3.59*
Veterans	7	4.30	4.01	4.30	3.49	4.17
Mental	2	3.07	2.85	2.79	2.38	2.96
University	2	4.48	3.37	4.50	2.83	3.77

beds per sample hospital as a percentage of the number of beds in its urban area (X_{17}, App. F) and the average trip length. The correlation between average trip length and the total urban area population was nearly as low ($r = 0.47$). Trips to VA and university hospitals are slightly longer than trips to general hospitals, whereas trips to mental hospitals are slightly shorter.

Like trip length averages, travel time averages are also strikingly similar by hospital type and size. Table B-21 gives door-to-door elapsed times as reported in the home interview surveys, including terminal and enroute delays. Even so, the averages range generally from only 15 to 20 min, the largest general hospitals creating the exception at about 28 min. Trips by automobile and taxi require about one-half the travel time of those by transit, at general hospitals averaging 19, 17 and 33 min, respectively.

Parking and Distances Walked

Most hospital tripmakers report parking free. At general hospitals, employees appear to have first priority on free off-street parking facilities: 80% vs only 45% for nonemployees (Table B-22). Still, only 5% of nonemployees need pay for off-street parking. Almost all off-street parking is on lots, not garages. Employees park on-street 16% vs 30% for nonemployees. About 80% of on-street parking is free. Although a few employees do not park, 20% of nonemployees do not park; these are the stop-and-go serve passenger trips. VA and mental hospitals report the greatest reliance on free off-street parking, particularly for employees. At university hospitals, however, off-street parking seems in such short supply that even 25% of the employees must pay for it.

Such responses do not, however, reflect the difficulty of finding parking space. Many highway officials feel that

TABLE B-21

HOME INTERVIEW AVERAGE TRIP TIME (MINUTES) TO SELECTED HOSPITALS, BY TRAVEL MODE

HOSPITAL TYPE	NO. OF HOSP.	TRAVEL MODE AUTO DRIVER	AUTO PASS.	TRANSIT PASS.	TAXI PASS.	ALL
General:						
Under 300 beds	10	16.0	16.9	29.7	10.8	17.8
300-399 beds	22	17.9	19.8	31.4	11.4	19.6
400-499 beds	11	18.8	20.2	32.2	17.0	20.8
500-599 beds	3	19.8	19.5	37.4	25.2	23.8
600-999 beds	6	19.5	18.7	30.8	18.3	21.4
1000 and over	2	23.6	27.2	34.8	21.6	28.5
Average	*54*	*18.7*	*20.3*	*32.9*	*17.2*	*21.4*
Veterans	11	19.4	20.4	38.6	19.5	21.5
Mental	3	15.7	16.4	20.0	—	17.2
University	4	13.1	14.2	27.6	12.7	15.0

local congestion due to inadequate parking facilities is the most critical hospital traffic problem. Apparently, hospital officials often agree: out of 45 responses to a question on the availability and adequacy of on-street parking, only 8 indicated it was fair to good; the remainder indicated it was poor to very inadequate (Table B-16). Although on-street parking was noted as not needed at a few hospitals with campus-like sites, the characteristic response denoted a definite on-street shortage.

Nor can hospital administrations always provide sufficient off-street parking. Table B-23 shows that 28 general hospitals with segregated parking lots provide only 20 employee spaces per 100 personnel, plus 32 visitor spaces per 100 hospital beds; 20 other general hospitals, with unsegregated parking lots, provided 32 spaces per 100 beds and personnel combined. The picture is brightest at hospitals with less than 500 beds—the larger the hospital, the more space for parking would seem at a premium. VA and mental hospitals provide more employee parking, but less visitor parking.

On the whole, hospital parking would seem to be a very serious problem. It may be surprising, then, that car pooling for trips to work at hospitals is almost non-existent. Of 27 hospitals for which car pooling was recorded in the home interview surveys, 22 had none reported, and 5 had less than 2% reported. Perhaps this is because so many doctors, nurses, and other technical personnel must be free to come and go at will.

According to the tripmakers' reports, both off-street and on-street parking is relatively near the hospitals. As re-

TABLE B-22

REPORTED PARKING CHARACTERISTICS OF HOME INTERVIEW AUTO DRIVER TRIPS TO SELECTED HOSPITALS (PERCENTAGE)

HOSPITAL TYPE	NO. OF HOSP.	WORK TRIPS: OFF-STREET PAID	WORK TRIPS: OFF-STREET FREE	WORK TRIPS: ON STREET	WORK TRIPS: NOT PARKED [a]	ALL OTHER TRIPS: OFF-STREET PAID	ALL OTHER TRIPS: OFF-STREET FREE	ALL OTHER TRIPS: ON STREET	ALL OTHER TRIPS: NOT PARKED [a]
General:									
Under 300 beds	8	1	81	18	—	3	49	30	18
300-399 beds	15	1	91	8	—	2	54	25	19
400-499 beds	9	6	57	37	—	8	29	46	17
500-599 beds	1	—	83	17	—	—	44	31	25
600-999 beds	5	3	84	12	1	8	43	27	23
1000 and over	3	4	84	11	1	8	47	23	22
Average	*41*	*3*	*80*	*16*	*1*	*5*	*45*	*30*	*20*
Veterans	6	6	84	10	—	6	56	25	13
Mental	3	—	97	3	—	—	62	14	24
University	3	25	67	7	1	7	39	12	42

[a] Auto left for service or repairs, cruised, or otherwise not parked.

TABLE B-23

REPORTED PARKING RATIOS AT SELECTED HOSPITALS HAVING SEGREGATED EMPLOYEE AND VISITOR PARKING LOTS VS SELECTED HOSPITALS HAVING UNSEGREGATED PARKING LOTS

HOSPITAL TYPE	NO. OF HOSP.	SEGREGATED LOTS: EMPLOYEE SPACES PER 100 PERSONNEL	SEGREGATED LOTS: VISITOR SPACES PER 100 BEDS	SEGREGATED LOTS: TOTAL SPACES PER 100 BEDS + PERSONNEL	UNSEGREGATED LOTS: NO. OF HOSP.	UNSEGREGATED LOTS: TOTAL SPACES PER 100 BEDS + PERSONNEL	GRAND TOTAL SPACES PER 100 BEDS + PERSONNEL
General:							
Up to 500 beds	22	21	52	31	9	41	32
Over 500 beds	6	18	8	14	11	29	20
All	28	20	32	24	20	32	26
Veterans	5	45	29	39	5	38	39
Mental	2	32	7	14	—	—	14

Source: For parking spaces, hospital questionnaire returns; for beds and personnel, *Hospitals* (Guide Issue) (various years).

ported in home interview surveys, 95% of the auto drivers walk less than a block; 98% walk less than two blocks; and almost 100% walk less than three blocks. Although respondent definitions of a block might vary, excessive distances clearly are not involved.

Car Loading Factors

The number of persons to a car, or the car loading factor, varies by trip purpose. Table B-24 shows that work trips are most often by lone drivers: the average of 1.1 persons per car holds regardless of hospital type or size. At general hospitals trips for medical purposes and social-recreation trips exhibit about the same car loading, about 1.6 persons per car. At the other hospital types, trips for medical purposes average between 1.3 and 1.4 persons per car. In all cases, "other" trips have the highest average loadings, due mainly to the high proportion of serve passenger trips.

Highway Design Factors

Table B-25 summarizes the composition of traffic to and from hospitals. Passenger car units (all four-tired vehicles) account for at least 97 to 98% of daily traffic regardless of hospital type or size. Trucks constitute only 2 to 3% of the daily traffic. During the peak hour, in the dominant direction of flow, trucks generally constitute less than 1% of the trips to, or from, hospitals. The table does not represent a "standard" peak hour; data were summarized for whatever hour of the day the two-way traffic peak was greatest at each individual hospital. Table B-26 shows that this was most often the hour beginning at 3 PM or 4 PM.

The two-way traffic peak-hour percentage for general hospitals is remarkably consistent at between 11.0 and 12.6%. At VA hospitals it averages 18.2%; at university hospitals, 24.8%; and at mental hospitals, 33.4%. During this peak hour, an average of 73% of the traffic flow would be to (or from) the general hospital, and 27% would be from (or to). The directional tendency would be even more unbalanced to VA, mental, and university hospitals: 83, 80, and 87% in the dominant direction, respectively. The dominant direction for 53 of the 78 hospitals is from, in other words, representing an afternoon or evening peak hour (see Table B-26).

TRIP GENERATION

The number of trips to particular land uses can be measured on many bases: (1) dividing trips by the area in square feet, acres, or even square miles, produces the traditional "land-use trip generation rate," which can be calculated in terms of land area or floor space; (2) comparing trips with some single key indicator of site activity, such as hospital beds, college campus population, or number of employees, produces another type of generation rate; (3) comparing trips with a combination of indicators produces multiple regression predictive equations. The aim is to develop a trip generation approach that is acceptably accurate yet simple to use.

Land-Use Trip Generation Rates

Comparison of site acreages and tripmaking indicates highly variable trip generation rates. This results principally from extremes in site sizes. The average site area for the 57 general hospitals used in the multiple regression analysis is 15.7 acres, with a range from 1.0 to 192.0 acres. The average site areas for VA and mental hospitals are 44.0 and 155.8 acres, with ranges from 5.5 to 132.0 acres, and from 89.0 to 218.5 acres, respectively.

At general hospitals, site acreage correlates positively with auto driver work trips ($r = 0.75$), auto driver nonwork trips ($r = 0.54$), total transit trips ($r = 0.79$), total auto driver trips ($r = 0.67$), and total person trips ($r = 0.64$). It correlates negatively with percent of transit trips ($r = -0.06$), and the correlation between site acreage and number of beds is only fair ($r = 0.68$). Clearly, however, the larger the hospital site the more trips it attracts.

Various transportation studies have found land-use trip

TABLE B-24

AVERAGE CAR LOADING FACTORS, HOME INTERVIEW AUTO DRIVER TRIPS TO SELECTED HOSPITALS, BY TRIP PURPOSE

HOSPITAL TYPE	TRIP PURPOSE TO				
	WORK	MEDICAL	VISITOR	OTHER	ALL
General:					
Under 300 beds	1.13	1.48	1.49	1.98	1.44
300-399 beds	1.11	1.61	1.56	1.90	1.43
400-499 beds	1.09	1.60	1.61	1.82	1.41
500-599 beds	1.08	1.77	1.44	1.78	1.44
600-999 beds	1.10	1.70	1.57	2.04	1.50
1,000 and over	1.16	1.48	1.58	1.62	1.38
Average	*1.11*	*1.59*	*1.56*	*1.85*	*1.43*
Veterans	1.10	1.32	1.66	1.70	1.29
Mental	1.15	1.31	1.60	1.71	1.32
University	1.17	1.46	1.63	1.84	1.44

TABLE B-25

COMPOSITION OF TRAFFIC TO AND FROM SELECTED HOSPITALS

HOSPITAL TYPE	DAILY TRAFFIC TO AND FROM (%)				PEAK-HOUR TRAFFIC TO AND FROM (%)		
	PASS. CARS	TAXIS	LIGHT TRUCKS [a] (%)	OTHER TRUCKS [b] (%)	PART OF DAILY TRAFFIC	TRUCKS [b]	DOMINANT DIRECTION
General:							
Under 300 beds	91.0	2.9	4.8	1.3	12.4	0.4	71
300-399 beds	91.0	3.2	4.1	1.7	12.6	0.3	77
400-499 beds	88.0	7.0	3.7	1.3	11.0	1.2	62
500-599 beds	90.7	6.8	2.0	0.5	11.6	0.2	66
600-999 beds	91.4	3.3	3.8	1.5	11.4	0.8	72
1,000 and over	87.7	6.4	4.5	1.4	12.5	0.9	76
Average	*89.9*	*4.6*	*4.1*	*1.4*	*12.1*	*0.6*	*73*
Veterans	91.8	3.1	4.4	0.6	18.2	0.2	83
Mental	91.6	1.7	4.3	2.4	33.4	—	80
University	91.3	4.7	2.3	1.7	24.8	0.9	87

[a] Light trucks have four tires only. [b] Other trucks and peak-hour trucks have six or more tires.

generation rates to decrease systematically with increasing distance from the center of the urban area. This holds true for hospitals as for most other land uses. Figure B-13 plots hospital trips per acre by destination ring, as reported in the Buffalo, Pittsburgh, and Wilmington studies ("rings" are amalgamations of traffic zones concentric about the central business district, the higher numbered rings being farthest out). In each case, trip rates decrease dramatically with increasing distance from the CBD: total person trips in Pittsburgh, for example, drop from about 700 per acre in ring 1, to 300 per acre in ring 2, to less than 10 per acre in rings 5, 6, and 7. This illustrates why site acreages and tripmaking are poorly correlated, and why land-use trip generation rates do not consistently apply to particular hospitals.

Floor Space Trip Generation Rates

Trip generation rates per unit of floor space show greater consistency. For general hospitals, floor space correlates positively with auto driver work trips ($r = 0.84$), auto driver nonwork trips ($r = 0.76$), total transit trips ($r = 0.56$), total auto driver trips ($r = 0.83$), and total person trips ($r = 0.85$). Scattergrams show, however, that there are relatively high standard errors. For other hospital types, floor space correlations are not as good.

Data from the Chicago Area Transportation Study (1956) show that floor space trip generation rates for general hospitals also vary with distance from the center of the urban area. The lowest rate, 4.45 person trips per 1,000 sq ft, was found in the central area (rings 0 and 1 together); the highest rate, 14.34 person trips per 1,000 sq ft, was found in the newer suburban growth area (ring 5). The over-all rate for the study area was 6.55 person trips per 1,000 sq ft. This variation suggests that floor space, like land area, is not an effective single predictor of tripmaking.

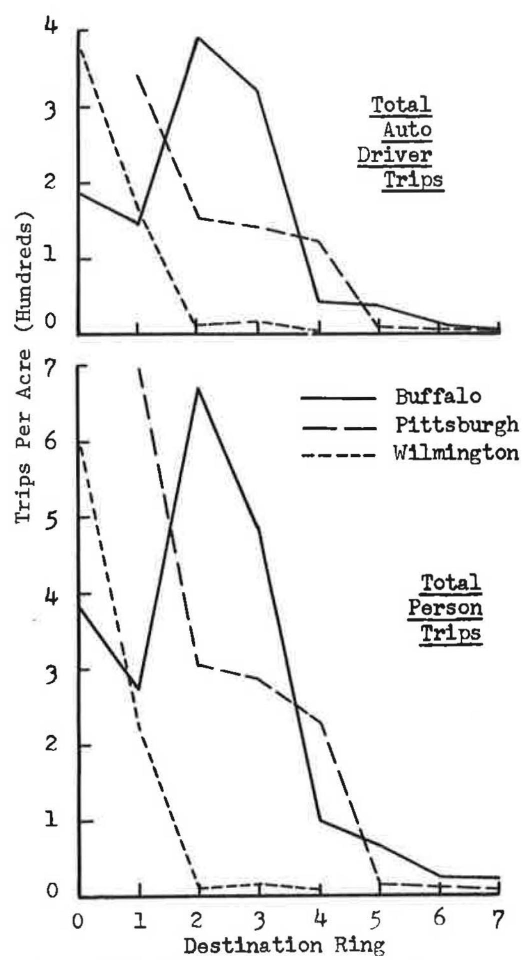

Figure B-13. Hospital trip generation rates by destination ring, selected cities.

TABLE B-26

PEAK PERCENTAGES AND DIRECTIONAL TENDENCY OF TRIPS TO AND FROM SELECTED HOSPITALS, ALL SURVEYS

HOSPITAL NO.	DAILY TRAFFIC TO AND FROM: PASSENGER CAR UNITS PLUS TRUCKS [a]	DAILY TRAFFIC TO AND FROM: TRUCKS (%)	DAILY TRAFFIC TO AND FROM: PEAK HOUR	PEAK-HOUR TRAFFIC TO AND FROM: PERCENT OF DAILY TRAFFIC	PEAK-HOUR TRAFFIC TO AND FROM: TRUCKS IN DOMINANT DIRECTION (%)	PEAK-HOUR TRAFFIC TO AND FROM: TOTAL TRAFFIC IN DOMINANT DIRECTION (%)	HOSPITAL NO.	DAILY TRAFFIC TO AND FROM: PASSENGER CAR UNITS PLUS TRUCKS [a]	DAILY TRAFFIC TO AND FROM: TRUCKS (%)	DAILY TRAFFIC TO AND FROM: PEAK HOUR	PEAK-HOUR TRAFFIC TO AND FROM: PERCENT OF DAILY TRAFFIC	PEAK-HOUR TRAFFIC TO AND FROM: TRUCKS IN DOMINANT DIRECTION (%)	PEAK-HOUR TRAFFIC TO AND FROM: TOTAL TRAFFIC IN DOMINANT DIRECTION (%)
1	2276	1.0	4 PM	12.7	—	58	38	4292	—	8 PM	10.3	—	59
2	3406	4.1	10 AM	12.6	—	60 [b]	39	1644	—	9 AM	12.5	—	73 [b]
3	3604	2.6	7 PM	13.3	—	92 [b]	40	2232	—	4 PM	26.7	—	87 [b]
4	5034	4.1	4 PM	14.7	—	95	41	2112	1.0	8 PM	14.2	—	100
5	3656	—	7 PM	9.2	—	57 [b]	42	1976	—	7 PM	14.9	—	74 [b]
6	1962	—	2 PM	13.9	—	79	43	2656	1.0	3 PM	8.8	6.3	87
7	11980	0.9	4 PM	10.3	—	70	44	4036	0.5	4 PM	11.0	—	67
8	3846	4.5	3 PM	9.3	6.5	60	45	3242	—	8 PM	13.4	—	87
9	2522	0.2	4 PM	20.6	—	83	46	3610	—	3 PM	10.6	—	77
10	1678	—	8 PM	11.3	—	68	47	2202	—	7 PM	18.8	—	65 [b]
11	1834	0.4	4 PM	17.8	—	78	48	3250	—	8 PM	17.3	—	69
12	4910	3.8	7 AM	10.5	3.1	61 [b]	49	2494	—	8 AM	19.2	—	68 [b]
13	7020	3.8	3 PM	11.7	—	70	50	2228	0.6	3 PM	13.0	—	74
14	16134	1.5	4 PM	14.6	—	79	51	2100	0.8	7 PM	12.9	—	67 [b]
14A	2308	1.6	4 PM	14.0	—	67	52	2304	3.4	Noon	10.0	—	57
14B	3914	1.8	4 PM	18.5	—	83	53	3048	1.4	3 PM	11.8	—	62
15	4546	0.3	3 PM	9.7	—	62	54	1986	1.4	3 PM	12.2	—	79
16	4866	—	7 AM	11.2	—	71 [b]	55	2512	2.6	8 PM	11.4	—	71
17	2824	0.5	4 PM	11.4	—	68	56	3022	1.9	4 PM	13.9	—	88
18	3292	1.2	7 AM	11.7	—	57 [b]	57	1690	0.9	10 AM	14.1	—	52
19	4408	0.6	3 PM	9.6	2.7	52	58	3910	0.5	4 PM	19.4	1.1	88
20	3104	0.5	2 PM	12.8	2.6	67 [b]	59	3050	0.9	3 PM	12.8	—	68
21	918	2.7	4 PM	16.2	—	100	60	2068	1.4	4 PM	17.2	—	89
22	3424	2.3	4 PM	10.9	3.3	65	61	1436	7.4	4 PM	15.1	—	67
23	2010	0.8	3 PM	14.9	—	92	62	3754	1.1	2 PM	8.7	—	55 [b]
24	2372	3.2	4 PM	13.8	—	81	63	2980	0.4	4 PM	11.8	1.7	65
25	1102	2.8	8 AM	23.4	—	100 [b]	64	2228	—	2 PM	11.7	—	72
26	556	4.9	4 PM	19.1	—	100	66	1040	—	7 AM	11.3	—	74 [b]
27	3060	2.8	3 PM	13.0	—	62	67	1056	—	3 PM	13.6	—	53
28	3194	1.5	3 PM	12.3	5.0	62	68	1580	—	5 PM	11.2	—	69
29	1608	0.8	4 PM	15.8	—	91	69	856	—	7 AM	20.1	—	88 [b]
30	1476	0.3	5 PM	13.5	—	85	70	2624	1.9	3 PM	9.9	—	59
31	9184	1.7	7 AM	11.7	1.6	76 [b]	71	2260	1.1	7 PM	12.4	—	53
32	2166	3.6	6 PM	11.1	—	92 [b]	72	1632	2.2	2 PM	10.9	—	54 [b]
33	3852	1.8	7 AM	8.5	—	79 [b]	73	1664	1.4	7 AM	21.0	—	84 [b]
34	4080	2.3	5 PM	11.0	—	61	74	8460	0.5	8 AM	17.9	0.4	88 [b]
35	2220	4.6	3 PM	10.5	—	100	75	13012	0.6	8 AM	10.3	0.5	83 [b]
36	1230	1.5	8 AM	15.7	8.5	55	76	5802	5.0	7 AM	11.3	1.3	95 [b]
37	2126	—	4 PM	15.2	—	67	77	5048	2.4	8AM	10.6	2.7	83 [b]

[a] Passenger car units include taxis and all trucks with only four tires; trucks include all vehicles with six or more tires.
[b] Dominant direction is to the hospital.

Key Indicator Trip Generation Rates

Previous research on hospital tripmaking has shown that the number of beds is the most important key indicator of total trip generation. In many cases, trip rates are presented without stratification by hospital type or size. *Access and Parking for Institutions* (*6*) provides an appendix table showing typical automobile traffic generation at hospitals in several cities. Tripmaking ranges from 1.5 to 5.4 trips per day. Comparable variation may be found in various consultant reports for particular hospitals. More recent research at the Chicago Area Transportation Study (*7*) matched total person trips to short-stay general hospitals and total hospital beds by traffic district (31 groups of traffic zones) for the whole study area. The correlation coefficient was $r = 0.97$, but two-thirds of the time the resulting regression equation would yield estimated tripmaking only within ± 28% of the actual tripmaking.

The results of matching total person trips and beds at the general hospitals in the present cross section mirror the Chicago experience. The correlation is $r = 0.93$ and the standard error related to the mean tripmaking ($S_{YX}/\overline{Y}$) is 31%. Separating work trips and nonwork trips produces only slightly different results (Fig. B-14). Appendix F provides statistics and predictive equations for all the work described in this section.

Another key indicator for predicting hospital trips is hospital personnel. As defined in *Hospitals, Guide Issues:*

> Personnel: for United States hospitals, excludes trainees (student nurses, interns and residents, other), private duty nurses, and volunteers; includes full-time equivalents for part-time personnel. For Canadian hospitals, includes interns, residents and students; does not include full-time equivalents for part-time personnel.

For the cross-section general hospitals, the correlation between total person trips and personnel is $r = 0.91$ and the $S_{YX}/\overline{Y}$ is 29%. From scattergrams it would appear that all hospital types could have been included in the statistical calculations without significantly affecting them. (With only 11 VA hospitals, 4 mental hospitals, and 4 university hospitals, simple and multiple regression analyses separately

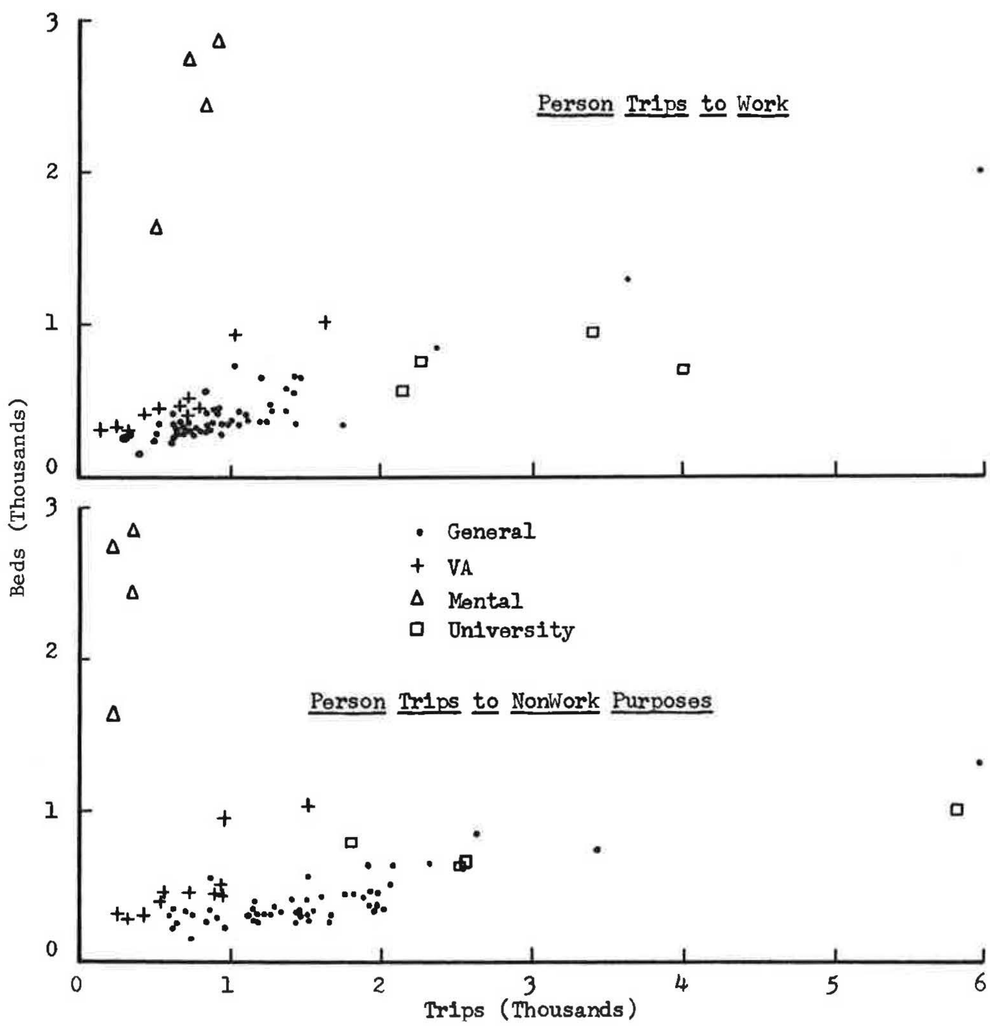

Figure B-14. Person trips to work and to non-work purposes related to hospital beds, by hospital type.

for them were omitted. Approximate trip predictive equations can be determined for them from the various sections of Appendix F.)

Treating person work trips only, all hospitals were included: The correlation is $r = 0.91$ and the $S_{YX}/\overline{Y}$ is 27% (see Fig. B-15). The predictive equation would indicate that there are approximately 1.2 trips to work per "personnel." (Normally, in predicting work trips from employment, there would be about 0.9 trips to work per employee, as absenteeism averages approximately 10%.) Daily work trips probably exceed personnel because trips by visiting physicians and trainees are included, whereas such individuals are not included as "personnel" (see previous definition). Treating nonwork trips only, at general hospitals only, the correlation is $r = 0.92$ and the $S_{YX}/\overline{Y}$ is 33% (see Fig. B-15).

Although there is variation from hospital to hospital, all of the foregoing show an obvious correlation between total person tripmaking and either general hospital beds or general hospital personnel. To derive automobile trips, the number of transit trips would need to be estimated and subtracted, and the remaining trips divided by an estimated average car loading. Alternatively, it is possible to predict auto driver trips directly.

For general hospitals, the correlation between total auto driver trips and hospital beds is $r = 0.84$ and the $S_{YX}/\overline{Y}$ is 38%. Separating work trips and nonwork trips provides substantially the same results. The correlation between total auto driver trips and personnel is $r = 0.88$ and the

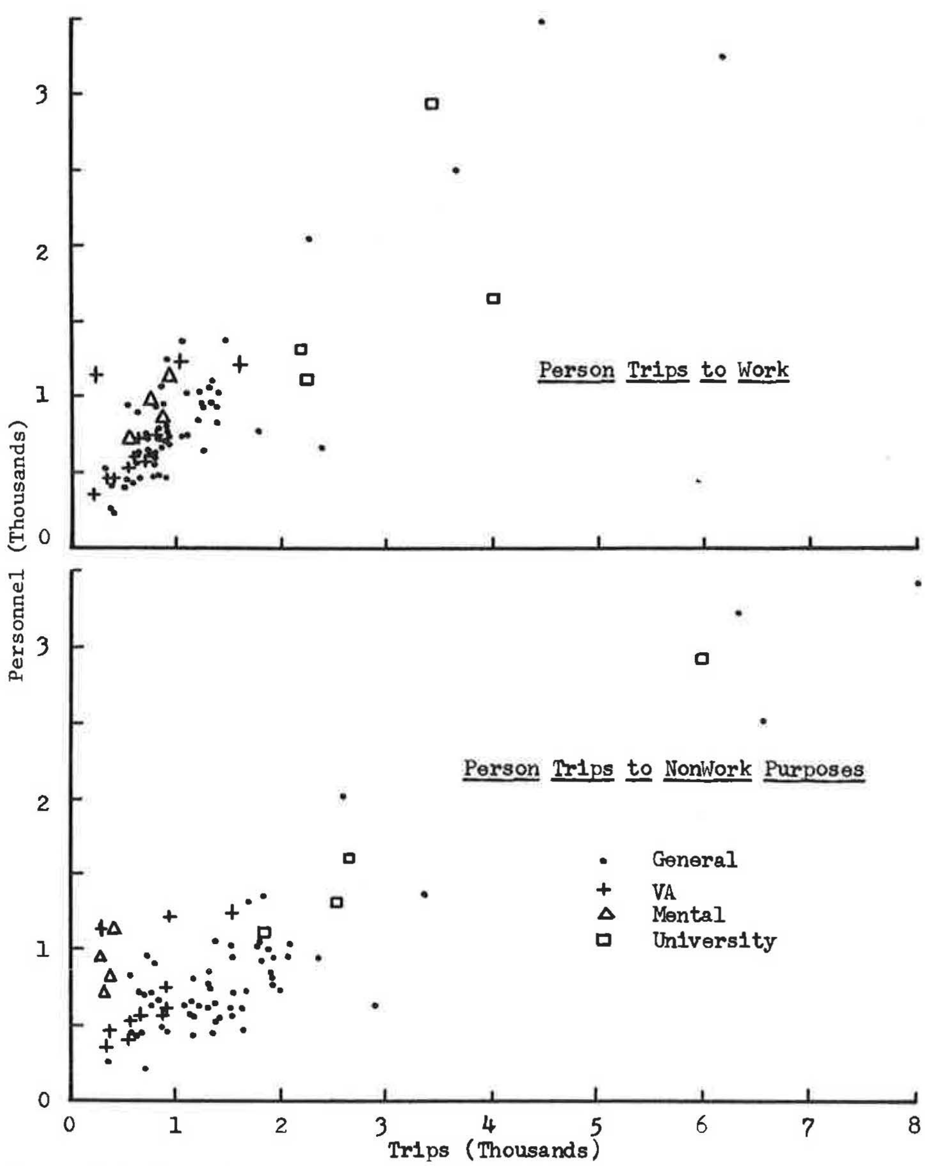

Figure B-15. Person trips to work and to non-work purposes related to hospital personnel, by hospital type.

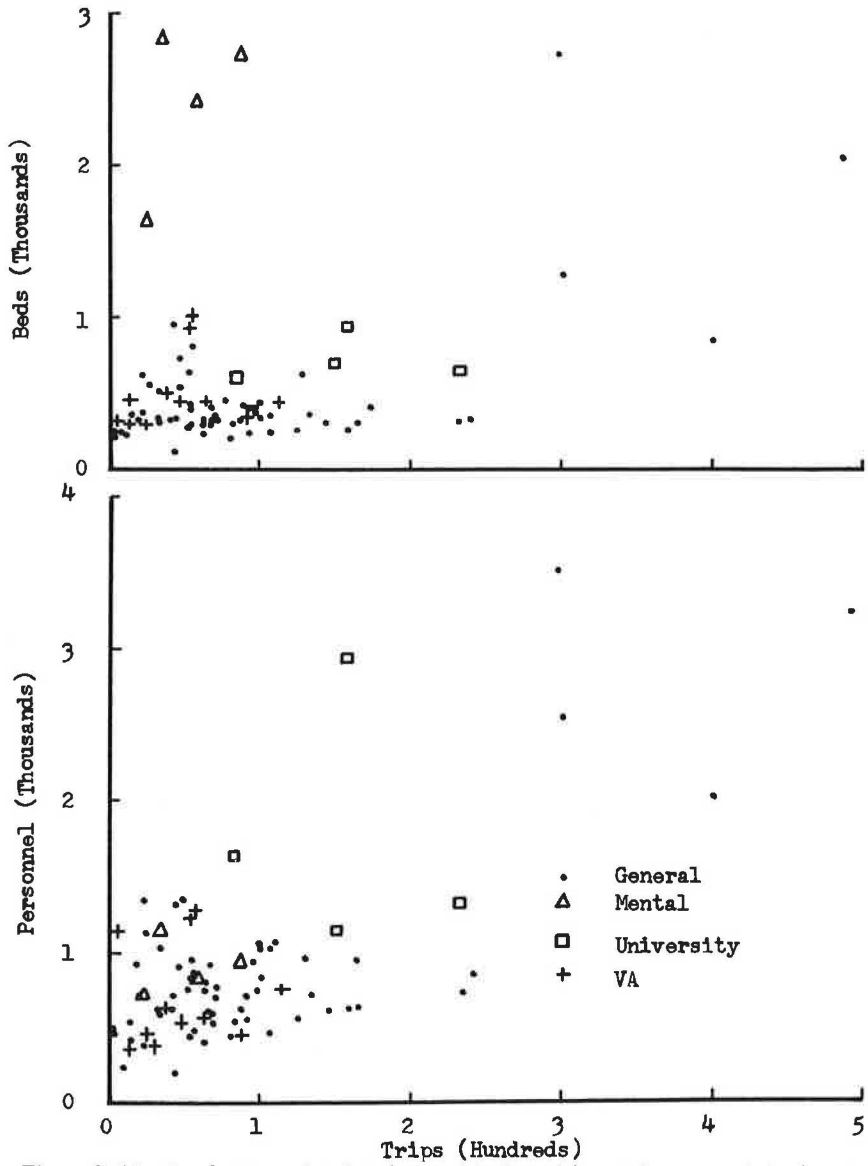

Figure B-16. Truck trips related to hospital beds and hospital personnel, by hospital type.

$S_{YX}/\bar{Y}$ is 34%. Again, separating work trips and nonwork trips hardly changes the results.

Attempts to relate truck tripmaking to hospital beds or hospital personnel were generally unsuccessful. Figure B-16 shows the scattergram relationships.

Multiple Regression Predictive Equations

Because many factors bear on the total trip generation at hospitals, multiple regression analysis provides one approach to assigning them proper weights. Although cause and effect are never proved, the association between and among variables can be demonstrated. Scores of variables may be pertinent, but the search for a practical predictive equation often results in using only a few independent variables which "explain" most of the variation in the dependent variable, and which themselves can be reliably predicted. Such is the present case.

Test data included 18 independent variables and 6 dependent variables for 57 general hospitals (2 of the cross-section hospitals were omitted because of data irregularities). The dependent variables represented various stratifications of tripmaking; the independent variables mainly described selected characteristics of hospital use, hospital sites, and hospital service areas (for this purpose defined as the area within a 3-mile radius of each hospital). Data were obtained from transportation study sources, from American Hospital Association publications or records, and from hospital questionnaires.

The results, using the "California Biomedical" stepwise regression program, were encouraging. Using the full models (that is, all independent variables) to predict each dependent variable, the multiple coefficients of determination (R^2) ranged from 0.76 to 0.92. However, standard errors of the estimate (S_E) as percentages of the dependent variable means ranged from 24 to 47%. In other words, the predictive equations were not as good as they might seem (see App. F for further statistical results and definitions of all variables).

The most significant "explainer" variables differed somewhat, depending on what dependent variable was considered. In predicting all types of auto driver trips, as well as total person trips, hospital personnel was consistently the most significant factor. Ground area ratio and total site acreage also ranked high as "explainers" (the higher the ratio, or the larger the site, the more trips). Population within a 3-mile radius of the hospital ranked high in predicting total auto driver trips and auto driver trips to work, but was insignificant in predicting auto driver trips to nonwork purposes and total person trips. The same "explainer" was the most significant predictor of the percent of transit trips, and the second most significant predictor of total transit trips. Appendix F gives the rank ordering of each independent variable as a predictor of each dependent variable.

The "best" predictive equation for each dependent variable—meaning in this case the equation with the lowest S_E—does not include every independent variable. It may be instructive to describe the predictive equation for total auto driver trips, variable by variable, as illustration. The eight independent variables behaved as follows: daily auto driver trips increase with increases in the number of hospital beds, hospital personnel and hospital floor space, as well as with an increase in the ratio of the average daily census to the number of hospital beds (in effect, the hospital "utilization" ratio); daily auto driver trips decrease with increases in the population within a 3-mile radius of the hospital, the average length of stay, ground area ratio, and number of annual outpatient visits.

The positive predictors in this illustration are easy to understand. The negative predictors may be interpreted to mean that: (1) the longer a patient stays in the hospital, the fewer daily trips he attracts (for one thing, the number of visitors tails off); (2) increased population within the 3-mile radius suggests higher levels of transit service, and lower car ownership, thus substitution of transit riding for auto driving; (3) higher ground area ratios connote more central locations associated with higher levels of transit service, and perhaps with greater parking and driving difficulties, thus again a substitution of travel modes; and (4) outpatient visits are predominantly by lower-income patients often not having access to an automobile. These are the inferences, at least, that must be drawn from the data representing the 57 general hospitals in the test. The individual effects of the independent variables in the remaining five predictive equations can be seen in Appendix F.

On the whole, this multiple regression analysis of trip generation at general hospitals is considered successful. Predictive results are certainly improved over those from the simple regression analyses using either hospital beds or hospital personnel. However, many researchers have pointed out the pitfalls of applying such results haphazardly (*8*). This report need only repeat that caution and much common sense are required.

Obviously, however, this is but a first pass at a very involved subject. Metropolitan hospital use may well be amenable to complete computer simulation. To distill the significant factors, in fact, is the subject of a $168,000 research project approved recently. Intensive correlation and covariance analyses are foreseen (*9*). The results will go far beyond the modest research reported here (see entry 11 under "Hospitals," App. J).

TRIP DISTRIBUTION

Trip rate curves describe the distribution of trip origins at various distances or travel times from the hospital. Rates are expressed as trips per 1,000 population. Based on home interview trips only, rates are calculated to a distance of 10 miles or a travel time of 20 min by 1-mile and 2-min increments, respectively.* Problems of directional distribution are discussed in a following subsection.

Distance Rates

Auto driver and total person trips per 1,000 population by distance are shown in Figure B-17. These are the weighted trip rate curves for 39 general hospitals, 8 VA hospitals, 3 mental hospitals, and 3 university hospitals in the cross section. The frequency of tripmaking to all four hospital types clearly decreases with increasing distance.

Taking general hospitals only, trip rates by trip purpose are shown in Figure B-18. Trips to work are the most affected by distance; that is, they produce the curve with the steepest slope. Visitor and "other" trips are the least affected. Trips for medical purposes are somewhere between; but clearly patients are assigned, or choose, their hospitals with some thought to the travel distance involved.

Time Rates

For cities such as Pittsburgh, with its irregular topography and winding streets, or Madison, Wis., with its looping lakefronts, the facility of travel between any pair of points certainly would best be expressed in time rather than airline distance. Travel time "trees" can be used to describe the over-the-road typical passenger car travel time between the traffic zone in which the hospital is located and all other traffic zones in the particular urban area. Although time required for parking and walking is excluded, such "tree" approximations have been used previously in areawide hospital planning (*10*).

* Certain mechanical differences between the distance-based and time-based curves might be noted. The time curves are more asymptotic to the vertical axis, appear to slope more sharply, and apparently show higher trip rates than do the distance curves. This is largely because the travel time curves represent a finer scaling of the horizontal axis—the equivalent of the distance scale truncated at perhaps the 6- to 7-mile limit and redivided into ten travel time increments. For example, at 0-1 mile on the distance scale, the plotted trip rate will normally represent a composite of several traffic zones; at 0-2 min on the time scale, the plotted trip rate will always represent only the "home" zone; that is, the zone in which the subject hospital is located. Throughout, in fact, each point on the time scale will generally represent fewer traffic zones. Thus, the time curve shows a more exact function than will the distance curve.

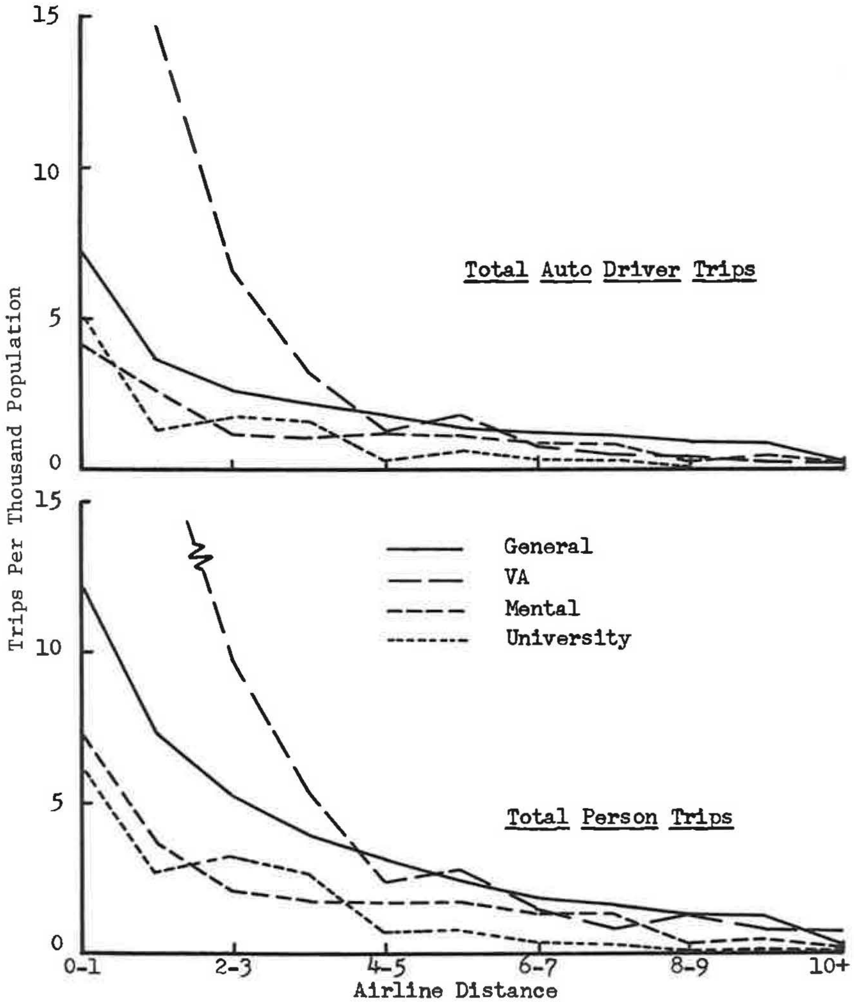

Figure B-17. Trip rates by distance and hospital type.

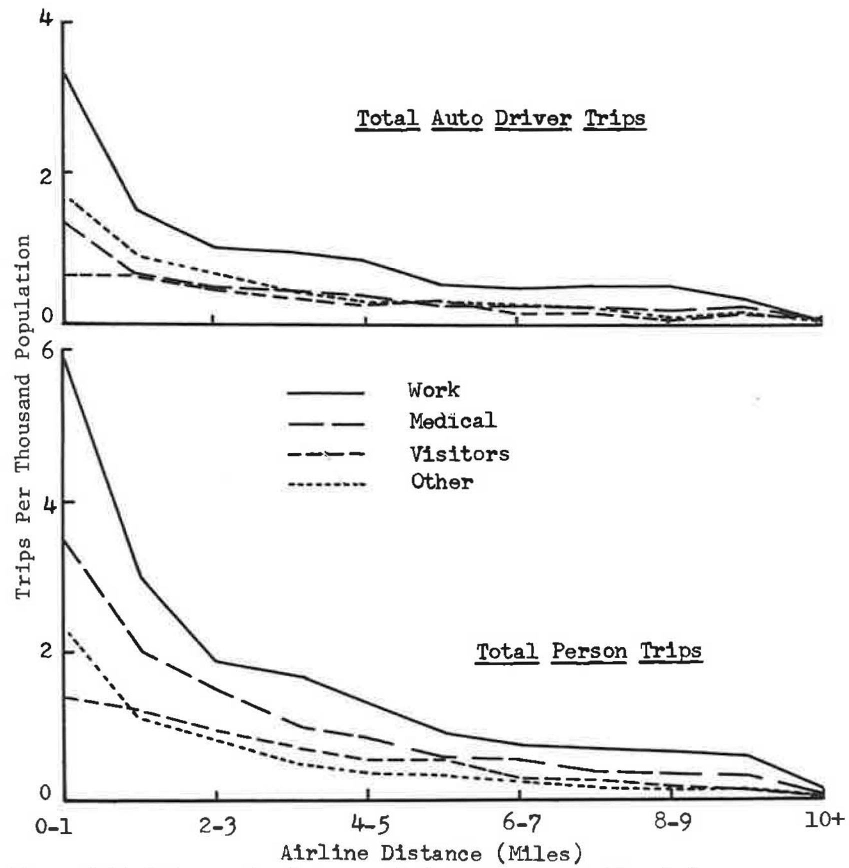

Figure B-18. Trip rates by distance and trip purpose, general hospitals.

Auto driver and total person trips per 1,000 population by travel time are shown in Figure B-19. These are the weighted trip rate curves for 22 general hospitals, 4 VA hospitals, and 3 mental hospitals in the cross section. The frequency of tripmaking to all three hospital types decreases with increasing travel time.

Figure B-20 shows trip rates by trip purpose for general hospitals only. As with distance, the frequency of tripmaking decreases regularly with increasing travel time, but variably according to trip purpose. Curiously, the medical and "other" purpose curves are practically straight lines, by contrast to the more curvilinear work and visitor purpose curves.

Directional Distribution

In predicting the proportion of hospital trips that arrive from various travel directions, some relationship with the distribution of population might be expected; for example, a quadrant of an urban area containing $X\%$ of the population within a stated radius of a subject hospital would also contain $X\%$ of the hospital trip origins. Various tests tend to support this expectation where hospital service areas are reasonably clearcut, but not where there is marked overlapping.

Ten general hospitals in Buffalo were taken as representative of the case of overlapping service areas. Trips and population were summed by quadrants drawn arbitrarily about each hospital. Figure B-21 shows that there may be significant mismatches between any given quadrant's share of population and its share of trip origins. When within each quadrant the distribution of population by mile increment is considered, however, and the composite Buffalo trip rate curve on distance is used to predict trips by quadrant, comparisons between predicted and actual tripmaking reflects considerable improvement (Fig. B-22). However, the results are still far from perfect.

Two general hospitals in Tucson were taken as representative of the case of more distinct service areas. Again, trips and population were summed by quadrants drawn arbitrarily about each hospital. The results are given in Table B-27. At both hospitals the proportions of population

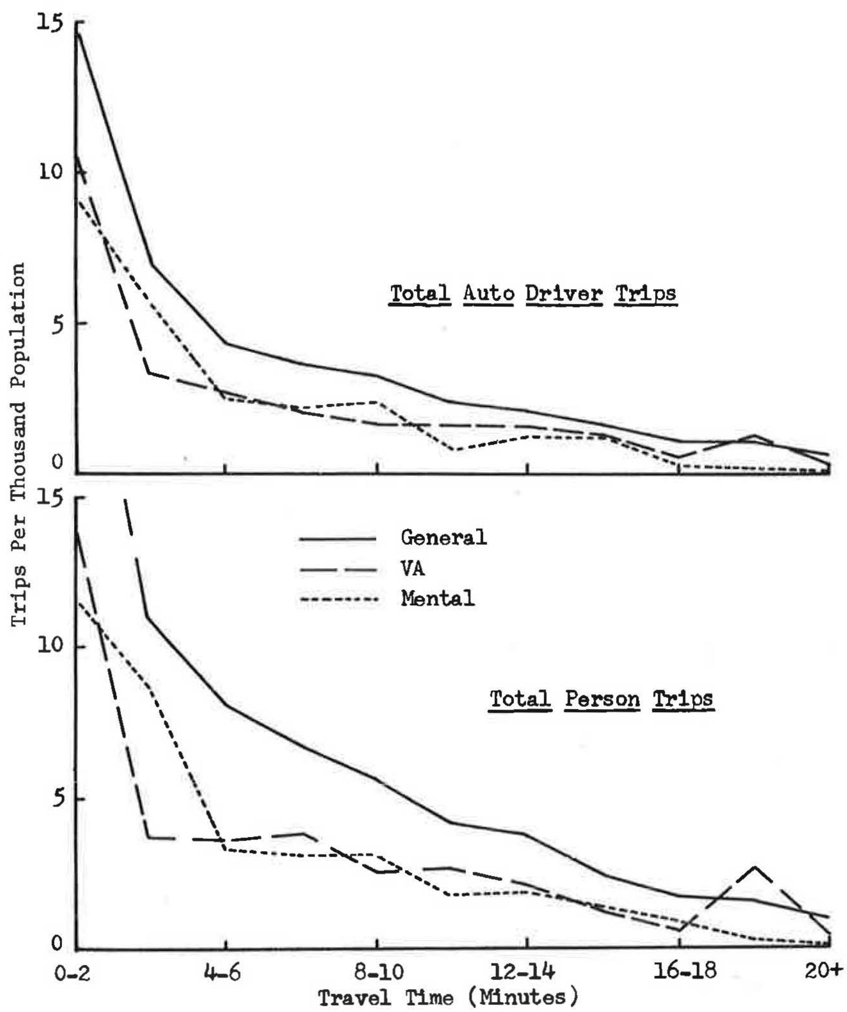

Figure B-19. Trip rates by travel time and hospital type.

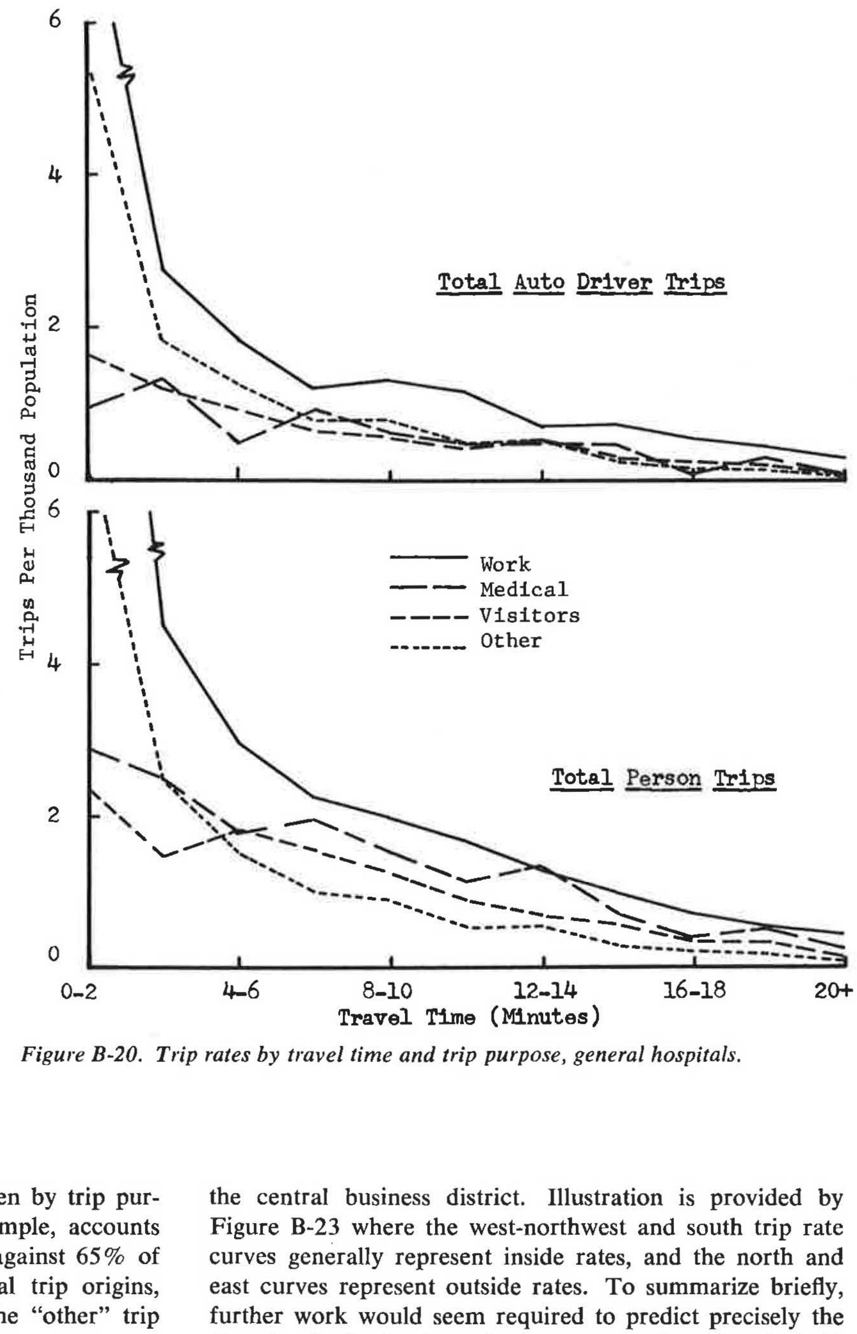

Figure B-20. Trip rates by travel time and trip purpose, general hospitals.

and trips by quadrant match quite well, even by trip purpose. Quadrant 4 for hospital 27, for example, accounts for 54% of the urban area population, as against 65% of the work trip origins, 53% of the medical trip origins, 54% of the visitor trip origins, 60% of the "other" trip origins, and 61% of the total trip origins.

Differences in the test cases stem largely from the fact that the two Tucson subject hospitals together represent 70% of the general hospital beds in the urban area (35% each, 1960) and are well separated geographically, whereas the ten Buffalo subject hospitals all told represent 77% of the general hospital beds in that urban area (the largest about 17%, 1962) but are not well separated geographically. Figures B-25 and B-27, discussed later under the heading "Service Areas," compare the extent of tripmaking overlap.

At any rate, unlike major shopping centers or manufacturing plants, hospitals do not seem to establish higher "outside" trip rates and lower "inside" trip rates (*11*). That is, the number of trips per 1,000 population is not higher in the direction of the suburban areas than in the direction of the central business district. Illustration is provided by Figure B-23 where the west-northwest and south trip rate curves generally represent inside rates, and the north and east curves represent outside rates. To summarize briefly, further work would seem required to predict precisely the directional distribution of trips to any given hospital. It would appear, however, that for highway design purposes an approximation can be derived by application of trip rate curves (either distance or time) to existing or projected population distributions.

SERVICE AREAS AND URBAN HOSPITAL SYSTEMS

Earlier it was reported that various components of travel to a particular hospital could be predicted reasonably well on the basis of the hospital and its service area characteristics. Competitive effects of other hospitals or medical offices were ignored. It may be helpful at this point to consider total tripmaking for medical purposes in several entire urban areas to determine whether any competitive effects actually exist.

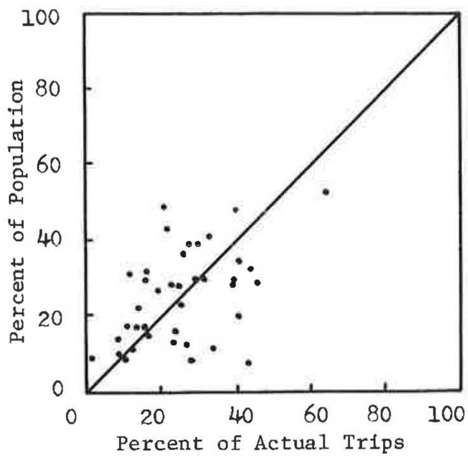

Figure B-21. Comparison of percentages of total person trips to ten general hospitals in Buffalo and percentage's of population by sector.

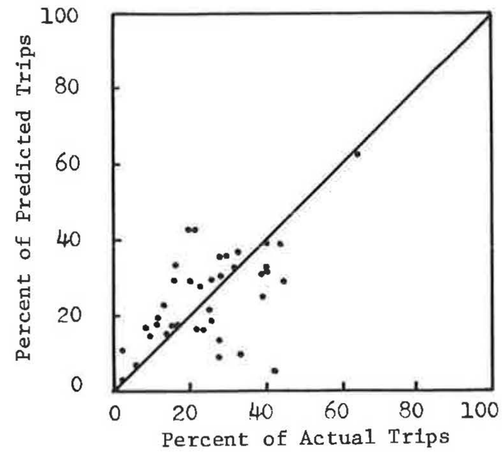

Figure B-22. Comparison of predicted vs actual trip percentages by sector for ten general hospitals in Buffalo.

Medical Trip Production

Some transportation studies use the distinct trip purpose "medical-dental." By typical definition this refers to trips "made for consultation about health with doctors, dentists, etc., and does not refer to trips made by doctors or nurses to see patients, which are classed as work." (*13*) Though trips

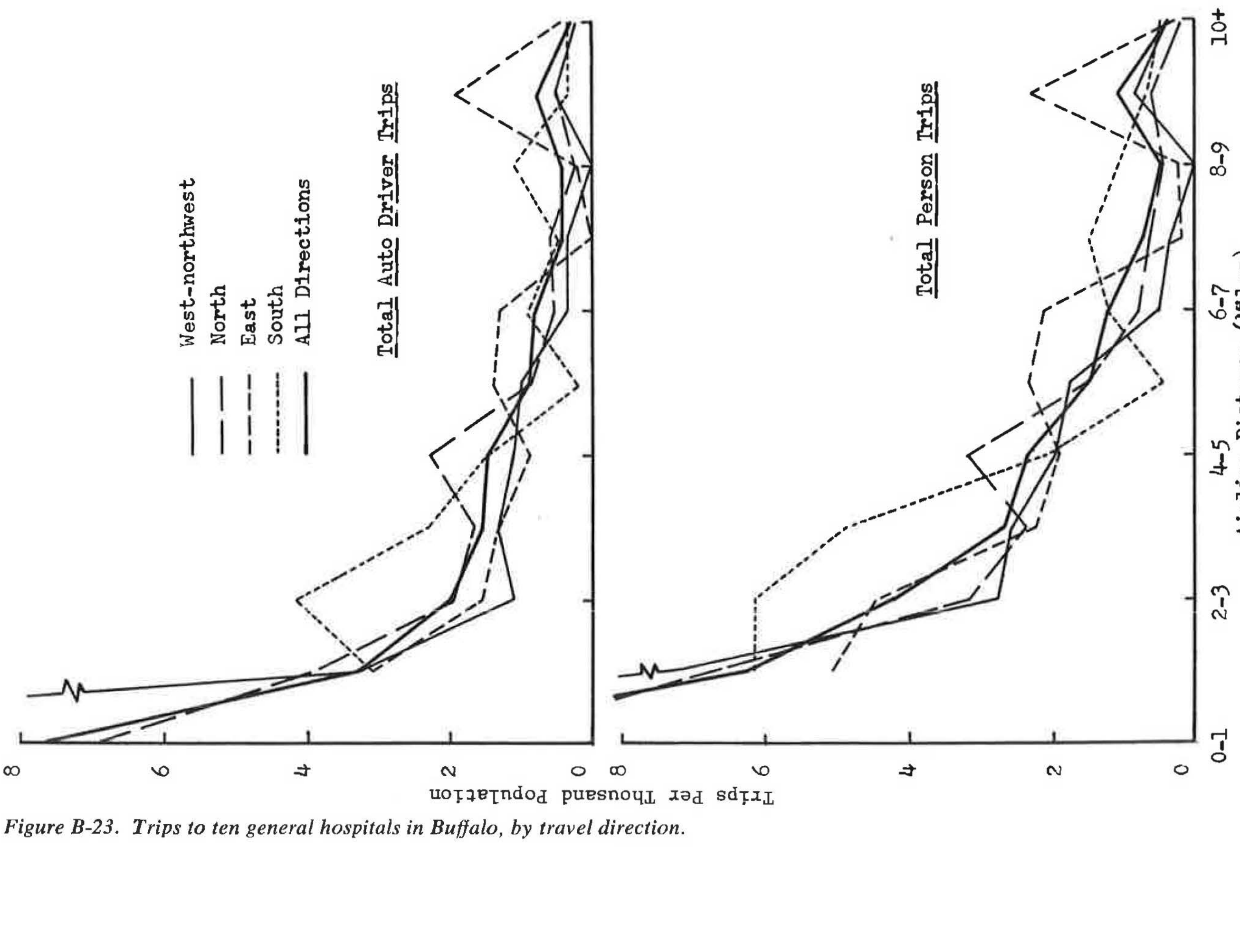

Figure B-23. Trips to ten general hospitals in Buffalo, by travel direction.

TABLE B-27

COMPARISON OF PERCENTAGES OF POPULATIONS AND HOME INTERVIEW TRIP ORIGINS WITHIN FIVE-MILE RADII OF TWO GENERAL HOSPITALS IN TUCSON, ARIZONA, BY TRIP PURPOSE, BY STUDY AREA SECTOR

HOSPITAL	TRIP PURPOSE TO	SECTOR 1		SECTOR 2		SECTOR 3		SECTOR 4	
		POP.	TRIPS	POP.	TRIPS	POP.	TRIPS	POP.	TRIPS
No. 27	Work		—		7		28		65
(326-Bed	Medical		3		3		41		53
general	Visitor		3		—		43		54
hospital)	Other		—		—		40		60
	All	2	1	3	4	41	34	54	61
No. 28	Work		17		56		26		1
(305-Bed	Medical		8		66		26		—
general	Visitor		27		32		41		—
hospital)	Other		20		45		35		—
	All	23	19	44	48	32	32	1	1

Source: Tucson Area Transportation Study.

to dentists' offices cannot be segregated, the following paragraphs tell much about total tripmaking for health purposes.

Table B-28 shows, for example, that medical-dental trips average about 1% of the total person trips in each of seven selected study areas—generally the smallest of the ten trip purpose groups typically used (and possibly why some studies have not used this purpose group). Transit and auto passengers represent slightly larger shares, and auto drivers a slightly smaller share, of the total study area tripmaking by travel mode.

Such data do not reflect the advent of the Medicare program. It can certainly be speculated that with an aging population, and the expanding scope of lower-cost medical services, the frequency of medical-dental trips per capita will increase through time. Medical-dental trips in Erie, Pa., for example, increased from 0.9% of all urban area person trips in 1950 to 1.4% in 1962 (*14*). In Erie, this meant an increase only from 1,639 to 4,440 daily person trips; in larger urban areas the increase could be much more dramatic.

Combining patient and visitor tripmaking, but excluding all other trips, provides a basis for comparing medical trip production in several of the cross-section urban areas. In New Orleans, 1960, such tripmaking included about 10,800 person trips to medical offices, about 12,500 person trips to hospitals, and about 1,200 person trips to other health establishments, daily. Interestingly, as Table B-29 shows, although city and suburban households produced about the same number of hospital trips per 1,000 population, suburban households produced half again as many trips to medical offices.

The New Orleans hospital trip rates are slightly higher than those for Pittsburgh and Buffalo given in Table B-30. (These studies did not distinguish medical offices and other medical establishments, combining them with other land-use categories.) Both the latter cities demonstrate more clearly the tendency for suburban households to make fewer trips per capita than do city households. Although it might appear that the higher-income suburban families should

TABLE B-28

PERCENTAGES OF TOTAL HOME INTERVIEW TRIPS TO MEDICAL-DENTAL PURPOSES FOR SELECTED STUDY AREAS, BY MODE OF TRAVEL

STUDY AREA	MODE OF TRAVEL			
	AUTO DRIVER	AUTO PASS.	TRANSIT PASS.	ALL
Ann Arbor	2.2[a]	NA	NA	NA
Atlanta	0.8	1.2	1.4	1.0
Indianapolis	0.6	1.3	0.9	0.8
Madison	0.5	1.2	0.9	0.7
New Orleans	0.7	NA	NA	1.2
Salt Lake City	0.8	1.4	2.3	1.0
Tucson	0.9	1.5	2.2	1.1

[a] Based on summarized home interview screen line crossings only.

TABLE B-29

HOME INTERVIEW TRIP PRODUCTION PER THOUSAND POPULATION FOR MEDICAL AND VISITOR PURPOSES[a] BY TYPE OF MEDICAL ESTABLISHMENT, AT CITY VERSUS SUBURBAN HOUSEHOLDS, NEW ORLEANS, 1960

	TRIPS PER 1,000 POPULATION		
DESTINATION LAND USE	CITY HOUSE-HOLDS	SUBURBAN HOUSE-HOLDS	TOTAL AREA
Medical offices	9.98	15.49	13.08
Hospitals	15.42	14.93	15.14
Other health estab.	1.16	0.88	1.39
Total	26.56	31.30	29.61

[a] Includes medical-dental, personal business, and social-recreation trip purposes.

Source: New Orleans Transportation Study data.

TABLE B-30

HOME INTERVIEW TRIP PRODUCTION PER THOUSAND POPULATION FOR MEDICAL AND VISITOR PURPOSES,[a] TO HOSPITALS AT CITY VERSUS SUBURBAN HOUSEHOLDS (BY RING), PITTSBURGH, 1958 AND BUFFALO, 1962

TRIP PRODUCTION RING	PITTSBURGH TRIPS PER 1,000 POPULATION	BUFFALO TRIPS PER 1,000 POPULATION
0	21.40	18.50
1	12.25	18.66
2	10.73	15.48
3	12.10	13.56
4	12.23	12.63
City	12.62	15.03
5	9.71	8.23
6	8.72	11.59
7	6.85	13.39
Suburban	8.91	10.78
Total	10.80	13.73

[a] Includes personal business and social-recreation trip purposes.

Source: Pittsburgh Area Transportation Study and Niagara Frontier Transportation Study.

make more hospital trips per capita, at least one prior study (*15*) has confirmed that they do not:

> In general, it was found that the lower the plane of living in an area within the city, the greater the proportion of its residents hospitalized. In a study of the use of hospitals in Syracuse, N. Y., for example, in which all admissions to hospitals were analyzed by economic groupings during a two-month period in 1951, it was found that the lowest of nine economic groups had 157.67 admissions per 1,000 residents per year while the highest economic group had 94.96 admissions per 1,000 residents per year.

Tripmaking to all general hospitals for all purposes is relatively consistent among all the urban areas in the cross section. Table B-31 gives the results of comparing estimated total annual person trips and total annual admissions.* Tripmaking ranges from New Orleans' 61 to Minneapolis-St. Paul's 70 trips per admission. This is the average number of trips that would normally be spread out during each patient's whole stay. The other indicator—daily trips per bed—is the average number of trips per day per bed; its

* For example, in the Buffalo urban area there were in 1962 approximately 30,000 person trips per weekday to all general hospitals. Assuming that Saturday and Sunday tripmaking each average 80% of the average weekday, there would be about 10.3 million annual person trips. During the same year, there were about 163,000 admissions. The result is about 64 person trips per admission.

TABLE B-31

PERSON TRIPS TO SELECTED GENERAL HOSPITALS, PER ADMISSION AND PER BED, IN SELECTED URBAN AREAS

	URBAN AREA HOSPITALS		CROSS-SECTION HOSPITALS	
URBAN AREA	TOTAL TRIPS PER ADMISSION	DAILY TRIPS PER BED	TOTAL TRIPS PER ADMISSION	DAILY TRIPS PER BED
Atlanta	NA	NA	49	5.51
Buffalo	64	5.10	66	5.66
Indianapolis	NA	NA	81	7.27
Madison	67	5.78	71	6.11
Miami	NA	NA	81	7.27
Minneapolis-St. Paul	70	6.72	62	5.25
New Orleans	61	5.13	63	4.74
Pittsburgh	63	5.30	68	5.43
Seattle	NA	NA	34	3.25
Wilmington	66	6.51	64	6.57

Source: *Hospitals* (Guide Issue) (various years) for beds and admissions; transportation study data for daily person trips, then used to estimate annual person trips.

relationship to total trips per admission varies due to differences in the average length of hospital stay from area to area. Table B-31 gives the companion results for only the cross-section hospitals in each urban area; again, the results are relatively consistent.

The cross-section hospitals account for a large share of the total general hospital admissions in each urban area, ranging from 22% in Pittsburgh to 98% in Indianapolis, or 55% for all urban areas. Inasmuch as cross-section hospitals represent the largest hospitals, any differences between their trip rates and the all-hospitals trip rates are suggestive of the trip generating characteristics of the smaller hospitals. From the six available comparisons, it would appear that the trip rates are not significantly different.

Health establishments tend to be more centralized than the travel production they generate. In New Orleans, for example, although only 33% of all person trips to medical offices are produced by city families, 46% of all such trips are attracted by city medical offices (Table B-32). Comparable figures for hospital travel are 45% trip production versus 57% trip attraction. However, medical offices do appear to be the more suburban-oriented. This is further illustrated by the Wilmington trip attraction data given in Table B-32 (trip production data not available).

In other words, a goodly number of suburban families still come to the city for medical care. Of course, some suburban families may already work or shop in the city (and vice versa) and combine such trips with those for medical care. Table B-33 shows, however, that about 76% of all medical-dental trips start at home; only 6% start from work, 3% from shopping, and 15% from all other purposes. Proportionately more auto, taxi, and transit passenger trips for medical care start at home.

Medical Trip and Tripmaker Characteristics

Taking New Orleans for continued illustration, and without going into great detail, certain differences between the characteristics of trips to medical offices and trips to hospitals can be noted: (1) About 52% of all medical office trips are by auto drivers, and 20% by transit passengers; only about 47% of all hospital trips are by auto drivers, but 34% by transit passengers. (2) About 63% of all medical office trips are for medical-dental purposes; only 25% of all hospital trips are for this purpose. Hospitals, of course, attract far more employee and visitor trips. (3) Hospital trips peak at 7 to 8 AM, with lesser peaks at 2 to 3 PM and 7 to 8 PM; medical office trips peak at 9 to 10 AM, with a nearly equal peak at 3 to 4 PM. Hospitals attract many evening trips; medical offices attract very few.

Other differences relate to tripmaker characteristics. Table B-34 gives the percentages of medical-dental trips in New Orleans with hospital destination, by sex, race, and occupation of tripmaker (subtracting any given percentage from 100 will give the percentage to medical offices). Immediately, it is seen that only 22% of the health care trips by white tripmakers are to hospitals (therefore, 78% to medical offices), as compared to 71% of such trips by nonwhite tripmakers—a remarkable variation. Male whites are more apt to seek health care at hospitals than are female whites; the reverse is true, and to a greater degree, among nonwhites. Table B-34 also shows some interesting variations by occupation group. Over-all, only 16% of clerical and salesworkers' medical-dental trips have hospital destinations, lowest of any group. Possibly this is because many such workers are employed downtown where they are within easy reach of many medical offices. By contrast, 59% of laborers' and service workers' medical-dental trips have hospital destinations. Although it is not known whether these proportions hold true in other cities, and whether they are changing through time, it does seem highly significant that, over-all, only 32% of all medical-

TABLE B-32

PERCENTAGES OF TOTAL HOME INTERVIEW TRIPS TO HEALTH ESTABLISHMENTS IN NEW ORLEANS AND WILMINGTON, BY TRIP DESTINATION AREA[a]

CITY AND TYPE OF HEALTH ESTABLISHMENT	TRIP DESTINATIONS AREA: CITY	SUBURBAN	ALL
New Orleans			
Medical offices	46.1	53.9	100.0
Hospitals	56.5	43.5	100.0
Other health estab.	40.0	60.0	100.0
All	51.5	48.5	100.0
Wilmington			
Medical offices	62.1	37.9	100.0
Other health estab.	82.3	17.7	100.0
All	72.6	27.4	100.0

[a] For New Orleans, "city" includes traffic zones 130 through 149, 200 through 226, and 900 through 934; "suburban" includes all other traffic zones. For Wilmington, "city" includes traffic rings 0 and 1; "suburban" includes traffic rings 2, 3, and 4.

Source: New Orleans Area Transportation Study and New Castle County Planning Program data.

TABLE B-33

PERCENTAGES OF TOTAL HOME INTERVIEW TRIPS TO MEDICAL-DENTAL PURPOSES, BY MODE OF TRAVEL, BY TRIP PURPOSE FROM

TRIP PURPOSE FROM	MODE OF TRAVEL: AUTO DRIVER	AUTO PASS.	TRANSIT PASS.	ALL
Home	68.1	79.7	85.0	75.8
Work	9.9	2.4	3.4	5.9
Personal business	3.6	2.3	1.3	2.7
Shop	4.5	2.8	1.3	3.2
Medical-dental	1.4	1.5	1.2	1.4
Serve passenger	7.8	0.8	—	3.6
Other	4.7	10.5	7.8	7.4
All	100.0	100.0	100.0	100.0

Source: Transportation study data (weighted averages) for Atlanta, Indianapolis, Madison, New Orleans, and Tucson.

TABLE B-34

PERCENTAGES OF TOTAL HOME INTERVIEW TRIPS FOR MEDICAL-DENTAL PURPOSES DESTINED TO HOSPITALS, BY TRIPMAKER SEX, RACE, AND OCCUPATION, NEW ORLEANS, 1960

	OCCUPATION GROUP					
SEX AND RACE	PROFESSIONAL AND MANAGERIAL	CLERICAL AND SALES	CRAFTSMEN AND OPERATIVES	LABORERS AND SERVICE WORKERS	OTHERS [a]	ALL
White, total	32	18	32	44	19	22
Male	32	19	31	42	15	25
Female	32	16	50	50	20	21
Nonwhite, total	40	—	80	70	74	71
Male	50	—	80	64	64	63
Female	33	—	—	82	76	75
Male, total	33	19	41	54	27	34
Female, total	32	16	50	73	31	31
All	32	16	42	59	31	32

[a] Includes students, housewives and retired persons.

Source: New Orleans Metropolitan Area Transportation Study.

dental trips in New Orleans in 1960 were to hospitals, as against 68% to medical offices.

Aside from sociological implications, several interesting questions which bear on providing travel facilities are suggested: What proportion of health care travel must necessarily be hospital-directed? Would the travel time savings resulting from having a larger number of smaller, decentralized hospitals offset the capital cost savings resulting from having fewer, larger, and more centralized hospitals? Must we always provide very large, centralized hospitals which, because of locations amenable to good transit service, can best serve low-income, carless families? Beyond the scope of the present work, these and related questions are among those encompassed in area-wide hospital planning.

Service Areas

Interest in defining hospital service areas has grown rapidly with the advent of area-wide hospital planning. Such planning calls for each hospital to assume responsibility for providing comprehensive community care to a specific geographic area (which, however, it may share in part with other medical care institutions). Lacking this approach, there can be the wrong number of hospitals in the wrong places. As the American Hospital Association (*17*) has put it:

> While the location and size of hospitals and other medical care institutions throughout this country generally reflect community need, as evidenced by their location in trading or transportation centers tailored in size to fit the population to be served, in some places special interests and local pride have unduly influenced both location and size of institutions. In such places, institutions, built in response to these influences, often are uneconomic to operate and maintain; they fail to meet established standards, and add to the total cost of patient care because of unnecessary duplication of facilities and services.

Defining service areas remains difficult, however. Because patients generally go to hospitals where their physician of choice is permitted to practice, the office location of physicians with medical staff appointments may be the key factor. Sigmond (*18*) has observed that

> The selection of an individual hospital by a patient involves a complex interplay of characteristics of patient, physician and hospital. In this community (Pittsburgh) most physicians have two or more staff appointments, but each physician's choice of hospital is relatively limited. Office location of physicians, their patient draw and their use of specific hospitals tend to be related in different ways for different hospitals.

Somewhat the same conclusion was reached in a recent California study (*19*): "The physician's role in determining where a patient is admitted is even more important than is generally accepted, and the distance from office to hospital, as measured by travel time, could influence the physician's choice of office location and of the hospital to which he admits patients." Perhaps this is why "an increasing number of hospitals are also finding it advantageous to build physicians' office buildings on-site or nearby, with space being leased to physicians for their private practice" (*20*). However, there is always the interesting speculation that many patients may in fact choose doctors on the basis of the hospital(s) with which they are known to be associated.

What do the present transportation study data reveal about patient and staff distribution for particular hospitals—about the delineation of service areas? For one thing, desire line plots of all trips to cross-section hospitals in selected cities show that service areas generally overlap: Figure B-24 traces total person trips to the four cross-section general hospitals in Pittsburgh. Each hospital seems

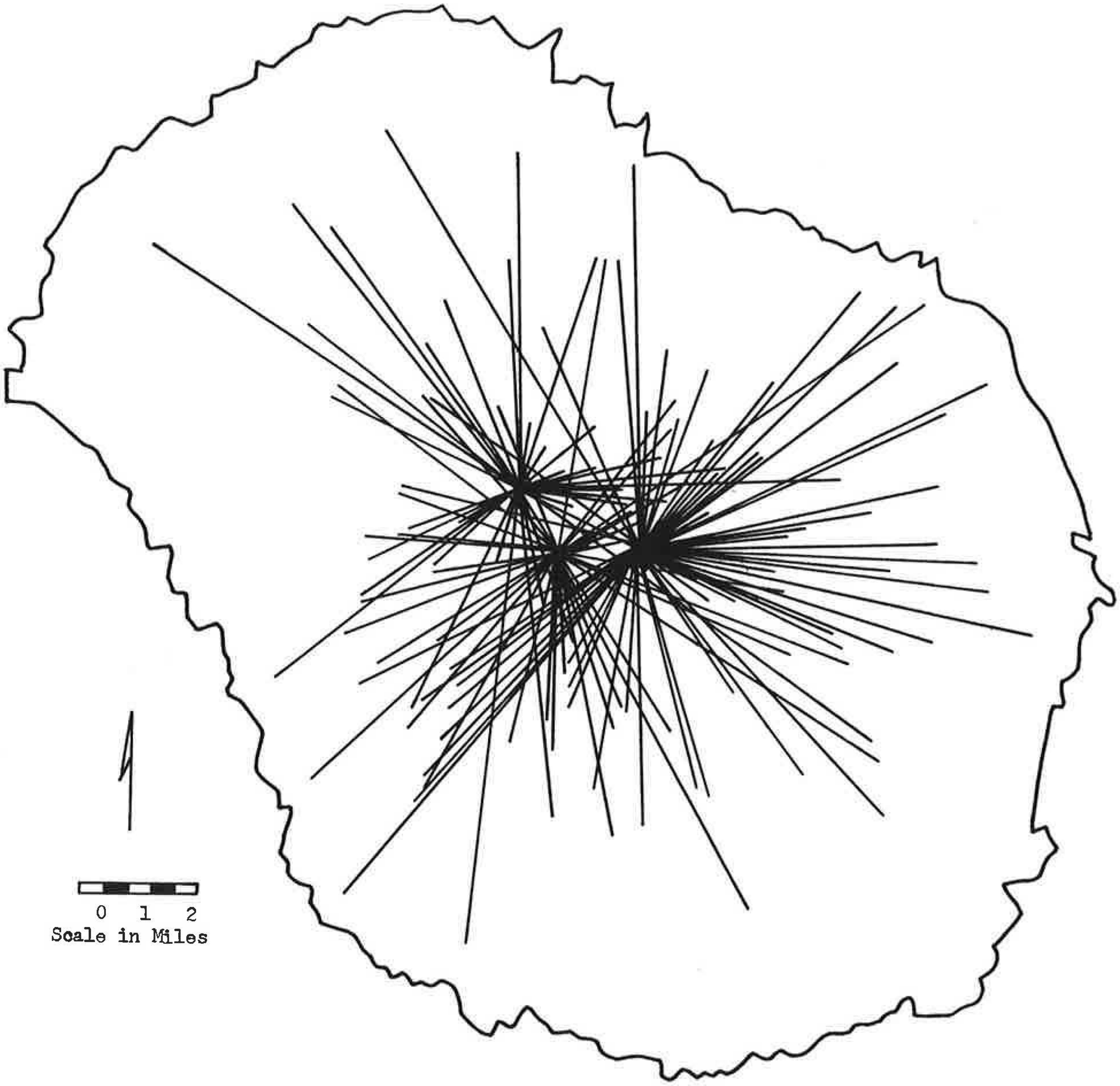

Figure B-24. Zonal interchange desire lines (unweighted by trip volumes) to four general hospitals in the Pittsburgh urban area, typical weekday, 1958. Compare Figure B-28, trips to all hospitals in Pittsburgh area.

to draw trips almost randomly from all parts of the study area. This experience seems typical of most of the desire line plots prepared. Figure B-25 traces total person trips to the two general hospitals in Tucson, and reflects the most clear-cut service areas to be found in the present data—and even they show considerable overlap. This experience with study data confirms many prior findings, among them (*15*):

> Of the 100 communitties first considered, those with clearly defined areas of service, those providing medical services exclusively to a limited area, and those located in communities in which less than 10 percent of the patients went outside the area for medical services were principally in the West and the Southwest. For example, the patterns of medical care in parts of the Midwest and the eastern seaboard states were generally exceedingly confused. There, in populous regions the service patterns of hospitals in adjoining communities often overlapped and duplicated each other. In these areas, too, a hospital might principally serve a specific economic, religious, or even ethnic group or one of a particular national origin, drawing its patients from a wide geographic area.

The overlapping of service areas can be confirmed, too, by mechanical plots of all hospital trips for a whole urban area. Figure B-26 shows a plot of all auto driver trips to work at all Buffalo area hospitals; Figure B-27 is a companion plot of all auto driver trips for medical purposes (both unweighted by trip volumes). Were the figures combined, and were trips by other modes and for other purposes added, the few reasonably distinct patterns would be blotted out. Because, among the mass of trips concentrated in the central city, there are at least 15 general hospitals, service areas in Buffalo would appear extremely difficult to define.

Further example is provided by Figure B-28, Cartographatron prints of total person trips by travel mode to all Pittsburgh area hospitals. Again, the travel patterns are extremely overlapping. Nevertheless, transportation planners should be interested to know that Cartographatron prints of trips to hospitals and physicians' offices in Chicago were used in a recent report of the Hospital Planning Council for Metropolitan Chicago, for whom they were specially prepared by the Chicago Area Transportation Study (*21*). On the subject of service areas, this report concludes:

> At least in urban areas, patients may not choose their hospitals so much as they choose their physicians. A double chain of propinquity between patient home and physician office and hospital is assumed to prevail as an important criterion in the patient's selection of physician and the physician's selection of hospital. This assumption has important implications to the rationale of delineating hospital service districts inside a metropolitan area. The distribution of physician's offices and their hospital affiliations may very well be a major key to patient-hospital links. These data are also the most elusive. There are no ready sources of information on either subject in most cities, including Chicago.

Although the delineation of service areas is still an inexact science, it has been accomplished not only in Chicago, but also elsewhere. The Hospital Planning Council of Allegheny County (*22*), for example, has established five planning areas based on the following factors: "availability of facilities, personnel and services; distribution and characteristics of the population; geographic and topographic features; patterns of transportation, communication and consumer shopping. The residents of each area utilized short-term hospitals within the Area borders for the majority of their inpatient care during the year 1960."

Most discussions of service areas ultimately consider the minimization of "customer" travel as a locational criterion for the particular service provided. If the service is unique, as for example an airport, and the location of "customers" fairly fixed, its location can be optimized rather simply by computer (*23*). This approach has been used in Sweden (*24*) to plan the location of regional hospitals: "It was, of course, a question of keeping the aggregate traveling times and traveling costs for the members of the public seeking medical aid as low as possible." Whether this technique can be applied to the area-wide planning of general hospitals, which are not unique but potentially competitive, is a good question for hospital planners.

To summarize on the subject of service areas and urban hospital systems:

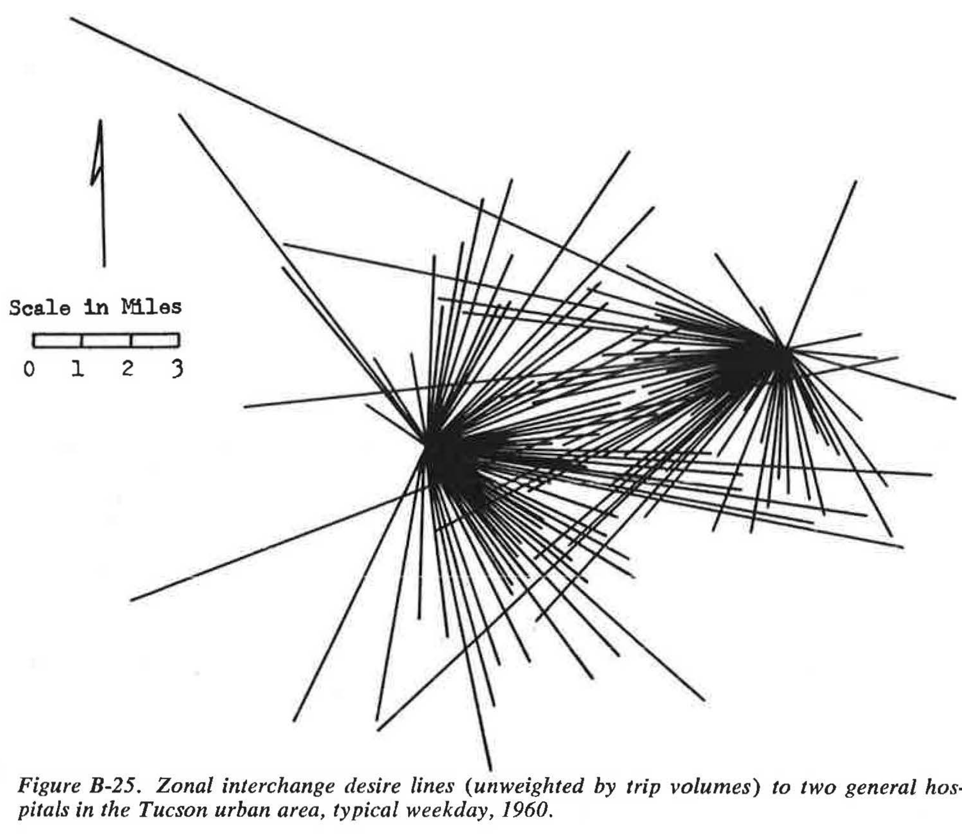

Figure B-25. Zonal interchange desire lines (unweighted by trip volumes) to two general hospitals in the Tucson urban area, typical weekday, 1960.

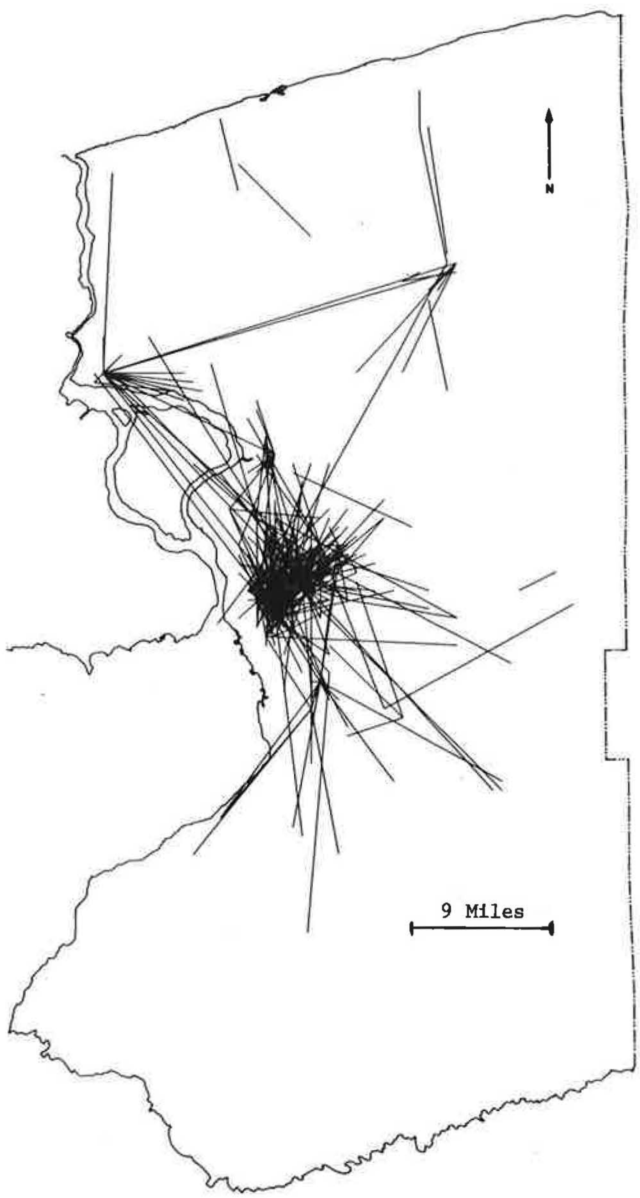

Figure B-26. Internal auto driver trips (unweighted by trip volumes) to all hospitals in the Buffalo urban area, to work, typical weekday, 1962. (Reduced from plot prepared by the Niagara Frontier Transportation Study.) Each trace represents about 28 trips.

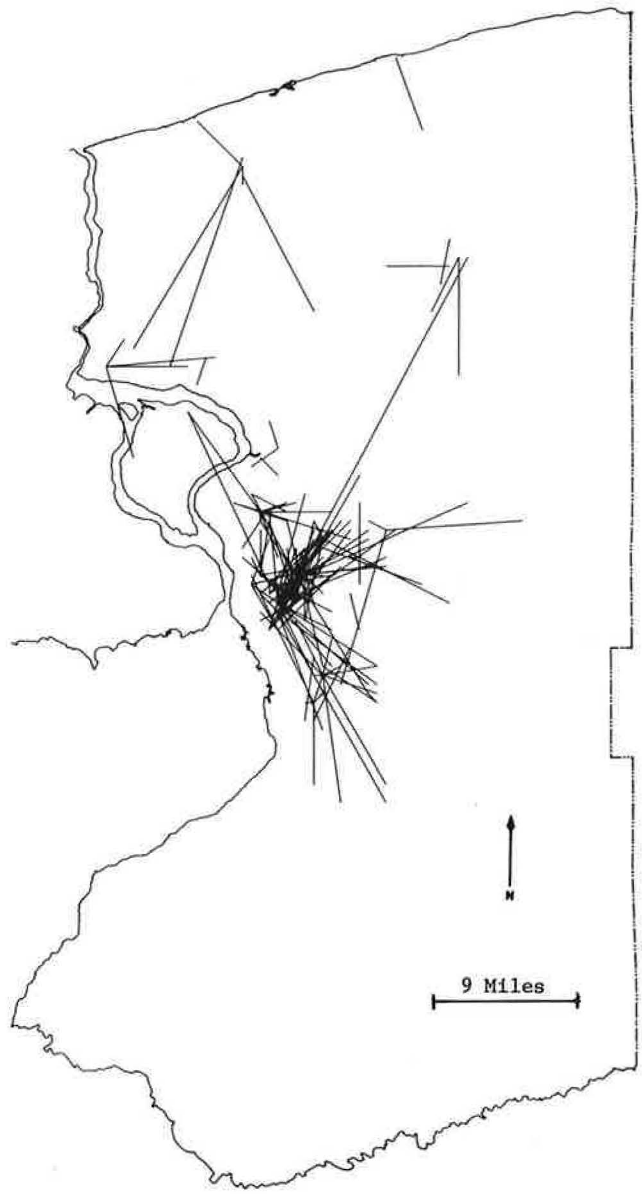

Figure B-27. Internal auto driver trips (unweighted by trip volumes) to all hospitals in the Buffalo urban area, for medical purposes, typical weekday, 1962. (Reduced from plot prepared by the Niagara Frontier Transportation Study.) Each trace represents about 28 trips.

1. There is "competition" among hospitals in the sense that their service areas sometimes overlap.

2. There is "competition" between hospitals and separate medical offices to the extent that certain health services are available at either.

3. However, because most hospitals tend to be fully utilized in any case, trip generation by, and trip distribution to, any particular hospital can be reasonably predicted for highway design purposes without the elaboration of "modeling" entire urban areas to account for any competitive effects.

TRAVEL IMPACT ON HIGHWAY NETWORK

Systems Considerations

The daily vehicle-miles of travel attracted by any single hospital represents only a small proportion of the total daily vehicle-miles of travel in the urban area. The cross-section hospitals in Pittsburgh provide what may be a typical example. In 1958 Pittsburgh's largest general hospital attracted only 0.21% of the total travel (hospital 3, Table B-35). All four cross-section hospitals together attracted less than 1%. In fact, all hospitals in the Pittsburgh area accounted for only about 2%—36,000 vehicle trips to and

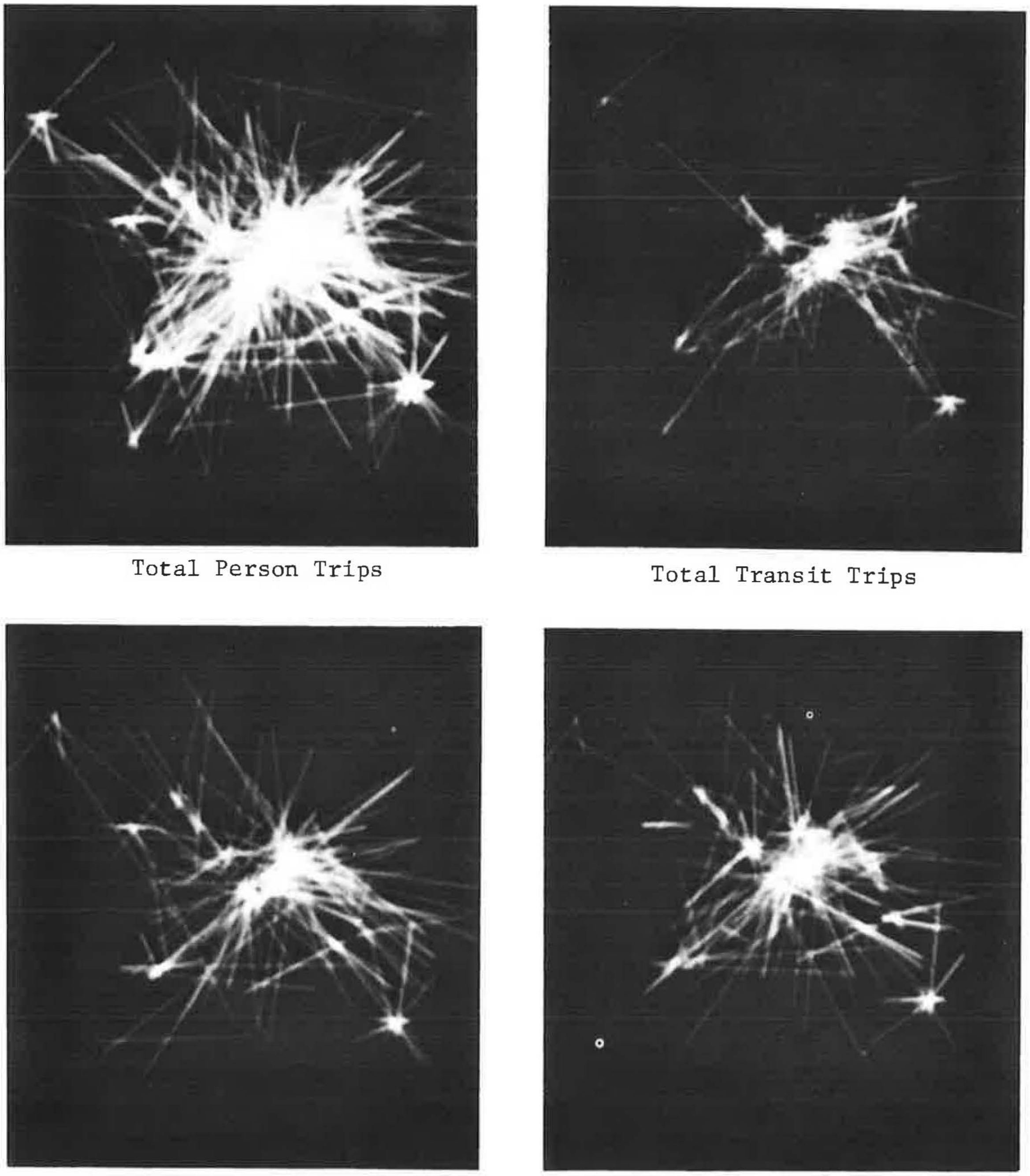

Figure B-28. Cartographatron displays of internal person trips to all hospitals in the Pittsburgh urban area, typical weekday, 1958. (Prepared from Pittsburgh Area Transportation Study trip tapes by the Chicago Area Transportation Study.) Each trace represents about 28 trips. Scale: about 1 in. = 10 miles.

from hospitals, producing roughly 200,000 vehicle-miles of travel, compared to the metropolitan total of 10,000,000 vehicle-miles of travel.

At the traffic zone level—an area averaging 1 to 2 sq mi—the traffic impact of the hospital is still slight. The largest Pittsburgh hospital accounts for only 5% of the daily vehicle-miles of travel on all streets in the zone in which it is located. Naturally this percentage would vary with the comparative sizes of the traffic zone and the hospital; a large hospital in a small traffic zone might account for up to 50% of the zonal travel (for example, the largest hospital in New Orleans accounts for 47%). However, although the largest Pittsburgh hospital accounts for only 5% of the zonal travel, it requires 15% of the available

TABLE B-35

TRAVEL IMPACT OF VEHICULAR TRIPS TO SELECTED GENERAL HOSPITALS IN PITTSBURGH, BY STUDY AREA, TRAFFIC ZONE, AND MAIN ACCESS ROAD

	HOSPITAL TRIPS VMT AS PERCENT OF		PART OF DESIGN CAPACITY USED BY HOSPITAL TRIPS (%)			
			ZONAL ARTERIAL STREET		MAIN ACCESS ROAD	
HOSPITAL	STUDY AREA VMT	TRAFFIC ZONE VMT	24 HOURS	PEAK HOUR	24 HOURS	PEAK HOUR
1	0.13	2	3	5	17	28
2	0.15	3	6	9	48	64
3	0.21	5	15	29	23	47
4	0.31	4	9	15	39	57

Source: Pittsburgh Area Transportation Study trip tabulations and street inventory data.

arterial street capacity in the traffic zone. During the 5 to 6 PM peak hour (which is not the hospital's peak hour) the requirement jumps to 29%. This begins to show its impact.

Probably the key comparison is the percentage of the main access road capacity required; that is, travel to and from the hospital on the main access road compared to its capacity. On a 24-hr basis, the example Pittsburgh hospital requires 23% of its main access road's capacity; on a peak-hour basis, 47%. Two of the other Pittsburgh cross-section hospitals exceed these percentages: though smaller hospitals, their traffic problem would appear greater.

Throughout this discussion of Table B-35, the particular values are not so meaningful; similar tables for other urban areas would result in different values. Rather, the discussion shows that hospitals may have slight traffic impact on the highway network at the metropolitan scale, yet may have significant, even critical, impact at the local scale. Thus, for area-wide freeway planning, hospital traffic normally might not affect the over-all configuration of the system (although it might affect the location of access ramps), whereas for community arterial street planning hospital traffic would very much need to be reckoned with.

Parking and Emergency Vehicle Access

Inadequate parking is probably the hospital traffic problem most obvious to the typical hospital visitor and to the hospital administrator. Almost all hospitals provide off-street parking lots. According to questionnaires, however, the majority of parking spaces are typically needed and set aside for the hospital staff. When lots are full and curb spaces are in short supply, visitors are apt to cruise around and around the block, to double-park waiting for another driver at the curb to pull away, or to make U-turns toward a space on the other side of the street. This milling about can seriously inhibit traffic flow on the adjacent streets. Although this happens at many important trip generators, the urgency of some health care travel makes parking difficulties at hospitals especially hard to bear. To the extent that there are such difficulties, the traffic impact on the highway network can be greatly compounded.

Where this occurs, emergency vehicle service can be dangerously impaired. Although ambulance trips to and from hospitals represent but a very small percentage of the total traffic, they should have priority access at all times. To some extent, any traffic improvement will automatically improve accessibility for ambulances. However, in addition, traffic officials should certainly bear in mind the need for designation of emergency access roads and the most direct traffic patterns between the highway system and hospital emergency department (*25*).

In time, some hospitals or hospital associations may have helicopter facilities to help alleviate ambulance problems. The Jackson Memorial Hospital (Metropolitan Medical Center) in Miami, Fla., already has its own heliport. Widespread application, however, must probably await the distant future, and may apply primarily to more remote areas (*26*). Special attention for ambulance services will continue to be needed in most large urban areas.

PREDICTING AND TESTING RELATIONSHIPS

One way to test the effectiveness of the relationships suggested in this appendix is to apply them to a new situation—to attempt to predict the existing tripmaking at hospitals not in the cross section from which the relationships were derived. This would not prove or disprove them (because they are already factually based), but would tend to determine whether they had general application and to point up remaining problems.

For this purpose a 194-bed general hospital in New Orleans, and a 376-bed general hospital in Pittsburgh were chosen. Various hospital and service area characteristics were used to predict several categories of daily trip generation. The results were encouraging—predictive accuracy averaged about ± 10%. The predicted distribution of trip origins, however, was less accurate. However, considering that many hospital service areas in these urban areas seem to have significant overlap, trip distribution was expected to be difficult (see Appendix F for further detail).

HOSPITAL	INDEPENDENT VARIABLES																		DEPENDENT VARIABLES					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	594	1105	290	60	207	1473	20	72	109	151	92	26	494	437	59	615	79	76	229	426	530	666	956	2905
2	360	849	362	76	210	1473	25	47	123	164	200	103	220	49	20	650	48	81	198	474	950	633	1424	3189
3	650	992	314	67	213	1473	21	111	136	158	65	49	561	262	15	623	87	91	165	636	914	543	1550	3288
5	306	615	50	22	440	1118	4	7	58	132	40	675	157	5	1	350	67	69	8	857	902	21	1759	2574
6	213	486	109	45	413	1118	10	15	56	116	42	60	113	43	1	300	47	84	66	481	500	86	981	1300
7	1300	2562	250	66	264	1118	22	54	126	298	52	285	991	80	255	400	286	79	157	2099	3407	1596	5506	10189
8	421	980	117	28	239	1118	10	15	92	143	43	300	275	21	40	500	93	86	211	900	822	611	1722	2891
10	255	401	84	29	345	394	21	88	62	107	40	57	190	76	72	314	150	71	83	350	417	96	767	1157
12	360	846	138	51	370	742	19	8	81	158	48	60	260	99	10	197	86	97	37	977	1234	127	2211	3415
13	870	2030	205	54	263	742	28	65	97	286	108	20	362	416	43	348	208	87	48	1563	1522	239	3085	4969
14	2019	3269	164	43	262	742	22	40	123	335	126	1920	2219	27	209	355	482	79	73	4029	3384	906	7413	12433
14A	291	651	103	35	340	742	14	50	76	123	59	87	96	25	1	199	69	87	54	405	578	87	983	1612
14B	330	791	198	58	293	742	27	83	82	129	35	55	150	63	101	348	79	88	62	1045	797	192	1842	3094
15	487	947	148	57	385	319	46	48	71	198	54	105	371	81	209	145	350	79	24	934	1244	77	2178	3207
16	670	952	159	59	371	319	50	71	78	245	65	100	520	119	10	131	450	78	17	851	1489	62	2340	3710
17	405	1094	208	53	255	688	30	53	64	234	81	60	305	116	12	269	138	92	144	600	689	336	1289	2338
18	773	1388	262	47	179	688	38	69	91	245	148	265	673	58	322	341	264	79	262	540	1029	1178	1569	4496
19	475	1097	262	47	179	688	38	60	62	236	75	60	375	143	12	341	162	85	89	860	1194	274	2054	3082
20	275	499	128	48	375	688	19	56	74	123	47	140	173	28	18	137	94	90	102	460	958	266	1418	2616
22	378	1040	129	40	310	321	40	76	85	140	64	40	236	136	94	324	306	89	72	440	1109	219	1549	3036
23	360	756	129	40	310	321	40	76	72	124	40	25	269	247	57	324	292	67	58	449	453	112	902	1915
24	317	630	137	42	307	321	43	55	76	109	40	65	310	110	50	351	257	71	25	433	636	49	1069	1983
27	326	717	52	22	423	244	21	16	61	156	54	709	285	9	10	100	350	80	24	667	619	42	1286	1740
28	305	634	53	16	302	244	22	80	59	162	45	167	144	20	8	120	350	86	15	668	771	31	1439	2115
32	293	588	400	83	208	844	47	101	64	133	45	20	123	141	11	630	54	80	267	334	519	511	853	1912
33	439	963	301	66	219	844	36	34	71	205	80	20	291	334	10	614	81	90	157	551	1075	433	1626	2761
34	462	1015	260	58	223	844	31	108	69	219	48	20	390	447	42	593	85	90	185	659	811	529	1470	2868
35	362	741	160	49	306	844	19	13	89	91	28	190	130	16	194	341	67	61	108	596	361	148	957	1377
36	400	410	213	45	211	844	25	111	219	55	16	200	160	18	1	579	74	82	278	300	238	308	538	1107
38	656	1397	314	69	220	1218	26	107	110	187	50	100	443	102	91	695	111	86	129	832	1179	437	2011	3396
40	311	804	325	70	215	1218	27	70	56	145	72	80	211	60	49	695	53	71	199	562	421	421	983	2116
41	348	661	378	92	243	1218	31	66	96	97	48	71	226	73	31	655	59	73	122	302	676	222	978	1823
42	274	502	157	49	312	1218	13	11	87	90	20	307	174	13	17	315	47	79	103	215	761	183	976	1780
43	979	1350	340	89	262	1218	28	50	215	131	34	680	505	17	109	517	166	79	324	588	637	865	1225	2671
44	532	1041	341	82	240	1218	28	90	96	181	125	64	350	125	43	628	90	90	202	658	1280	709	1938	3509
45	360	732	146	33	226	1218	12	58	87	133	58	30	221	169	44	413	61	88	138	417	1149	402	1566	2915
46	358	625	70	27	386	1218	6	67	83	119	60	30	204	156	13	417	61	76	69	751	963	186	1714	2708
47	300	486	99	26	263	1218	8	43	86	92	50	20	200	229	28	361	51	72	193	388	647	346	1035	1795
48	444	785	366	97	265	1218	30	114	91	154	68	295	334	26	31	621	75	87	239	616	921	692	1537	2894
50	850	859	178	50	281	1377	13	85	212	78	50	85	750	202	107	200	128	53	254	305	687	554	992	2182
51	309	602	226	66	292	1377	16	53	59	124	40	55	209	87	1	250	47	75	137	409	558	248	967	1798
52	444	714	248	70	282	1377	18	71	139	81	25	25	336	308	76	300	67	69	250	422	518	624	940	2500
53	391	754	210	51	243	1377	15	38	94	130	48	38	291	175	46	400	59	85	187	537	804	451	1341	2407
54	203	446	138	33	239	1377	10	47	68	96	35	39	92	54	10	250	31	88	193	263	618	308	881	1593
55	281	585	210	51	243	1377	15	105	80	116	62	77	300	112	10	200	43	91	151	333	770	327	1103	2169
56	316	603	226	66	292	1377	16	71	70	163	85	10	210	482	6	200	48	98	55	413	969	135	1382	2455
57	420	859	248	70	282	1377	18	60	68	185	72	26	290	257	18	300	64	82	165	325	440	202	765	1224
59	301	568	64	18	281	110	58	69	78	114	50	250	188	17	28	150	300	80	35	554	842	82	1396	2314
62	345	701	74	18	243	124	60	71	69	152	55	170	500	68	26	150	300	81	13	787	950	34	1737	2564
63	315	491	48	14	292	124	39	6	72	92	40	297	310	24	25	150	300	57	47	671	748	108	1419	2314
64	587	934	151	51	338	1435	11	30	125	130	25	45	487	248	69	300	94	77	155	541	436	264	977	1699
66	287	274	93	29	312	1435	6	64	120	58	15	51	187	84	3	300	46	67	48	276	236	38	512	796
67	314	704	145	48	331	1435	10	84	58	139	49	35	415	271	10	200	50	70	57	496	413	73	909	1285
68	361	950	151	51	338	1435	11	53	63	169	75	13	261	458	14	300	58	81	104	389	370	131	759	1258
70	421	564	76	23	303	175	43	65	81	128	64	63	247	90	2	264	284	84	82	548	626	158	1174	1938
71	289	430	76	23	303	175	43	51	77	105	56	55	246	102	9	264	195	82	27	412	664	47	1076	1711
72	145	220	80	24	300	175	46	42	81	48	20	60	100	38	1	233	98	73	80	313	432	97	745	1220

Figure B-29. Multiple regression inputs, hospitals.

TABLE B-36

SUMMARY OF TRIPS TO HOSPITALS, BY SURVEY SOURCE [a]

		HOME INTERVIEW					ROADSIDE			TRUCK-TAXI	
CITY	HOSPITAL NO.	AUTO DRIVER	AUTO PSGR.	TRANS. PSGR.	TAXI PSGR.	WALK-TO-WORK	AUTO DRIVER	AUTO PSGR.	TRUCKS	TRUCKS	TAXIS
Pittsburgh	1	776	711	666	84	283	180	205	5	23	154
	2	1204	680	633	53	274	220	125	—	99	179
	3	1230	693	543	26	166	320	310	5	124	123
	4	1688	1103	1176	134	237	440	560	20	145	224
Miami	5	1753	685	21	—	107 [c]	6	2	—	69	—
	6	981	167	86	—	66 [c]	—	—	—	—	—
	7	5313	2467	1596	170	357 [c]	193	93	—	300	184
	8	1716	363	611	54	137 [c]	6	4	—	162	138
	9	955	245	206	—	78 [c]	149	129	4	103	46
Salt Lake	10	759	250	96	30	—	8	14	—	60	11
Indianapolis	11	823	282	23	—	84 [c]	28	11	8	54	8
	12	2076	827	127	—	141 [c]	135	109	9	231	4
	13	2605	1052	239	66	218 [c]	480	309	11	389	25
	14	6248	2365	906	108	572 [c]	1165	1079	86	408	160
	14A	907	408	87	—	70 [c]	76	64	17	142	12
	14B	1698	747	192	22	166 [c]	144	125	—	71	45
Wichita	15	2093	779	77	62	32	85	79	—	67	28
	16	2259	1098	62	16	128	81	66	—	54	39
Atlanta	17	1172	486	336	22	89 [c]	117 [c]	117 [c]	9 [c]	89	33
	18	1425	1041	1168	302	100 [c]	143 [c]	143 [c]	4 [c]	42	253
	19	1867	486	274	24	123 [c]	187 [c]	187 [c]	10 [c]	101	40
	20	1289	452	266	—	86 [c]	258 [c]	258 [c]	10 [c]	96	5
	21	316	125	45	—	28 [c]	63 [c]	63 [c]	2 [c]	23	3
Wilmington	22	1222	464	219	50	221	327	533	36	68	59
	23	693	236	112	15	357	209	293	—	62	41
	24	901	334	49	33	196	168	302	18	68	31
	25	428	145	65	—	—	95	58	6	17	5
	26	159	31	16	—	15	101	170	4	9	5
Tucson	27	1270	391	42	—	—	16	21	3	230	11
	28	1422	625	31	—	—	17	20	3	142	13
	29	697	206	22	—	31	13	17	2	89	4
Ann Arbor	30	240	24	—	—	—	428	794	30	18	22
New Orleans	31	3174	1821	6008	464	102	270	576	6	292	850
	32	824	454	511	21	40	29	33	—	125	105
	33	1532	490	433	41	42	94	129	—	95	205
	34	1384	609	529	108	21	86	131	2	98	470
	35	858	156	148	—	—	99	116	—	133	20
	36	508	235	308	—	—	30	26	—	22	55
	37	934	312	325	—	—	27	57	2	35	65
Buffalo	38	1886	746	437	25	140	125	37	—	22	113
	39	769	190	319	—	56	9	9	—	32	12
	40	881	401	421	59	140	102	112	—	62	71
	41	913	433	222	31	140	65	19	—	32	46
	42	968	595	183	26	—	8	—	—	—	12
	43	1166	378	865	58	56	59	89	—	44	59
	44	1867	680	709	55	56	71	71	—	33	47
	45	1511	669	402	—	224	55	54	—	43	12
	46	1697	630	186	—	168	17	10	—	40	51
	47	998	338	346	—	56	37	20	—	54	12
	48	1510	647	692	—	—	27	18	—	52	36
	49	1120	526	202	—	28	75	69	—	52	—
Twin Cities	50	968	535	554	—	84 [c]	24	17	—	56	66
	51	937	497	248	—	68 [c]	30	18	—	33	50
	52	924	581	624	257	86 [c]	16	10	—	90	122
	53	1308	435	451	22	109 [c]	33	49	—	99	84
	54	854	326	308	—	61 [c]	27	17	—	80	32
	55	1076	607	327	39	65 [c]	27	28	2	91	60
	56	1359	833	135	—	77 [c]	28	23	1	54	26
	57	755	133	202	59	62 [c]	10	3	—	66	62
	58	1757	640	283	55	158 [c]	109	112	—	55	34

TABLE B-36 (*Continued*)

CITY	HOSPITAL NO.	HOME INTERVIEW AUTO DRIVER	AUTO PSGR.	TRANS. PSGR.	TAXI PSGR.	WALK-TO-WORK	ROADSIDE AUTO DRIVER	AUTO PSGR.	TRUCKS	TRUCK-TAXI TRUCKS	TAXIS
Durham	59	1041	414	82	26	143	355	253	22	61	46
	60	655	129	33	—	9	292	289	11	52	24
Raleigh	61	484	164	—	—	55	121	112	10	77	26
	62	1448	504	34	9	16	289	264	10	60	70
	63	1112	431	108	16	—	307	340	15	38	18
Seattle	64	973	325	264	—	133	4	—	—	47	90
	66	494	240	38	—	—	18	6	2	8	—
	67	903	278	73	—	25	6	—	2	16	—
	68	752	338	131	—	27	7	3	—	16	15
	69	326	88	80	32	—	14	14	1	—	75
Madison	70	1014	279	158	67	90	160	170	3	72	69
	71	947	384	47	37	45	129	122	—	12	42
	72	624	164	97	22	63	121	129	1	42	28
	73	674	183	53	—	33	113	116	1	12	32
University [b]	74	2614	995	591	58	44	1430	915	25	57	104
	75	4407	1910	237	39	228 [c]	1700	1700	56	123	220
	76	2414	1198	515	33	200 [c]	119	139	3	229	136
	77	1873	585	440	87	270	391	400	12	138	110

[a] From transportation study data.
[b] University hospitals are each in a different city.
[c] Estimated.

TRENDS

Hospital use has approximately trebled since 1935. Admissions have boomed from 59 to better than 150 per year per 1,000 population. Meanwhile, the number of hospitals has increased only moderately, and the average number of beds per hospital has remained fairly constant. It follows that the average length of stay per patient has decreased—from about 15 days to just over 7 days. Thus, even where beds or other new facilities have not been added, the generation of patient and visitor trips to existing general hospitals has increased through time.

Total hospital personnel have increased, too. In 1950 there were about 73 personnel per 100 hospital beds; today there are about 120 personnel. In 1950 there were about 84 personnel per 100 patients; today there are nearly 140 personnel. Although automation has entered the hospital field, every medical advance brings with it the need for more doctors, nurses, and laboratory technicians to apply it. Thus, the generation of hospital work trips has increased through time, as well.

More than likely, there has been a continuing shift from public transit to the automobile on the part of both patients and personnel. Because the majority of present transit users lack cars or driving licenses—and the evidence suggests that many will drive when they become able—future transit use will probably decrease. One observer (*27*) notes that "The great values of the private car for the aging are particularly marked. The needs of the aging [a large proportion of whom require periodic hospitalization] cannot be solved by any of the present thinking and planning to replace the automobile in the central city with transit only." The result would be that vehicle trip generation increases faster than person trip generation.

Moreover, new hospitals are tending to be built in the suburbs. Some urban areas have too many hospitals in the central city; they stayed while service area populations thinned down. Suburban hospital construction is restoring a better balance. An interesting prediction is that the increase in needed hospital beds will occur "either through the expansion of existing hospitals or the development of satellite hospitals—or branches of a large hospital—rather than the establishment of new hospitals" (*20*). Either way, however, the suburban hospitals are likely to be auto-oriented, not transit-oriented.

Hospitals are apt to grow larger, particularly in terms of peripheral development. Already many are finding it desirable to expand staff residential accommodations, to offer office space for physicians, to provide enlarged outpatient facilities, to add special clinics in separate buildings, etc. A further prediction (*20*) is that "The next generation will see: (1) fewer hospitals . . . but the hospitals will be larger; (2) an increasing number of long-term care institutions and these will be either an integral part of a hospital, or more closely affiliated with a hospital; and (3) greater emphasis on the hospital as the center of all health activities in the community." With Medicare and its logical extensions providing strong momentum, the hospital of tomorrow will become an increasingly important focal point of urban travel.

CONCLUSION

Major hospitals are clearly major trip generators. Of the 78 hospitals in the cross section, 8 have more than 9,000 person trips (to or from) per day. Two of them—both medical centers embracing a complex of hospitals at one location—exceed 20,000 person trips per day. At this scale, hospital trip generation equals that of major plants or shopping centers.

Up to one-half of the trips to general hospitals are made by staff and visiting physicians. Roughly 25% are made by patients, and another 18% by visitors. Such proportions may, of course, vary considerably at any particular hospital. At long-stay Veterans Administration and mental hospitals, relatively more trips are made by personnel, and fewer trips by patients and visitors.

Most trips require an automobile. About 75% of all trips to general hospitals are as auto drivers or auto passengers. This proportion is even higher for long-stay hospitals. Transit use is strongly related to city size and hospital location, and to tripmaker sex, race, occupation, and car ownership. There is marked variation from hospital to hospital. Taxi use is surprisingly light.

Most hospital trips start from home. Distribution of trip origins, therefore, tends to follow the distribution of population. Trip rates per capita decrease with increasing distance or travel time from the hospital. There is a greater decrease for work trips than for patient trips. In very large urban areas, where there may be 10 to 20 central-city hospitals, service areas tend to overlap significantly. This seems to upset the relationship between trip origins and population, and makes the directional prediction of trips difficult.

Hospital travel can have critical impact on the local travel facilities which serve to provide hospital access. Although trip origins are scattered and have little system-wide effect, traffic converging on the hospital may require a relatively large share of the capacity of the main access roads. Shortage of parking space often aggravates the situation, and produces problems for both traffic officials and hospital administrators.

APPENDIX C

COLLEGES AND UNIVERSITIES

This appendix describes and analyzes travel patterns associated with another institutional land use—colleges and universities. The need for such study may be less evident than for studies of more ubiquitous land uses such as shopping centers or manufacturing plants. Colleges and universities are major travel generators, however, and what is known of their impact on urban travel patterns does not appear commensurate with their significance.

There are more than 2,000 institutions of higher learning in the United States. They employ more than 500,000 faculty members, and at least that many more nonfaculty staff members. They spend about $10 billion annually and serve nearly 6,000,000 students. Although the rate of freshman enrollments has dipped from 1964 and 1965 "when colleges were feeling the peak of the post-World War II baby boom" (*19*), the total number of students continues to climb dramatically.

One measure of higher education's future importance on the urban scene is reflected in a report to the Tri-State Transportation Commission (*30*). Citing regional services such as higher education as an organizing influence in the New York-New Jersey-Connecticut region, the author proposed some 10 to 15 new urban centers of 500,000 population each, each formed about a nucleus of a new university with an enrollment of 20,000 students. Yet these new universities, with their 300,000 students, would accommodate only one-half the expected increase in regional enrollments by 1985.

Such growth trends generate an impressive demand for investment in both public and private educational facilities. The State University in New York, for example, has announced (*31*) a master plan for state universities, colleges of arts and sciences, medical centers, and other specialized institutions, that requires a $1.35 billion expansion program. On the national level, the U. S. Department of Health, Education and Welfare (*32*) in 1960 estimated that by 1966 public institutions needed to expand instructional accommodations by 53%. It was noted that some 8,000 new construction or rehabilitation projects were planned by colleges and universities for completion between 1960 and 1965 at a cost of $7.5 billion. At this level of investment during the immediate past, and with much more to come, it becomes crucial to understand and to anticipate the resultant transportation requirements that must be met.

Large colleges and universities generate as much travel as the central business districts of medium-sized cities. Of the nearly two score institutions of all sizes surveyed in this report, ten have maximum parking accumulations exceeding 3,000 vehicles, and three surpass 5,000 vehicles. Such accumulations are roughly equivalent to those found in the central business districts of cities having between 75,000 and 150,000 population. Although this does not mean that total traffic flows are the same, it suggests that university traffic problems are of the magnitude to attract public attention.

Thus, ranging from the relevance of universities in public planning policy to the more specific concerns of campus parking, knowledge about the relationships between campus characteristics and travel becomes vital. The present cross section for study includes 38 * colleges and universities in 16 metropolitan areas (see App. A). Many campus and community sizes are represented (in Table C-1 and subsequently, "campus population" includes faculty, staff, and total student enrollment; "community size" is based on 1960 SMSA census data), and the ratio of campus population to community size ranges from 1 to 50%. Twenty-five institutions have graduate schools, and 13 do not (usually marking the difference between a "university" and a "college"). Sixteen institutions are supported by state or local governments, and 22 are supported privately (of which 17 are church-related). One institution has more than 90% female students, three have more than 90% male students, and the remainder are essentially "balanced coeducational."

Such categorizations may be misleading, however, because colleges and universities tend to be unique in many ways. For example, for individual institutions in the cross section the proportion of resident students averages 28%, but ranges from 0 to 90%. Moreover, group averages show that the proportion decreases with increasing campus population (Table C-2) and with increasing community size. Similar ranges exist with respect to such other variables as the proportion of part-time students, the ratio of faculty and staff to student enrollment, campus size and location, campus population density, and policies toward parking and student use of automobiles (Tables C-2 and C-3, and Fig. C-1). As will be shown, such variables tend to create unique differences in trip generation.

Although their characteristics confirm that a diversity of

* There are actually 40. In two instances, where traffic zone configuration made it impossible to separate trips to two contiguous institutions, each pair was treated as one institution in the cross-section. Where possible, all resulting 38 samples form the body of data for analysis, though each institution is not necessarily represented in every subsequent table.

TABLE C-1

SAMPLE COLLEGES AND UNIVERSITIES BY CAMPUS POPULATION GROUP BY COMMUNITY SIZE [a]

CAMPUS POPULATION GROUP	NO. OF COLLEGES OR UNIVERSITIES IN COMMUNITY OF: A. UNDER 100,000 POPULATION	B. 100,000 TO 499,999 POPULATION	C. 500,000 TO 999,999 POPULATION	D. 1,000,000 AND OVER POPULATION	ALL
I. Under 1,000	3	2	—	—	5
II. 1,000-4,999	1	2	6	6	15
III. 5,000-9,999	1	2	1	2	6
IV. 10,000-19,999	1	2	1	4	8
V. 20,000 and over	1	1	—	2	4
All	7	9	8	14	38

[a] Subsequent tables with similar stratifications show only the numeric and alphabetic designations given here for campus population and community siz groups (1960 SMSA population).
Source: *American Universities and Colleges* (33) and 1960 Census data.

TABLE C-2

SELECTED COLLEGE AND UNIVERSITY SAMPLE CHARACTERISTICS BY CAMPUS POPULATION GROUP

CAMPUS POPULATION GROUP	RESIDENT STUDENTS (%)	FACULTY/STAFF TO STUDENT RATIO	AVERAGE CAMPUS SIZE (ACRES)	CAMPUS POPULATION PER ACRE
I	61	0.159	68	13.8
II	32	0.131	149	27.9
III	31	0.226	302	25.9
IV	23	0.236	336	67.4
V	27	0.348	446	72.5
Avg.	28	0.260	223	48.8

Source: University and college *Bulletins*, questionnaire returns, and transportation study data (for campus acreage where otherwise unobtainable).

TABLE C-3

UNIVERSITY QUESTIONNAIRE RESULTS [a]

UNIV. NO.	CONTROL CODE [b]	TYPE AREA AND GROWTH [c]	TRANSIT SERVICE	INTENSITY OF STREET PARKING	GEN'L ADEQUACY AND AVAILABILITY OF PARKING	CARS ON CAMPUS POLICY [d]
1	1	I [e]	*	Very	Very limited	All may drive.
2	1 [f]	C	Good	Very	Good	Decal issued to students yearly.
3	3	I [g]	Fair	Not tight	Fair to good	Discouraged, not prohibited
4	1	C	Good	Heavy	Inadequate	Special reduced rate to students on available space.
5	1	I	Some	High	None	Parking as available.
6	1	S [e]	Good	None [e]	Poor [e]	No restrictions.
7	2	S	Excell.	Minimal	Inadequate	Freshmen may not have cars.
8 [h]	1 [e]	S [e]	Good [e]	Medium [e]	Adequate [e]	*
9	3	S [e]	*	Moderate	*	No restrictions.
10 [h]	3	I [e]	*	*	*	*
11	1	I	Good	High	Not adequate	Students may have cars but may not drive on campus during class hours.
12	1	S [e]	Fair	*	Good [e]	Unlimited.
13	1	S	20-min.	None	Poor	Regulated.
14	1	S [e]	20-min.	*	*	Cars permitted on campus.
15	1	I	20-min.	Very dense	Not adequate	Cars permitted on campus.
16	3	I	Good	Ample	Ample	*
17	3 [f]	S [g]	*	Low	Adequate	*
18	1	I	Good	High	Tight	No restrictions, but all vehicles must be registered.
19 [h]	3 [e]	I [e, g]	Good [e]	Low [e]	Adequate [e]	*
20	3	I	Good	Low	Inadequate	Faculty and student parking permitted.
21	3 [i]	I [g]	Average	*	Not a problem	Seniors only.
22	2	I	Good	Heavy	Barely adequate	By permit.
23	3	S [e, g]	Good	None	*	*
24	3	I [g]	Very good	Very Heavy	Very close	Car registered; regis. sticker on car.
25	2	*	Good	Dense	Inadequate	No undergraduates except with special permission.
26	2	I	Fair	Heavy	Good	No restrictions.
27	3	C	Fair	Heavy	Poor	None.
28	1	I	Fair	Very little	Inadequate	$1.00 fee for students per year.
29	3	S [e]	Good	None [e]	Adequate [e]	All students allowed to drive on campus.
30	1	I	Fair	91%	Fair	Priority system.
31	3	S [e]	*	High	Average	Faculty only.
32	3	O [e]	Good	Heavy	Good	Allowed.
33 [h]	3 [e]	S [e]	Fair [e]	Low [e]	Adequate [e]	*
34	3	I [e]	Good	Jammed	Inadequate	None.
35	1	I	Poor [e]	Very heavy	Poor	No student driving dur-class hours.
36	1	O	Excell.	Little	*	Students register automobiles.
37 [h]	3 [e]	I [e, g]	Poor [e]	Low [e]	Adequate [e]	*
38	1	I [e]	Poor [e]	Low [e]	Adequate [e]	Undergraduates in univ. housing may not have cars.

* Not given and otherwise not known.

[a] See also Figure C-1 for additional university data.
[b] 1 = public, nonsectarian; 2 = private, nonsectarian; 3 = private, sectarian.
[c] C = central business district; I = intermediate; S = suburban; O = outlying.
[d] Generally much abbreviated versions of published policies, which vary widely in content.
[e] The researchers' judgment, based on university site inspection and/or consideration of university *Bulletin*.
[f] Men only.
[g] Stable enrollment; all others report increasing enrollment.
[h] No response.
[i] Women only.

HOSP.	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	
NO.	Y_{14}	Y_{15}	Y_{16}	Y_{17}	Y_{18}	Y_{19}	Y_{20}	Y_{21}	Y_{22}	Y_{23}	Y_{24}	Y_{25}	Y_{26}	Y_{27}

01	173	83	78	2	7	316	3461	2952	124	12700	1081	8	15568	
01	2320	4357	9	6590	13193	23796	28723	1990	4672	216	26403	4769	8128	13506	3162

```
02344 97 688  246 1421094 838 57 1300 2919 3869 16
02 199 57741554 2107 2113 4907 2591310484 470813041859 15451061
03344 97 688  316  22  20      84  203  496 1104
03  36  748 174  380  194  301 306 149221  265  41  41  183  41
04344 97 688   56  10 200 360395  360      3592  5
04  18 2143 246 1571  326 1364 384 179442 1346 157 979  210 112
051501001218  335  79 390 490106 4409 216612194 20
05  44 2169 409 1212  548 1448 304 307510 1404 272 721  411 218
061501001218  575 178          62  423  776 3658
06 122 63631598 2973 1792 3942 9171229442 382011941640  986 878
07112 97 110  1731136           8 3000 4826 1442
07 537160493563 4734 7752 7494 5662355296 695720851602 32701503
08112 97 110  113  53          55  380 1224 1274
08 116 1035 449  337  249  693 149 229382  577 280 127  170 170
09151122 742  463  60 100 450 17  117  578  340
09  20 1780 196  836  748 1225  43  87222 1205 195 483  527  87
10151122 742  523 286          16  417  966 3235
10 198 3942 864 1154 1924 2896 173 497208 2698 667 895 1136 323
11136105 175  165 5674084 588 51 7134 758914144 66
11 671187736532 5143 709811178318244293001050738962591 40202131
122801011118  743 245 5012393 65  488      15435 32
12  74 7877 724 5978 1175 6107 167 531501 6033 6174829  587 451
132801011118  633 260 9663695 62 2885 4125 9181374
13 295191411913 7589 963913430 44513892581313515985831 57061096
141551071377  429 420 800 750  7 1034  586 1368 50
14 262 35331330 1287  916 2801 419 987460 25391146 815  578 825
151551071377  169 26412594818116 8781 479116986
15104719624438610265 497312113292835664291106625565733 27771802
161551071377  379  45          45  279  713 1027
16 100 1753 314  418 1021 1188 222 169301 1088 295 134  659 148
171551071377  459  46  73 284 48  229  254 1700  6
17 123 2266 391 1101  774 1409  79 253367 1286 301 576  409 162
18 81127 124  193 25019393673 47 2844 5565 3313 19
18 576161283807 4455 786611086 14323412671051029343231 43451669
19 81127 124   73  15          50  100  400  220
19  32  533 203  157  173  313  16 127306  281 115  67   99  46
20 81127 124  123  35          24  100  500  232
20  15  626 228  209  189  313  73 158307  298 142  63   93  89
21 81127 124  303 170  44 140  6  186  735   71  4
21  30  885 146  142  597  546  25 112177  516  81  96  339  46
22338 77 844  277 129 5931060 98 3558 2265 6796 22
22 210 98612159 4072 3630 657815151488278 636813472822 2199 785
23338 77 844  307  62          17  122  352  574
23  26 1245 202  557  486  594 578 101234  568 180  53  335 100
24338 77 844  207  10   2  2108  120  278  681
24  31  627 152  432   43  154 451  95707  123  44  77    2  15
25351 881473  439 106 575    177 3699 105013954
25 114118062638 6452 2716 667825142155586 656413073618 16391023
26351 881473  519  59 400 450106 1094 1761 3419107
26  94 5034 858 3168 1008 2980175 658461 2886 5381593  755 359
27351 881473   99   9  20    626  539  510 4588
27 117 2986 532 2272  182 11281392 448630 1011 307 599  105 223
28113122 394  227 637 4524792 24 3912 1594 9794628
28 226146662642 6018 600610657 47116383571043120174328 40861128
29113122 394  187  26          17   45  220  180
29  39  254  51  136   67  219  30  38533  180  51  91   38  38
301131191435  346 63643762949 58 4744 597119991768
30 348165675213 6141 52131177619839314651142838024225 34012627
311131191435  326  20  80  90 77  169  563  800 30
31  47  885 115  276  494  593  32  96302  546  48 201  297  32
321131191435  846 125 100 300 16  155 1040  817
32   5 1044 188  403  453  699  25 121331  694 146 282  266  80
331131191435  246  60          54  202  946 2105
33  16 1588 350  712  526 1174  50 208418 1158 296 542  320 167
341131191435   76  23         165  382  717 2696
34  47 1793 377  902  514 1246 131 189464 1199 320 569  310 137
35 40122 244  127 135         103 1911 3463 8478
35 324171482557 5832 875912838  9317772691251419504524 60401154
36 78113 319  347 140 2302100 44  465  339 5318 20
36 136  984 326  478  180  622     274579  496 285 187   24 235
37 78113 319  327  20  30 165 34   73  190  424  5
37   7  858 101  597  160  481  48  84530  474  67 309   98  50
38 73121 321 1213 150          47 1424 3024 2576
38 225 56911582 2047 2062 4037  951096385 381211231249 1440 736
```

Figure C-1. Multiple regression inputs, universities.

institutional types was selected, the cross section was not scientifically drawn. The number and nature of the sample institutions was dictated as much by the availability of travel data as by the desire for a representative selection. Although weighted toward larger institutions to minimize sampling variability in the travel data, the cross section is felt to be reasonably well balanced for the purpose of this study.

Institutional statistics were obtained from several sources, but mainly from questionnaires (see Fig. C-2). Each institution was asked to provide information on employment and enrollments, campus size, parking facilities, campus housing, public attractions such as museums, auditoriums and athletic facilities, and so forth. College *Bulletins* and *Catalogs* and a standard reference, *American Universities and Colleges* (*33*), were used for amplification. And, because the assembly of transportation study data required visiting the metropolitan areas involved, most campuses were inspected at first hand.

GENERAL TRIP CHARACTERISTICS

Mode and Purpose of Person Travel

MODE, ALL TRIP PURPOSES

Table C-4 shows that 90% of all trips to colleges and universities arrive by automobile—64% as auto drivers and 26% as auto passengers. Only 9% arrive as transit passengers, and less than 1% as taxi passengers. Walk-to-work trips were not available for 15 of the 38 sample institutions; where available, proportions ran from 0 to almost 10%. (Because the average was under 2%, they were not estimated where unavailable—as they were for hospitals. As a result, walk-to-work percentages in Table C-4 are slightly low.)

Although Table C-4 reflects little systematic variation in the travel mode distribution by campus population group, for individual institutions the distribution is highly variable. Auto driver trips range between 19 and 82%, auto passenger trips between 3 and 51%, and transit passenger trips between 0 and 73% (see Table C-5). Throughout this and subsequent discussions, the travel mode distribution for trips from colleges and universities is basically the same as for trips to colleges and universities.

Two points with respect to modal distribution are worthy of special note. First, one institution with two campuses about a mile apart has been treated as a single campus (the only such case in the cross section). Trips between the campuses are provided for by free inter-campus bus. Because the high number of resulting trips distorts comparisons with other institutions, they are omitted from most tables. Second, trips originating outside the study area—roadside interview trips—are virtually all auto drivers or auto passengers; were they included in Table C-4 and in the various travel mode tables to follow, auto driver and auto passenger percentages would be slightly higher, and the transit, taxi, and walk-to-work percentages would be slightly lower.

Institutions located toward the center of urban areas tend to show lower proportions of auto driver trips and higher proportions of transit trips. Table C-6 shows that 3 cross-section institutions are located in central business districts, 21 in intermediate areas, 12 in suburban areas, and 2 in outlying areas. With transit service typically thinning out toward the suburbs, the decrease from 8.3% transit trips to CBD institutions to 2.8% to outlying institutions might be expected. Borderline problems of locational definition are clarified by combining and comparing CBD and intermediate area percentages versus suburban and outlying area percentages: the former calculate at 9.0% transit trips; the latter, at 6.6% transit trips. This locational variation is far less significant, however, than that of hospitals (compare Table B-17).

MODE, BY TRIP PURPOSE

Three basic groups of college and university trips are generally dealt with: work trips, school trips, and all other trips. Sometimes, as in Table C-7, home trips and social-recreation trips are broken out of the "other trips" mixture for closer examination. Table C-7 summarizes travel mode distributions by trip purpose by unweighted percentages for the 38 sample institutions, and provides a convenient reference for discussion.

Work trips produce a higher proportion of auto driver

TABLE C-4

PERCENTAGE TRAVEL MODE DISTRIBUTION, HOME INTERVIEW PERSON TRIPS TO SELECTED COLLEGES AND UNIVERSITIES, ALL PURPOSES

CAMPUS POPULATION GROUP	TRAVEL MODE [a] AUTO DRIVER	AUTO PASS.	TRANSIT PASS.	TAXI PASS.	WALK TO WORK	ALL
I	55.9	32.8	7.2	0.4	3.7	100.0
II	62.8	22.2	13.7	0.2	1.1	100.0
III	64.8	24.9	9.4	0.4	0.5	100.0
IV	68.1	25.0	6.0	0.2	0.7	100.0
V	60.3	28.1	9.9	0.8	0.9	100.0
Average	64.1	26.0	8.7	0.4	0.8	100.0

[a] Excludes trips by inter-campus bus at one institution.

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
Project 7-1/1
Data Needs at Generator Sites
UNIVERSITIES

SURVEY YEAR__________

Name: ______________________________

Address: ______________________________

Location: Downtown___ Intermediate___ Suburban___ Outlying___

Type of Institution: Private___ Public___
Nonsectarian___ Sectarian___
Coeducational___ Men___ Women___
Tuition______ Other Annual Costs________

Campus Characteristics: Urban neighborhood, little or no grounds___
Compact site, some grounds___
Large site, all facilities together___
Dispersed in several sites___

Faculty: Total_____ Part time_____ Full Time_____
Men _____ Women_____

Staff: Total_____ approximate per cent White Collar _____
approximate per cent Blue Collar _____

Enrollment: Undergraduate _____ Men _______ Women_______
Full Time Men _______ Women_______ Total_____
Part Time Men _______ Women_______ Total_____

Graduate _____ Men _______ Women_______
Full Time Men _______ Women_______ Total_____
Part Time Men _______ Women_______ Total_____
Military and/or special students
not normally counted__________

Enrollment Trends in past several years: Stable_____ Increasing_____

Summer Extension: ____ Enrollment______ Weeks______
Maximum on site at once: ________
Extension courses off campus: ____________

Short Courses: (Business or Professional, on Campus. Please list with approximate registration and dates:) ____________

____

____

Transit Service: Type_____ Quality______ Student Discount________

Figure C-2. University and college questionnaire.

Universities Data Needs (con't.)

Cars-on-Campus Policy: ______________________________

Parking Spaces: On Campus_____ Faculty_____ Student_____ Visitors______

Lots and Garages off Campus: Private_____ Public______
Intensity of Street Parking________
General adequacy and availability________

Major Generators:

Stadium___ Auditorium___ Gymnasium___ Library___ Museums___
Student Center___ Research Facilities___
Other businesses (press, bookstore, etc.)___
List facilities attracting public visitors:

________ ________ ________
________ ________ ________
________ ________ ________

Major Education Emphasis:

Undergraduate

Business Administration___
Education___
Engineering___
Liberal Arts___
Physical Sciences___
Social Sciences___

Graduate

Agriculture___
Art - Architecture___
Dentistry___
Divinity___
Education___
Engineering___
Law___
Medicine___
Physical Science___
Social Science___
Other__________

Maps, Catalogs, Class Schedule data available for Survey Year______:

____

____

____

Housing on Campus:

	Number of Accommodations	
Residence Halls	Men_____	Women_____
Fraternities	_____	
Sororities	_____	
Married Couples	_____	
Faculty and Staff	_____	

TABLE C-5

HOME INTERVIEW TRIPS TO UNIVERSITIES AND COLLEGES, TRAVEL MODE DISTRIBUTION BY TRIP PURPOSE; AND PERSON TRIPS TO AND FROM UNIVERSITIES AND COLLEGES, TRIP PURPOSE DISTRIBUTION

	TRAVEL MODE DISTRIBUTION (%)												TRIP PURPOSE DISTRIBUTION (%)									
	ALL TRIPS				TRIPS TO WORK				TRIPS TO SCHOOL				UNIVERSITY TRIP END					NON-UNIVERSITY TRIP ENDS				
UNIV.	AUTO. DRIV.	AUTO. PSGR.	TRANS. PSGR.	OTHER	AUTO DRIV.	AUTO PSGR.	TRANS. PSGR.	OTHER	AUTO DRIV.	AUTO PSGR.	TRANS. PSGR.	OTHER	WORK	SCHOOL	SOC.-REC.	HOME	OTHER	HOME	WORK	SCHOOL	SOC.-REC.	OTHER
1	60	34	4	2	72	23	3	2	62	27	10	1	12.8	29.0	18.6	22.0	17.6	50.8	4.6	5.7	17.4	21.5
2	82	12	5	1	85	7	8	0	89	7	3	1	26.7	36.8	6.8	20.1	9.6	58.5	3.9	0.8	10.0	26.8
3	31	19	47	3	15	71	0	14	6	7	87	0	20.0	54.0	—	1.6	24.4	72.8	13.1	—	1.6	12.5
4	63	19	18	0	64	18	18	0	62	17	21	0	11.0	74.6	6.9	—	7.5	75.6	12.6	—	3.7	8.1
5	65	20	14	1	67	26	7	0	59	21	20	0	19.6	55.8	1.2	—	23.4	68.9	4.5	1.5	5.2	19.9
6	60	25	15	0	75	18	7	0	54	20	26	0	24.6	47.9	3.1	—	24.4	73.8	3.6	—	3.4	19.2
7	41	19	4	36 [a]	58	24	11	7	30	12	1	57	19.7	29.6	4.3	29.1	17.3	46.4	3.3	20.6	4.9	24.8
8	54	19	17	10	62	11	11	16	33	26	33	8	40.4	34.6	1.4	9.7	13.9	69.0	4.3	0.9	1.9	23.9
9	68	25	2	5	100	0	0	0	56	27	6	11	11.5	44.3	6.4	16.9	20.9	59.5	9.6	2.0	10.2	18.7
10	69	26	4	1	78	7	15	0	78	20	2	0	22.4	30.2	16.5	17.2	13.7	56.5	11.5	6.3	10.2	15.5
11	57	22	18	3	60	20	14	6	50	16	33	1	32.7	27.6	10.5	9.6	19.6	57.7	5.5	4.7	9.9	22.2
12	77	21	2	0	87	10	3	0	81	16	3	0	8.8	76.0	7.1	—	8.1	80.5	4.8	0.2	2.5	12.0
13	68	29	2	1	84	15	1	0	77	21	2	0	9.6	38.6	9.5	29.9	12.4	47.7	2.4	6.7	11.8	31.4
14	72	15	13	0	87	9	4	0	63	10	27	0	37.5	36.7	3.7	5.5	16.6	57.5	9.7	8.8	3.1	20.9
15	56	28	15	1	58	21	21	0	56	29	15	0	22.5	53.5	5.1	2.9	16.0	75.0	6.6	1.3	3.7	13.4
16	63	24	13	0	94	0	6	0	31	60	9	0	18.4	24.6	8.6	23.4	25.0	55.2	8.1	5.0	5.8	25.9
17	57	40	3	0	77	17	6	0	52	42	6	0	17.3	47.8	14.9	4.2	15.8	72.9	10.9	3.1	5.2	7.9
18	66	32	1	1	81	13	3	3	74	24	1	1	21.3	26.3	5.6	32.6	14.2	46.5	4.4	7.6	4.8	36.7
19	56	29	4	11	63	0	6	31	41	51	8	0	31.6	28.5	—	10.7	29.2	61.5	4.7	9.0	—	24.8
20	46	31	13	10	62	11	8	19	27	54	14	5	36.4	30.2	3.6	18.1	11.7	56.9	11.7	13.8	—	17.6
21	58	36	3	3	53	15	16	16	69	30	0	1	13.9	15.2	9.7	27.3	33.9	43.9	7.9	7.0	3.5	37.7
22	65	19	16	0	62	9	25	4	69	16	15	0	21.5	40.6	12.2	12.5	13.2	63.3	7.0	3.3	8.9	17.5
23	47	3	50	0	89	0	11	0	8	2	90	0	20.0	43.3	1.0	—	35.7	47.1	7.9	—	6.2	38.8
24	19	8	73	0	28	14	58	0	17	7	76	0	24.0	69.3	6.7	—	—	83.2	3.2	—	1.7	11.9
25	55	19	23	3	50	10	32	8	57	21	22	0	22.6	60.8	5.8	—	10.8	85.4	5.7	0.4	2.3	6.2
26	56	19	24	1	63	10	20	7	51	20	29	0	16.7	65.2	9.0	—	9.1	84.6	4.6	—	1.7	9.1
27	33	19	48	0	58	16	26	0	27	18	55	0	17.9	78.9	0.5	—	2.7	87.4	4.2	0.5	0.5	7.4
28	72	24	3	1	77	18	3	2	72	24	4	0	17.0	41.7	16.9	11.3	13.1	54.2	9.5	3.6	12.0	20.7
29	78	7	15	0	100	0	0	0	67	11	22	0	25.2	63.6	7.4	—	3.8	75.2	7.4	—	9.9	7.5
30	69	21	7	3	73	11	8	8	69	20	11	0	31.3	37.7	7.6	1.5	21.9	68.3	7.7	0.4	3.7	19.9
31	62	28	4	6	41	11	0	48	74	24	2	0	10.9	30.2	7.4	24.0	27.5	35.7	12.1	7.0	8.3	36.9
32	67	26	3	4	78	7	7	8	71	20	3	6	18.4	39.6	5.1	25.1	11.8	54.0	7.6	4.9	9.6	23.9
33	73	22	3	2	85	4	0	11	77	20	3	0	22.2	47.1	10.3	0.9	19.5	65.5	5.1	1.5	2.1	25.8
34	67	24	7	2	85	0	7	8	63	28	9	0	21.1	50.7	11.1	2.3	14.8	58.3	18.1	1.5	1.0	21.1
35	63	36	0	1	76	15	2	7	78	21	1	0	14.5	33.5	13.9	22.9	15.2	51.5	3.3	3.8	17.6	23.8
36	49	51	0	0	90	10	0	0	17	83	0	0	22.9	47.2	23.6	—	6.3	82.0	2.4	—	8.5	7.1
37	55	39	6	0	67	16	17	0	50	43	7	0	10.4	56.0	18.7	—	14.9	72.1	3.2	3.1	7.3	14.3
38	71	26	2	1	77	22	1	0	64	31	5	0	27.0	33.5	7.7	6.6	25.2	68.4	5.5	1.0	8.6	16.5
Avg.	60	24	13	3	71	13	10	6	55	25	18	2	20.9	44.6	8.0	15.1	16.3	63.9	9.5	3.5	5.9	19.7

[a] Includes inter-campus bus.

TABLE C-6

PERCENTAGE TRAVEL MODE DISTRIBUTION, HOME INTERVIEW PERSON TRIPS TO COLLEGES AND UNIVERSITIES, BY TYPE AREA IN WHICH THEY ARE LOCATED

		TRAVEL MODE [b]				
AREA TYPE [a]	NO. OF INST.	AUTO DRIVER	AUTO PASS.	TRANSIT PASS.	TAXI PASS.	ALL
Central bus. dist.	3	73.5	17.7	8.3	0.5	100.0
Intermediate	21	63.5	26.5	9.4	0.6	100.0
Suburban	12	67.1	26.0	6.8	0.1	100.0
Outlying	2	53.9	43.3	2.8	—	100.0

[a] Based on definitions in the 1950 Edition of *Highway Capacity Manual* (*34*).
[b] Excludes all walk-to-work trips, and trips by inter-campus bus at one institution.

trips (71%) than do trips for all purposes combined (60%). At individual institutions the proportion ranges from 15 to 100% (see Table C-5). Auto passengers, transit passengers, and the combination of taxi passengers and persons walking to work average 13, 10, and 6%, respectively. Again, proportions vary at individual institutions. Transit passengers, for example, range from 0 to 58%, with six institutions (located in Minneapolis, New Orleans, and Pittsburgh) exceeding 20%.

School trips produce the highest transit use (18%) of the trip purposes considered. But 13 institutions have less than 5% transit trips to school, whereas 6 have more than 30%. (Of the latter, 4 are all-Negro institutions; one has a very large campus within which trips by intracampus * bus tend to inflate its transit trip percentage; and one seems simply to have the advantage of unusually good transit service.) Auto drivers, auto passengers, and taxi passengers account for 55%, 25%, and about 2% of the remaining school trips, respectively. It seems highly significant, considering the broad range of examples represented, that more than one-half of all students who do not walk to school drive to school.

Two transportation studies reported walk-to-school trips where these were the first trip of the day. At two smaller colleges, where walking trips accounted for 78 and 79% of all trips to school, 21 and 38% of the walking trips began off-campus. Average walking trip travel times were 12 and 14 min. At two larger universities, where walking trips account for 26 and 47% of all trips to school, only 2 and 7% of the walking trips began off-campus. Travel times for walk-to-school trips to these universities were 6 and 13 min.

Social-recreation trips have the highest proportion of auto passenger trips (49%) and the lowest proportion of auto driver trips (45%). This is typical of social-recreation trips to most travel generators, and simply reflects the high average car loading. Transit and taxi passenger trips account for 13% and 3%, respectively.

Home trips generally represent students and faculty re-

* Not to be confused with the institution for which *inter*-campus bus trips are generally omitted. Throughout this chapter, all *intra*campus trips are included in the analyses. Although intracampus trips account for up to 20% of all trips generated at institutions with large campuses, the average for the cross section is only 4%, and 21 of the 38 sample institutions generate less than 2%. Intracampus trips are discussed subsequently under a special heading.

TABLE C-7

PERCENTAGE TRAVEL MODE DISTRIBUTION, HOME INTERVIEW PERSON TRIPS TO COLLEGES AND UNIVERSITIES, BY TRIP PURPOSE TO (UNWEIGHTED AVERAGES)

	TRAVEL MODE [a]				
TRIP PURPOSE TO	AUTO DRIVER	AUTO PASS.	TRANSIT PASS.	TAXI PASS.	ALL
Work	70.8	13.2	10.0	6.0 [b]	100.0
School	54.9	25.1	17.5	2.5	100.0
Social-Recreation	45.1	49.3	4.0	1.6	100.0
Home	51.1	37.6	5.5	5.8	100.0
Other	88.4	7.5	2.2	1.9	100.0
Average	59.6	24.4	13.0	3.0	100.0

[a] Excludes trips by inter-campus bus at one institution.
[b] Includes walk-to-work trips; see also Table C-5.

turning from various off-campus activities to on-campus living quarters. Many are made late in the evening, after transit service has been reduced, which may be why home trips have the highest proportion of taxi passenger trips (6%). Auto drivers, auto passengers, and transit passengers account for 51, 38, and 6%, respectively.

Other trips include such miscellaneous purposes as medical-dental, personal business, shopping, eat meal, and serve passenger. The majority are serve passenger trips, and this accounts for the group as a whole having the highest proportion of auto driver trips (88%). Medical-dental trips would represent a significant percentage of trips to those institutions having major teaching hospitals were not such trips excluded from these analyses on the grounds that such hospitals are atypical campus activities and may or may not require campus locations.*

TRIP PURPOSE, ALL MODES

Taking all modes together, Table C-8 shows that trips to school represent about 40% of all trips regardless of campus size. The percentages vary at individual institutions from 15 to 79%—less than 30% at ten institutions, more than 50% at twelve institutions (see Table C-5).

Work trips average 21% of all trips, but vary by institution from 9 to 40%. The lowest proportions are associated with institutions having the lowest faculty-to-student ratios. The composition of the college and university work force averages 58% professional and technical personnel; 15% clerical and sales personnel; 20% craftsmen, laborers and service workers; and 7% miscellaneous, including students.

Social-recreation trips average 10% of all trips. As Table C-8 shows, the proportion seems to rise with increasing campus population. This makes sense—the larger universities have sufficient students to sustain a wider range of curricular activities.

Home trips average 13% of all trips. The percentages at individual institutions vary greatly—dependent on the proportions of resident students—several institutions having no home trips at all. This somewhat distorts the proportions of other trip purposes: for example, institutions with home trips average 37% school trips and 22% work trips; institutions without home trips average 61% school trips and 18% work trips.

"Other" trips account for an average of 16% of all trips. About three-fourths of them are serve passenger trips. Although such trips proceed to other destinations after picking up or dropping off a rider, they nevertheless enter the campus area and use campus street facilities, and must be considered in any trip generation study. Most of the remaining "other" trips are for various personal business purposes.

To complete this discussion, what are the purposes of trips from colleges and universities? The majority (56%) are to return home. The next largest distinct purpose is for social-recreation (10%), followed by eat meal (7%), shop (6%), and work (6%). Mixed purposes account for the remainder (15%). As Table C-9 shows, average percentages by campus size are fairly consistent, although there is considerable variation for individual institutions, relating primarily to the amount of on-campus housing provided. That is, the higher the proportion of resident students, the lower the percentage of trips from school to home; and the lower this purpose percentage, naturally, the higher the other purpose percentages.

In a broad sense, there are two types of "from" trips just as there are two types of "to" trips. Consider at one extreme an institution with no resident students or resident faculty/staff. It is strictly an attractor of trips; tripmakers who live elsewhere first come and then leave. Consider at the other extreme an institution with all resident students and resident faculty/staff. Except for visitors, it would be strictly a producer of trips; tripmakers who live there first leave and then return. Most institutions fall somewhere between these extremes. This dichotomy sets colleges and universities apart from almost all other types of land uses, which tend to be predominantly either attractors or producers of trips, but not both.†

* Trips to such hospitals were, however, analyzed in Appendix B. To obtain total trip generation at those institutions with major teaching hospitals, therefore, the reader may pair up trip statistics as follows: university 1 and hospital 75; university 7 and hospital 74; university 11 and hospital 77; university 15 and hospital 76.

† Throughout this appendix all "to" trips and all "from" trips are combined without regard to whether they are "produced" by residents or nonresidents. Strictly speaking, they cannot be segregated, because it is impossible in many transportation study trip records to determine whether the tripmakers live on or off the campus. Even without definitive evidence, however, it should be perfectly clear that, like small cities, colleges and universities are generally both attractors and producers of travel.

TABLE C-8

PERCENTAGE PURPOSE DISTRIBUTION, HOME INTERVIEW PERSON TRIPS TO COLLEGES AND UNIVERSITIES, ALL MODES

CAMPUS POPULATION GROUP	TRIP PURPOSE TO					
	WORK	SCHOOL	SOCIAL-RECREATION	HOME	OTHER	ALL
I	22.6	37.8	9.1	11.1	19.4	100.0
II	22.7	43.6	7.6	8.7	17.4	100.0
III	25.1	39.7	5.6	14.6	15.0	100.0
IV	16.8	42.5	10.2	16.5	14.0	100.0
V	21.3	36.4	12.6	11.2	18.5	100.0
Average	20.4	40.0	10.0	13.4	16.2	100.0

TABLE C-9

PERCENTAGE PURPOSE DISTRIBUTION, HOME INTERVIEW PERSON TRIPS FROM SELECTED COLLEGES AND UNIVERSITIES, ALL MODES

CAMPUS POPULATION GROUP	TRIP PURPOSE TO HOME	SOCIAL-RECREATION	EAT MEAL	SHOP	WORK	OTHER	ALL
I	47.2	11.3	4.6	3.5	7.3	26.1	100.0
II	59.5	6.9	3.8	6.6	9.1	14.1	100.0
III	59.9	6.2	7.8	5.0	4.0	17.1	100.0
IV	55.1	10.5	9.2	6.6	5.4	13.2	100.0
V	55.5	12.8	6.0	4.8	5.5	15.4	100.0
Average	56.3	10.4	7.2	5.7	5.7	14.7	100.0

Factors Associated with Travel Mode

Primarily, the following discussion deals with factors that affect the degree of public transit use at colleges and universities. This has particular relevance because of the widely held belief that transit may be the key to minimizing campus traffic congestion.

CAMPUS CAR REGISTRATION POLICIES

One means of controlling the car population is by administrative order. Some institutions direct that freshmen, freshmen and sophomores, and so forth, may not keep cars on campus. Other institutions find it simpler to limit the parking facilities provided, and to control their use by sticker systems with permits issued on some priority basis (obviously the institutions that provide few, if any, parking facilities have an almost self-enforcing method of controlling the car population, but this has its disadvantages).

The larger the institution, it would seem, the more complicated the restrictive rules become (*35*). Questionnaire returns (see Table C-3) could not satisfactorily describe full details. In some cases, published car ownership and car use policies—some running to ten pages of fine print—were attached to the returns. In other cases, general policies were given in *Bulletins* or *Catalogs*. Even where policies were known, however, it proved impossible to measure their effect on car use separate from the many other variables involved. Throughout the following paragraphs, therefore, it must be assumed that such policies, and their degree of enforcement, have some slight, but unknown, tendency to increase transit use by decreasing car use.

CAMPUS AND COMMUNITY SIZE

It might be supposed that the larger the institution, the larger the proportion of transit trips it would attract. Table C-10 shows, however, that the averages both for trips to school and for all trips are relatively constant regardless of campus size. The lowest transit use, in fact, occurs at a large university in a city of 250,000 population having high car ownership and relatively poor bus service, whereas the highest transit use occurs at a small Negro college in a larger city having low car ownership but relatively good bus service. Parenthetically, the six Negro institutions in the cross section attract an average of 34% of their daily trips by transit, compared to 9% at all other institutions. The effect of excluding the Negro institutions from the averages is shown in Table C-10.

Transit use appears to relate more strongly to community size than to campus size: Table C-11 shows that the larger the community, the higher the proportion of transit trips, both for all trips and for school trips. However, simple regressions show that the relationships are equally weak: excluding the six Negro institutions, the percentage of transit trips correlates at $r = 0.42$ with community size, and at $r = 0.51$ with campus size.

CAR OWNERSHIP

Car ownership in the university tripmaker's household was available in the trip records from three urban areas. On the average, only 8% of all trips to the six institutions represented were by tripmakers from zero-car households. This seems reasonable: most faculty, staff, and student households, or students parents' households, would be expected to afford cars. Significantly, this 8% of all trips from zero-car households accounted for 20% of the total transit tripmaking to the six institutions (such tripmakers might also have made a higher percentage of walking trips, but such trips are not recorded). Stated another way, 54% of all university trips from zero-car households were by transit, 24% from one-car households were by transit, whereas only 14% from multi-car households were by transit. In this aspect of modal choice, it would seem that university tripmakers are no different from other tripmakers.

SEX AND RACE

At the cross-section institutions, males made 70% of their trips as auto drivers, but females only 45%. Females made more of their trips by transit: 19%, as compared to 12% for males. At the six Negro institutions only, males made 56% of their trips as auto drivers, and females 31%. The proportions of trips by transit were higher than the all-institutions averages for both sexes: 31% for males, and 46%

TABLE C-10

PERCENTAGE OF HOME INTERVIEW PERSON TRIPS TO COLLEGES AND UNIVERSITIES BY TRANSIT, ALL TRIPS AND TRIPS TO SCHOOL, BY CAMPUS POPULATION GROUP (UNWEIGHTED AVERAGES)

CAMPUS POPULATION GROUP	ALL TRIPS		TRIPS TO SCHOOL	
	ALL INSTITUTIONS	EXCLUDING NEGRO INSTITUTIONS	ALL INSTITUTIONS	EXCLUDING NEGRO INSTITUTIONS
I	8.2	8.0	10.6	9.7
II	18.1	7.6	25.6	9.0
III	13.8	13.8	15.5	15.5
IV	7.8	7.8	9.3	9.3
V	8.7	8.7	12.0	12.0
Average	13.0	9.0	17.5	11.0

for females. That five of the six Negro institutions also had a substantial majority of female students helps explain the higher proportion of transit use at these institutions reflected in Tables C-10 and C-11.

OCCUPATION

Table C-12 shows that commuting to work by transit is less likely among the professional and technical staff than among the supporting clerical and maintenance staff. Four-fifths of the former drive to work—significantly higher than any other occupation group—whereas 15% commute as auto passengers and only 5% as transit passengers. By contrast, about 15% of all other workers commute as transit passengers and roughly 20 to 30% as auto passengers. That faculty members have the highest propensity to drive is borne out by special studies at the University of Pennsylvania (*36*) and the University of Minnesota (*37*).

AGE

Although most college students are old enough to drive, the older the student the more likely that he will actually have a car available. Table C-13 shows, for ten institutions in three urban areas, that about one-third of all trips to school by students under 20 are as auto drivers, as compared to two-thirds by students between 20 and 30, and three-fourths by students over 30. The proportions of transit use are 29, 12, and 11%, respectively. The relatively high transit use by students under 20 may reflect, to some extent, restrictions on such students using cars on campus.

DRIVER LICENSING

Other things being equal (a *caveat* which might well have been expressed for each factor discussed so far) drivers are less likely to use transit than nondrivers. For all trips to a selected university, for all age groups combined, nondrivers use transit at twice the rate (34%) that drivers do (17%). The differences are more striking in the older age groups. Inasmuch as only 6% of the campus population over 20 do not drive, and only 8% of the total campus population, driver licensing would hardly determine transit use (see Table C-14).

INCOME

At the two institutions for which tripmaker incomes are reported, there is a slight tendency for the poorer students to make better use of transit. Considering trips to school only, students with a family income of less than $8,000 make 31% of their trips by transit; students from families exceeding this level make 19% of their trips by transit. Considering all trips to these institutions, by students and

TABLE C-11

PERCENTAGE OF HOME INTERVIEW PERSON TRIPS TO COLLEGES AND UNIVERSITIES BY TRANSIT, ALL TRIPS AND TRIPS TO SCHOOL, BY COMMUNITY SIZE GROUP (UNWEIGHTED AVERAGES)

COMMUNITY SIZE GROUP	ALL TRIPS		TRIPS TO SCHOOL	
	ALL INSTITUTIONS	EXCLUDING NEGRO INSTITUTIONS	ALL INSTITUTIONS	EXCLUDING NEGRO INSTITUTIONS
A	6.6	3.0	9.6	3.0
B	4.0	4.0	5.6	5.6
C	26.8	9.0	37.5	9.4
D	13.6	13.6	18.1	18.1
Average	13.0	9.0	17.5	11.0

TABLE C-12

PERCENTAGE TRAVEL MODE DISTRIBUTION, HOME INTERVIEW PERSON TRIPS TO WORK AT COLLEGES AND UNIVERSITIES BY TRIPMAKER OCCUPATION (UNWEIGHTED AVERAGES)

OCCUPATION OF TRIPMAKER	TRAVEL MODE [a] AUTO DRIVERS	AUTO PASS.	TRANSIT PASS.	ALL
Professional and technical	80	15	5	100
Clerical and salesworkers	55	30	15	100
Craftsmen and service workers	65	20	15	100
Misc., including students	54	32	14	100

[a] Excluding taxi passenger and walk-to-work trips.

TABLE C-13

PERCENTAGE TRAVEL MODE DISTRIBUTION, TRIPS TO SCHOOL AT TEN UNIVERSITIES AND COLLEGES IN PITTSBURGH, THE TWIN CITIES, AND SEATTLE, BY STUDENT AGE GROUP

STUDENT AGE GROUP	PERCENTAGE OF STUDENTS	TRAVEL MODE AUTO DRIVER	AUTO PASS.	TRANSIT PASS.	ALL
Under 20	31	32	39	29	100
20 to 29	56	69	19	12	100
30 and over	13	76	13	11	100

TABLE C-14

PERCENTAGE OF HOME INTERVIEW PERSON TRIPS BY TRANSIT BY TRIPMAKER AGE GROUP BY DRIVERS VS NONDRIVERS, ALL TRIP PURPOSES

TRIPMAKER AGE GROUP	PERCENTAGE OF CAMPUS POPULATION	PERCENTAGE OF TRIPS BY TRANSIT DRIVER	NONDRIVER	AVERAGE
Under 20	21	38	33	37
20 to 25	23	14	31	15
26 to 35	22	13	33	13
36 and over	34	10	44	12
Average	100	17	34	18

Source: Madison Area Transportation Study data.

nonstudents alike, the comparable rates of transit trip-making are 17% and 14%, an interesting but inconclusive finding.

TRANSIT SERVICE

Transit use must certainly be affected by the availability of transit service; yet measuring the kind and amount of service to a specific site is a difficult problem. Measurement should consider route pattern and boarding points, schedule variations during the day, transfer possibilities, etc. Although methods might have been devised to account for such variations, because all of the cross-section institutions had some type of transit service, precise quantification was not attempted.

Questionnaire returns generally indicated that transit service was adequate to meet the demand. Of the 27 institutions that answered the question on transit service, 16 rated it good to excellent and 11 rated it fair (see Table C-3). Of the remainder, three institutions might be regarded as having poor transit service (based on field checks), the rest fair to good transit service. None of the cross-section institutions had rapid transit or express bus service, but relied entirely on local buses and/or streetcars.

Table C-15 shows the association between the average transit trip percentages at institutions in each of the 16 subject urban areas with the areawide transit trip percentages. Although it might be held that the latter percentages vary more with differences in comparative urban area land use and population characteristics than with differences in transit service, where transit service is still widely available (as in New Orleans) it is demonstrable that trips to colleges and universities will be made by transit from all parts of the city (see Figure C-3).

Availability of service does not mean comparability with automobile service. Door-to-door travel times averaged from the tripmakers' estimates show that transit trips took longer than automobile trips, regardless of city size or campus location. In most cases, transit travel times were at least one-half again as great. In the three cases where times were almost equal, the institutions were located in or on the fringe of the central business district. Using travel times as an index, it might be concluded that none of the institutions had outstanding transit service.

TABLE C-15

PERCENTAGE OF PERSON TRIPS BY TRANSIT, SUBJECT INSTITUTIONS VS URBAN AREAS

URBAN AREA	NUMBER OF UNIV.	PERSON TRIPS BY TRANSIT (%)	
		SUBJECT INST.	TOTAL URBAN AREA
Ann Arbor	1	4.6	5.1
Atlanta	3	11.0	9.6
Buffalo	2	14.3	10.0
Durham	2	4.2	6.0
Indianapolis	2	3.8	8.3
Madison	1	17.0	7.3
Miami	2	2.3	8.3
Minneapolis-St. Paul	4	13.4	12.4
New Orleans	3	21.7	26.5
Pittsburgh	3	25.6	20.3
Raleigh	4	1.4	3.0
Salt Lake City	2	3.4	5.5
Seattle	5	6.6	6.0
Tucson	1	0.5	4.7
Wichita	2	2.6	2.3
Wilmington	1	1.7	8.2

Truck and Taxi Travel

TRUCKS

Colleges and universities are not major generators of truck trips. There were about 7,200 internal and about 800 external truck trips to the cross-section institutions. Roughly 70% were made by medium or heavy trucks (vehicles with six or more tires), as against 30% by light trucks. Seven smaller institutions had no medium or heavy truck trips, and 21 had fewer than 50 trips a day (see Table C-16). The smallest campuses average 3.78 truck trips per 100 person trips and 6.81 truck trips per 100 auto driver trips; the largest campuses average 4.10 and 6.79, respectively (see Table C-17). For estimation purposes, total truck activity might be projected at 3 to 4 trips per 100 person trips, or at 5 to 7 trips per 100 auto driver trips.

TAXIS

There were about 850 taxi trips to the cross-section institutions (as compared to about 1,200 taxi passenger trips). Twelve institutions had no taxi trips, and 26 had fewer than 20 trips a day (see Table C-16). Again, Table C-17 fails to show significant differences in the rate of tripmaking as related to campus size. For estimation purposes, taxi activity might practically be ignored.

Time Patterns

MONTHLY

Tripmaking to colleges and universities may be somewhat seasonal, although marked variation seems likely. However, no substantial evidence on seasonality has been found.

DAILY

Tripmaking by day of the week may vary less than class schedules might indicate. Although there are more classes on Mondays, Wednesdays, and Fridays than on Tuesdays and Thursdays, other class-related activities such as library work, writing, and the preparation of teaching notes may require travel to the campus every day. Moreover, work trips by full-time maintenance and clerical staff, social-recreation trips by students and teaching staff, *et al.*, all would help to level total daily attendance.

Consultant reports bear this out: At McMaster University (Hamilton, Ont.) the consultant indicates (*38*) "Very little day-to-day variation was observed in the peak-hour traffic volumes." At Florida State University the consultant found (*39*) that each of the five weekdays represented between 14.3 and 18.1% of the total weekly traffic on campus streets, and between 14.8 and 17.1% on off-campus peripheral streets. At Vanderbilt University the consultant found (*40*) that daily traffic varied only ± 7% from the five-weekday average, and at the University of Tennessee (*41*) only ± 6% from the five-weekday average.

HOURLY, PERSON TRIPS

Plots of hourly distributions of total person trips to individual institutions show considerable consistency. Taken from them, Figures C-4 and C-5 compare the composite distributions of trips to and trips from, by trip purpose.

Regarding trips to: students, faculty and staff go to school or to work at about the same time and in the same proportion—both trip purpose groups peak between 8 and 9 AM at about 28% of their respective total daily arrivals. Work trips peak again between 1 and 2 PM (probably indicating returnees from lunch), as do school trips between 7 and 8 PM (probably indicating the start of evening classes). Other trips take place throughout the day, the 7 to 8 PM peak largely representing social-recreation trips and returns to campus from various off-campus trip purposes.

TABLE C-16

SUMMARY OF TRIPS TO UNIVERSITIES, BY SURVEY SOURCE

	HOME INTERVIEW					ROADSIDE			TRUCK-TAXI	
UNIV.	AUTO DRIVER	AUTO PSGR.	TRANS. PSGR.	TAXI PSGR.	WALK [a]	AUTO DRIVER	AUTO PSGR.	TRUCKS	TRUCKS	TAXI
1	23411	13169	1726	576	*	2992	1705	393	1803	124
2	4620	719	259	44	*	88 [b]	44 [b]	—	199	14
3	204	125	306	21	*	61 [b]	31 [b]	—	36	18
4	1312	394	384	—	*	35 [b]	18 [b]	—	18	3
5	1377	430	304	—	31	27	27	—	44	—
6	3604	1488	917	—	56	216	138	—	110	12
7	5714	2683	5436 [c]	41	84	1243	797	90	263	76
8	470	162	174	8	49	107	64	—	100	16
9	1115	409	129	—	*	90	37	—	20	—
10	2660	1027	173	22	*	38	22	—	198	—
11	9754	3839	3195	119	365	853	661	60	549	62
12	5836	1598	167	—	*	197	79	18	56	35
13	12860	5453	445	33	*	275	75	9	286	12
14	2454	518	419	—	*	86	56	6	248	8
15	10779	5414	2928	61	*	279	163	13	932	102
16	1061	411	222	—	*	29	30	—	92	8
17	1250	864	79	—	*	35	38	3	112	8
18	9670	4669	175	48	137	840	588	55	501	20
19	209	110	16	—	41	72	85	8	24	—
20	250	165	73	10	41	48	37	3	12	—
21	435	272	25	—	16	81	52	10	20	—
22	6291	1824	1515	21	43	77	90	5	170	35
23	542	30	578	—	—	27	68	—	26	—
24	116	52	451	—	—	5	3	—	26	5
25	5909	2055	2514	52	209	655	412	5	68	41
26	2736	892	1175	—	53	150	28	10	34	50
27	951	549	139	—	—	60	33	5	69	43
28	10186	3429	471	75	30	245	230	39	172	15
29	157	15	30	—	—	23	29	1	34	4
30	11212	3329	1198	—	432	216	180	2	286	60
31	534	240	32	—	55	12	12	—	47	—
32	627	247	49	—	13	67	41	5	—	—
33	1083	322	50	—	39	75	19	—	16	—
34	1183	427	131	—	32	16	4	—	47	—
35	12412	4215	93	10	190	102	126	12	294	18
36	345	534	—	—	*	141	92	2	84	50
37	438	312	48	—	*	35	25	—	7	—
38	3082	1136	95	30	*	729	619	61	162	2
All	156849	63527	26121	1171	1916	10327	6758	815	7165	841

[a] * = not available.
[b] Estimated.
[c] Includes 4,870 trips via inter-campus bus.

TABLE C-17

RATIOS OF TOTAL TRUCK AND TAXI TRIPS TO TOTAL PERSON AND AUTO DRIVER TRIPS BY CAMPUS POPULATION GROUP, ALL PURPOSES

CAMPUS POPULATION GROUP	PER 100 PERSON TRIPS		PER 100 AUTO DRIVER TRIPS	
	TRUCK TRIPS	TAXI TRIPS	TRUCK TRIPS	TAXI TRIPS
I	3.78	0.13	6.81	0.23
II	3.60	0.25	5.81	0.41
III	2.90	0.70	4.93	1.18
IV	1.75	0.18	2.59	0.26
V	4.10	0.35	6.79	0.58
Average	3.01	0.32	4.77	0.50

Regarding trips from: students evidently leave school in fairly even numbers all day, whereas faculty and staff keep more regular hours; that is, they leave work around 4 to 6 PM. Other trips also are spaced out all day. All from trips peak at lower percentages than do to trips, with from-work trips peaking at about 25%, from-school trips at about 12%, and from-other trips at about 10%.

HOURLY, AUTO DRIVER TRIPS

Taking all trip purposes together, Figures C-6 and C-7 compare the composite distributions of auto driver trips to and trips from, by campus size. All of the peaks are comparatively low, trips to barely exceeding 20% between 8 and 9 AM, trips from falling somewhat below that. There is

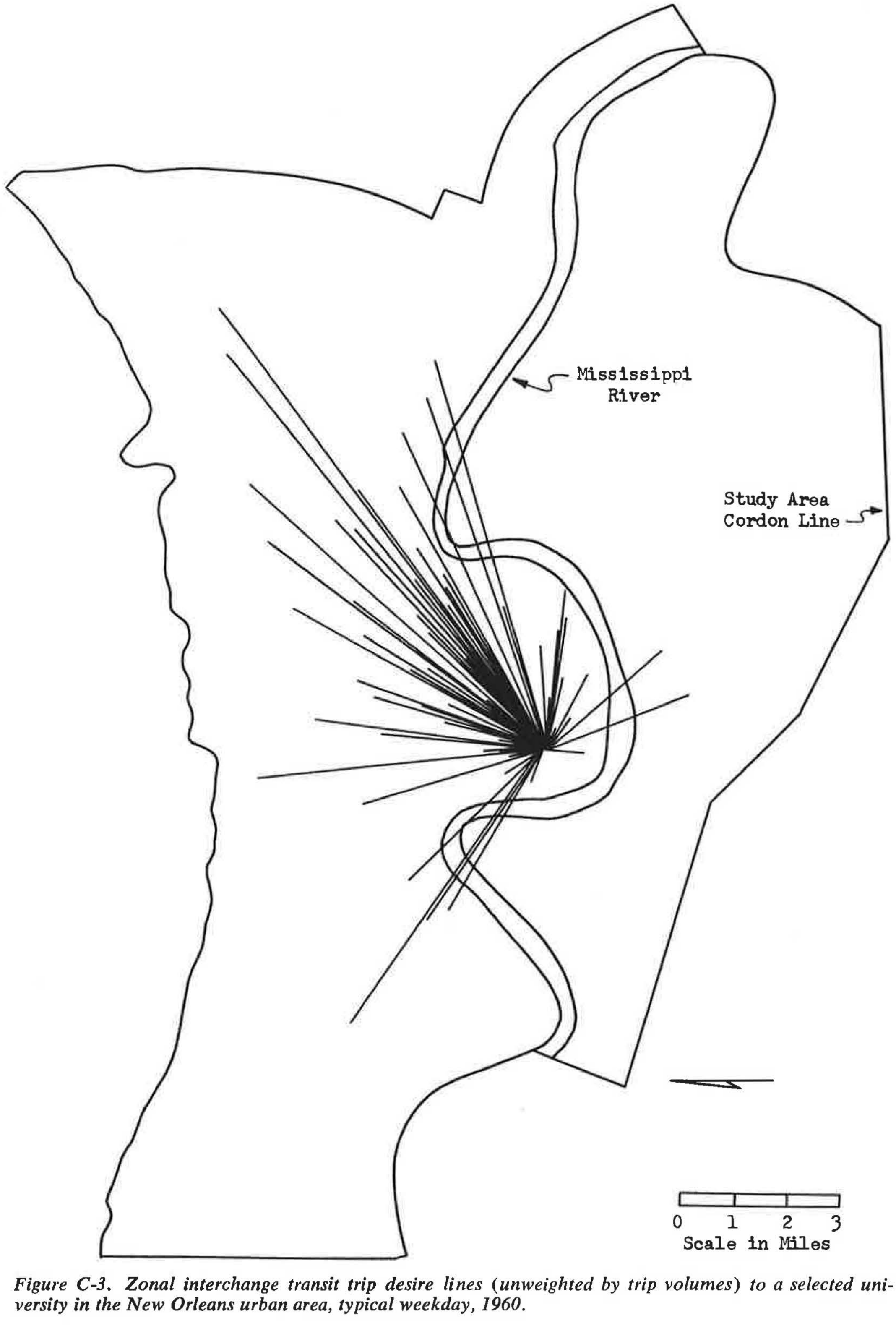

Figure C-3. Zonal interchange transit trip desire lines (unweighted by trip volumes) to a selected university in the New Orleans urban area, typical weekday, 1960.

significant traffic between 6 PM and midnight: arrivals total around 20% of the daily volume, and departures nearly 27%. Patterns by campus size are not significantly different.

HOURLY, TRANSIT PASSENGER TRIPS

By contrast with other travel modes, transit passenger trips to colleges and universities are highly peaked (Fig. C-8).

Because they are mostly trips to school or to work, the 8 to 9 AM arrival peak (40%) and the 3 to 4 PM departure peak (24%) might be expected.

HOURLY, TRUCK AND TAXI TRIPS

Figures C-9 and C-10 show daily truck and taxi activity. Taxi trips decrease slightly from early morning until midnight; only the 8 to 9 AM peak exceeds 10% of the daily total. Truck trips hold fairly constant between 6 AM and 6 PM, excepting a drop around noon; only the 8 to 9 AM peak exceeds 15% of the daily total.

PEAK HOURS

For 25 institutions with at least 1,000 vehicle trips, the peak arrival hour was invariably 7 to 8 AM or 8 to 9 AM. The peak departure hour differed: for three institutions it came at 3 to 4 PM; for twelve, between 4 and 5 PM; for eight, between 5 and 6 PM; for one, between noon and 1 PM; for the last, between 8 and 9 PM. Arrival peaks varied from 11 to 43%; departure peaks, from 11 to 21%. To trace the possible cause of these variations, the percentages were re-averaged on the basis of various campus characteristics. From Table C-18 it would appear that arrival peak percentages might best be based on the percentage of resident students, whereas departure peak percentages might more simply be based on the mean of 16%. (A subsequent section deals with percentages for two-way traffic.)

ACCUMULATION CURVES, AUTOMOBILE TRIPS

Time patterns for automobile accumulations have been developed by using the times of arrivals and departures for trips to and from the campus. The excesses of arrivals over

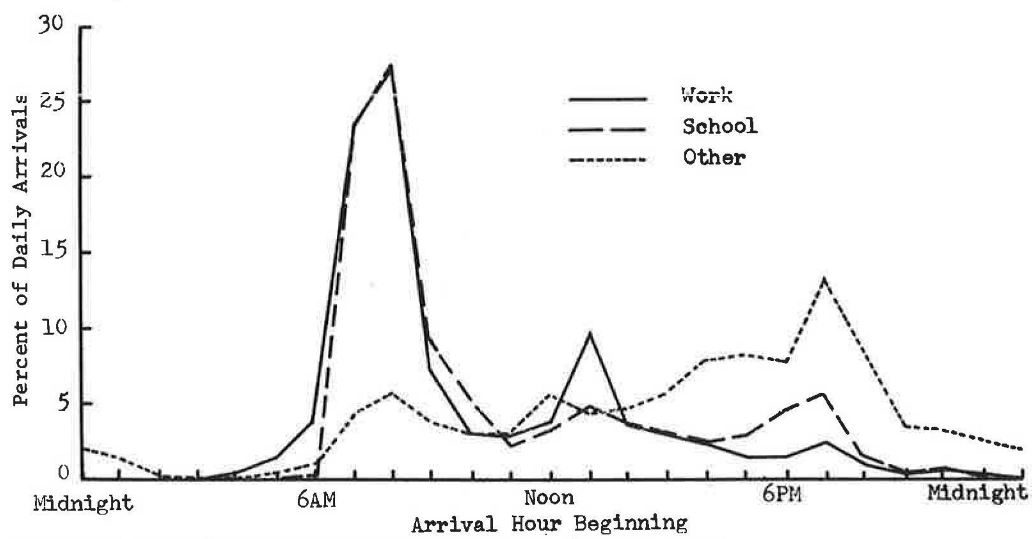

Figure C-4. Home interview person trips to universities, by trip purpose.

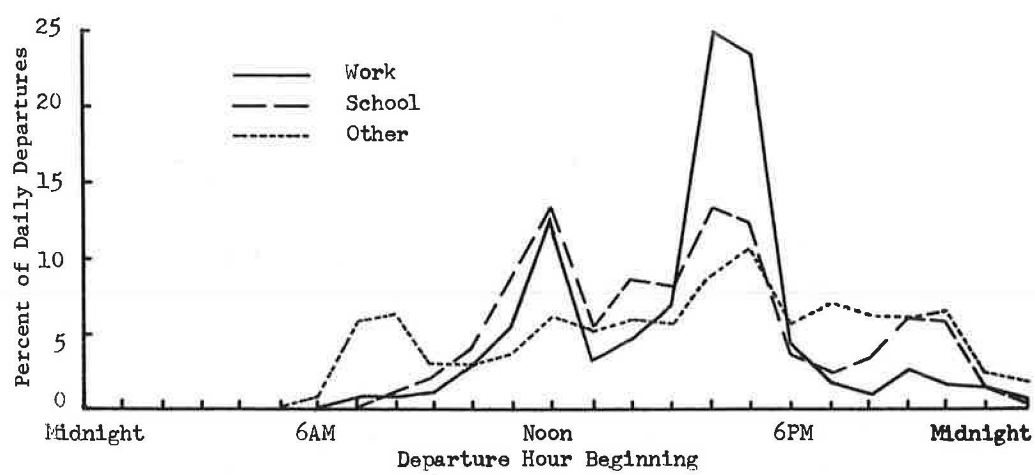

Figure C-5. Home interview person trips from universities, by trip purpose.

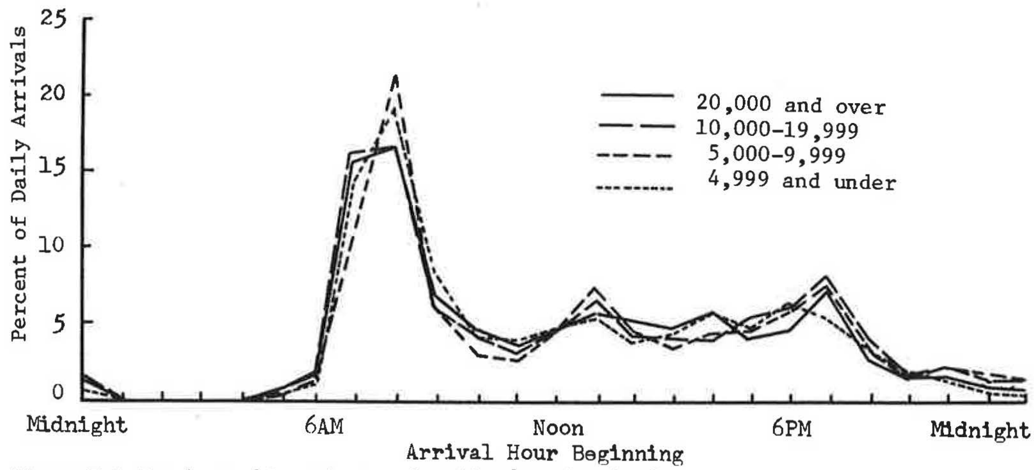

Figure C-6. Total auto driver trips to universities, by university size.

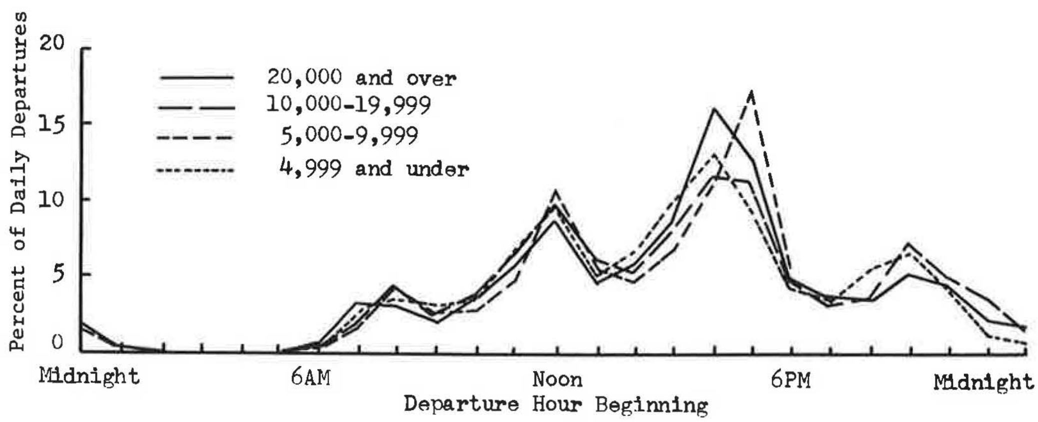

Figure C-7. Total auto driver trips from universities, by university size.

departures during morning hours were determined, for example, and the net differences for successive hours were added to obtain a picture of the rise and fall of parking demand. Comparison between institutions was facilitated by plotting accumulations as percentages of daily arrivals, and by assuming zero accumulation at 5 AM (to apply such curves to particular situations, it is necessary to add an appropriate percentage to account for autos parked overnight).

Figure C-11 plots the composite accumulation curves by campus size. The curves rise rapidly to 9 AM, then more slowly to peaks at 10 to 11 AM; there is a dip and a recovery at lunchtime, then the curves fall off regularly until after 6 PM; the evening build-up is perhaps one-third that of the morning. Although the patterns are the same regardless of campus size, in general, the larger the institution the smaller the peak percentage accumulation. They vary greatly, of course, for individual institutions. Depending on campus size, peak accumulations range from 50 to 6,200 vehicles, or from 21 to 71% of daily arrivals. (Table C-19 gives for the cross-section institutions the peak accumulation of volumes, the corresponding percentages of daily arrivals, the hours that the peak accumulations occur, and the peak accumulation volumes per 1,000 campus population.)

Various means of predicting maximum accumulations as percentages of daily arrivals were attempted without great success. The best single predictor found was the percentage of nonresident students, producing a correlation of $r = 0.59$ (see Fig. C-12). Peak percentage accumulations were also entered as a dependent variable in the multiple regression work; with 13 predictor variables the resulting correlation was much stronger ($r = 0.85$), but the standard error of the estimate was still rather high (see Table C-20).

Maximum accumulations as direct volumes are more directly predictable. The best single predictor found was daily vehicular trip arrivals—for 29 institutions with less than 20% home trips producing a correlation of $r = 0.97$; for 8 institutions with more than 20% home trips, a correlation of $r = 0.99$ (see Fig. C-13). Direct volume accumulations were not entered in the multiple regression work.

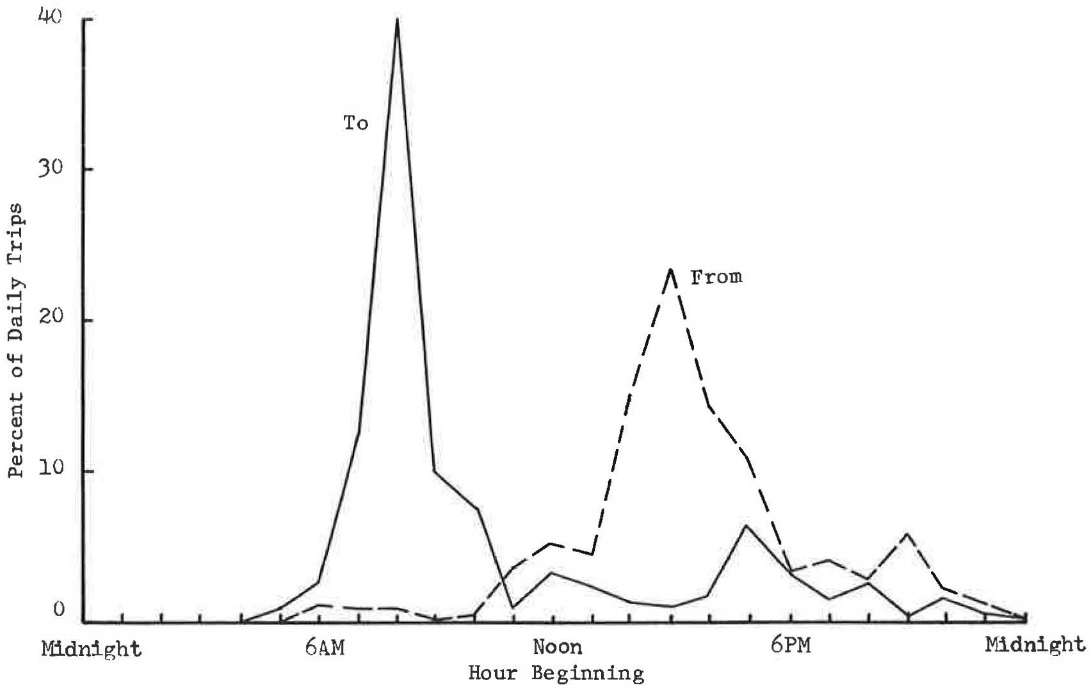

Figure C-8. Transit trips to and from universities.

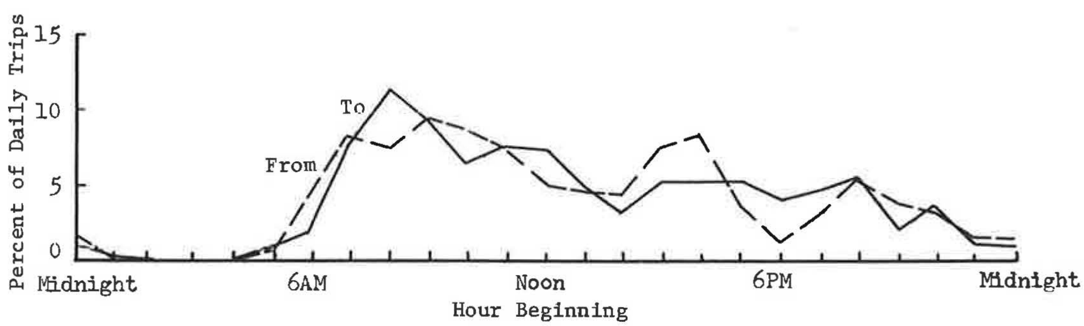

Figure C-9. Taxi trips to and from universities.

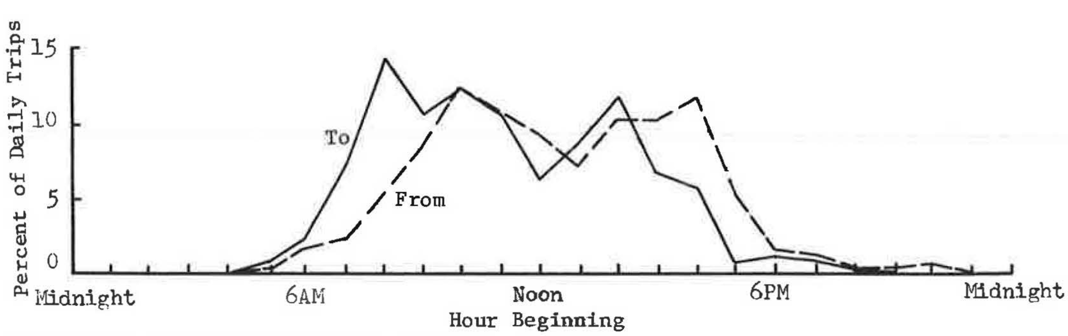

Figure C-10. Truck trips to and from universities.

TABLE C-18

PEAK ARRIVAL AND PEAK DEPARTURE HOURS AS PERCENTAGES OF DAILY ARRIVALS AND DAILY DEPARTURES, BY CAMPUS CHARACTERISTIC GROUPINGS, TOTAL VEHICLE TRIPS (UNWEIGHTED AVERAGES)

CAMPUS CHARACTERISTIC GROUPING		PEAK-HOUR PERCENTAGE OF DAILY ARRIVALS	PEAK-HOUR PERCENTAGE OF DAILY DEPARTURES
Campus population group:	I	22	16
	II	21	16
	III	28	18
	IV	20	15
	V	21	15
Community size Group	A	16	17
	B	23	14
	C	18	15
	D	25	16
Percent part-time students:	0-9	19	16
	10-39	23	15
	40+	24	16
Percent resident students:	0-19	28	16
	20-39	20	15
	40-59	20	15
	60+	15	17
Average, 25 institutions		22	16

TABLE C-19

TOTAL VEHICLE TRIPS, ALL SURVEYS, MAXIMUM PARKING ACCUMULATION CHARACTERISTICS[a]

UNIVER-SITY	HOUR OF OCCUR-RENCE	% OF DAILY ARRIVALS	MAXIMUM ACCUMU-LATION	ACCUM. PER 1,000 CAMPUS POP.
1	10 AM	21.6	6204	151
2	9 AM	48.4	2374	294
3	10 AM	22.1	53	29
4	10 AM	44.2	586	149
5	10 AM	51.0	711	38
6	10 AM	44.2	1730	356
7	10 AM	29.6	2218	185
8	9 AM	38.2	217	58
9	11 AM	22.2	272	263
10	9 AM	20.8	602	131
11	10 AM	30.0	3066	106
12	10 AM	50.1	3054	192
13	10 AM	25.8	3463	215
14	10 AM	46.0	1167	390
15	10 AM	42.9	5196	170
16	1 PM	30.1	358	177
17	9 AM	36.7	517	237
18	10 AM	26.7	2960	253
19	10 AM	30.6	86	119
20	9 AM	30.7	96	115
21	10 AM	17.7	90	91
22	10 AM	27.8	1769	140
23	10 AM	23.4	133	127
24	10 AM	70.7	87	81
25	10 AM	58.6	3530	189
26	10 AM	46.1	1265	202
27	9 AM	63.0	606	108
28	9 AM	35.7	3805	249
29	10 AM	53.3	117	263
30	10 AM	46.5	5477	149
31	11 AM	30.2	179	117
32	10 AM	33.1	231	115
33	9 AM	41.8	491	151
34	9 AM	46.4	578	152
35	10 AM	26.9	3453	249
36	9 AM	57.9	360	59
37	9 AM	53.0	255	371
38	9 AM	38.5	1554	221

[a] Assuming *no* accumulation at 5 AM.

Travel Times and Distances

TRAVEL TIMES

Table C-21 compares by community size the mean door-to-door trip times as reported by home interview respondents. Auto driver times increase from 12.9 min for institutions in cities up to 100,000 population, to 21.5 min for institutions in cities over 1,000,000 population. Transit times increase less markedly with increasing community size, from 24.7 to 34.1 min. Ratios of transit times to auto driver times show that in the smaller communities transit trips take almost twice as long as auto driver trips (ratio = 1.91), whereas in the larger communities they take only one-half again as long (ratio = 1.59).

Taking all travel modes together, school trips averaged 20.5 min; work trips, 18.3 min; "other" trips, 17.1 min. Auto driver trip times were slightly lower than the all-modes averages: school trips, 19.0 min; work trips, 17.3 min; "other" trips, 16.4 min (see Table C-22) for variations by individual institutions). When terminal delays for parking and walking are excluded (by using minimum-path trees) the resulting on-the-road travel times for auto driver trips are low indeed. Averages for 13 institutions for which trees were available show that driving times were 8.1, 8.8, and 6.5 min for work, school, and "other" trips, respectively. Although the work and school trip averages are not much different, frequency distributions show that considerably more work trips start within a very short time radius.

DISTANCES

City-to-city comparisons of average airline trip lengths can be deceptive due to differences in topograpy: in city A the relationship of over-the-road distance to airline distance might be very different from that in city B because of more indirect travel connections. Comparative trip lengths do, however, provide some sense of scale. For example, the over-all average trip length for the cross-section institutions is 3.58 miles. Work trips average 3.46 miles; school trips, 4.02 miles; "other" trips, 3.19 miles. These averages are a useful reminder that trips in urban areas tend to be surprisingly short.

Where they could be compared, time and distance relationships were generally parallel. That is, institutions which attracted longer trips also attracted trips with higher travel

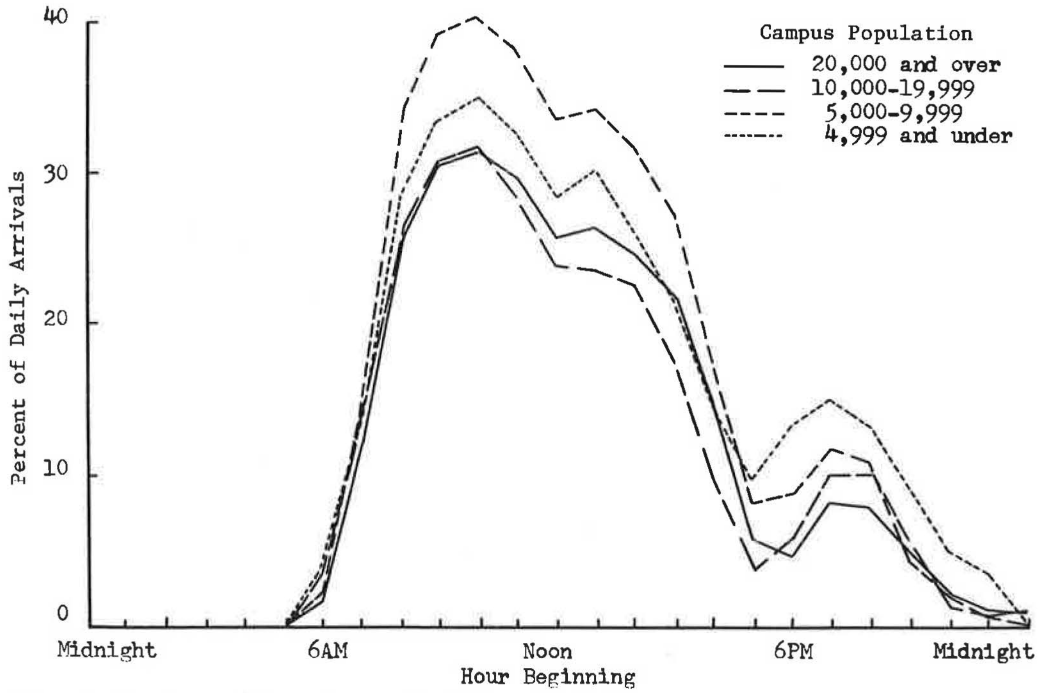

Figure C-11. Accumulation curves, auto driver trips to universities (assuming no accumulation at 5 AM), by campus population.

times. It is pertinent that longer trips in the suburbs can often be made in the same driving time as shorter trips in the city. Perhaps this is why institutions in the suburban or outlying areas were found to attract somewhat longer trips than those in the central business district or intermediate areas.

Parking and Distances Walked

Campus parking can be a major headache for the college or university administrator. The parking problem also tends to be unique at each institution. The magnitude of parking demand, the importance attached to it, the attention given

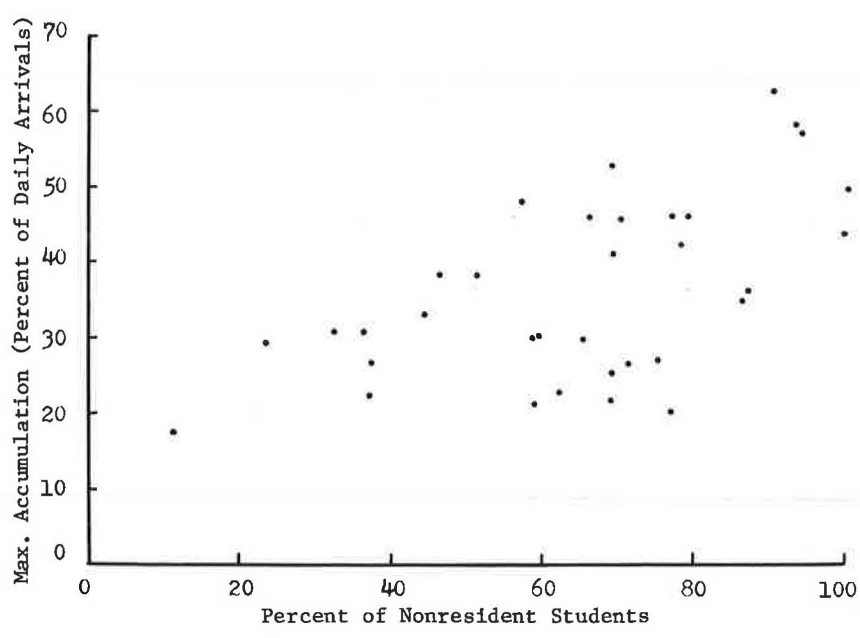

Figure C-12. Maximum vehicular accumulation at universities related to percent of nonresident students.

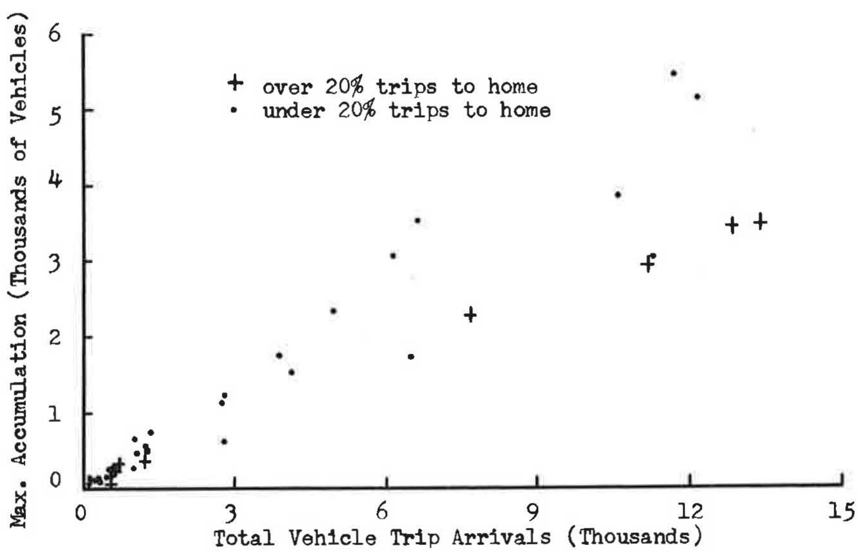

Figure C-13. Maximum vehicular accumulation at universities related to total vehicle trip arrivals.

TABLE C-20

SIMPLE REGRESSION RESULTS, UNIVERSITIES

EQ. NO.	EQUATION	r	N	$S_{YX}/\bar{Y}$
1	Total person trips = 22 + 0.824 campus population	0.91	36	0.52
2	Person trips to work = 394 + 0.606 faculty/staff	0.92	36	0.49
3	Person trips to school = 57 + 0.391 student enrollment	0.92	36	0.45
4	Person trips to school = —327 + 0.493 student enrollment	0.98	34	0.23
5	Person trips to "other" purposes, excluding trips home = —272 + 0.279 campus population	0.91	30	0.52
6	Person trips to "other" purposes, excluding trips home = —304 + 0.350 student enrollment	0.89	30	0.58
7	Total auto driver trips = 58 + 0.509 campus population	0.90	36	0.54
8	Auto driver trips to work = 304 + 0.400 faculty/staff	0.92	36	0.52
9	Auto driver trips to school = 21 + 0.252 student enrollment	0.89	36	0.53
10	Auto driver trips to "other" purposes, including trips home = —459 + 0.329 campus population	0.90	30	0.62
11	Max. veh. parking accumulation [a] = —24 + 0.406 total daily veh. trip arrivals	0.97	29	0.27
12	Max. veh. parking accumulation [b] = 81 + 0.260 total daily veh. trip arrivals	0.99	8	0.08
13	Max. veh. parking accumulation as % of total daily veh. trip arrivals = 156 + 3.250% (times 100) of non-resident students	0.59	34	0.25

[a] Universities with less than 20% home trips.
[b] Universities with more than 20% home trips.

TABLE C-21

COMPARATIVE TRAVEL TIMES OF AUTO DRIVER TRIPS AND TRANSIT TRIPS TO COLLEGES AND UNIVERSITIES BY COMMUNITY SIZE GROUP

COMMUNITY SIZE GROUP	TRAVEL TIME (MIN)		RATIO TRANSIT TIME/ AUTO DRIVER TIME
	AUTO DRIVER TRIPS	TRANSIT TRIPS	
A	12.9	24.7	1.91
B	14.0	25.7	1.83
C	17.8	31.6	1.77
D	21.5	34.1	1.59
Average	17.7	30.0	1.70

TABLE C-22

HOME INTERVIEW TRIPS TO UNIVERSITIES AND COLLEGES, AVERAGE DOOR-TO-DOOR TRAVEL TIMES BY TRAVEL MODE AND TRIP PURPOSE

	AVERAGE DOOR-TO-DOOR TRAVEL TIME (MIN)									
	BY MODE, ALL TRIP PURPOSES				BY TRIP PURPOSE, ALL MODES			AUTO DRIVER TRIPS		
UNIV.	AUTO DRIV.	AUTO PSGR.	TRANS. PSGR.	TOTAL	WORK	SCHOOL	OTHER	WORK	SCHOOL	OTHER
1	11.8	11.9	24.2	12.1	11.5	11.8	10.9	11.3	11.5	10.7
2	17.8	14.8	30.0	18.3	20.5	19.1	21.0	18.6	19.3	15.0
3	12.6	12.0	31.4	20.6	9.4	29.6	13.5	12.0	6.0	13.5
4	26.2	23.0	27.5	25.8	29.5	25.9	18.0	30.8	26.4	20.7
5	19.3	19.1	31.0	21.0	16.8	26.8	13.8	14.4	24.5	13.6
6	17.2	14.4	33.7	19.1	15.3	23.4	15.0	14.5	21.0	14.5
7	11.8	12.9	20.2	11.5	16.8	8.9	11.1	16.9	8.0	10.6
8	11.5	12.3	32.0	15.3	13.5	22.2	9.7	11.1	16.4	8.0
9	17.6	16.1	18.0	18.3	12.0	18.0	20.3	12.0	18.3	19 4
10	16.6	12.0	45.8	16.8	19.1	18.3	14.7	13.7	20.1	15.3
11	11.4	12.6	13.2	11.8	12.6	10.4	11.9	12.6	9.9	12.0
12	24.9	24.5	57.0	25.5	21.8	27.2	21.6	21.4	25.8	22.3
13	16.4	18.1	36.8	17.3	18.6	19.4	15.3	17.5	19.5	12.9
14	17.2	18.6	26.4	18.6	15.6	22.3	17.5	14.3	20.6	18.5
15	24.2	25.9	35.8	26.5	28.2	28.5	20.1	25.3	26.1	19.2
16	18.7	15.9	27.3	19.2	16.2	24.6	17.6	15.0	35.0	16.8
17	22.0	23.1	39.0	23.1	18.4	24.8	23.2	15.7	24.0	24.0
18	11.1	12.1	26.0	11.5	12.6	10.2	11.7	11.5	10.3	11.4
19	17.0	12.0	30.0	16.8	16.5	22.0	12.9	13.2	30.0	14.0
20	15.2	11.5	26.0	15.6	16.2	12.5	14.4	14.6	13.0	18.0
21	11.9	12.2	26.0	12.3	14.3	13.4	11.7	13.7	11.3	11.6
22	18.2	15.9	30.3	19.5	21.4	19.3	18.6	20.2	17.5	17.7
23	18.2	36.0	36.2	27.7	19.2	33.9	24 5	15.4	12.0	20.6
24	15.4	42.0	33.4	30.4	26.3	32.1	27.0	30.4	16.5	—
25	25.9	24.7	34.6	27.4	28.3	27.7	25.2	28.3	27.7	21.7
26	21.8	21.1	40.3	26.1	27.0	27.1	21.8	20.2	24.0	17.5
27	30.3	27.9	31.6	30.5	30.6	30.9	21.0	29.5	31.4	24.0
28	14.9	16.5	22.6	15.5	15.0	15.7	15.6	14.3	14.9	15.1
29	20.0	6.0	18.0	18.8	21.0	18.0	18.0	21.0	19.7	18 0
30	22.0	22.0	30.1	22.4	20.8	24.7	21 4	20.2	24.4	21.2
31	19.0	20.8	21.0	18.9	19.0	20.0	18.3	18.0	22.0	17.0
32	11.8	15.6	42.0	13.6	12.0	10.4	17.4	10.9	8.6	15.0
33	13.3	15.0	25.5	13.9	11.1	15.2	14.1	11.2	15.3	11.4
34	22.4	26.1	41.0	24.6	22.9	25.6	24.0	23.6	23.0	19.8
35	10.7	10.2	30.0	10.8	14.8	9.9	9.7	14.8	10.3	8.9
36	18.5	13.4	6.0	15.2	15.8	15.2	13.2	16.9	22.0	12.0
37	15.0	14.7	34.0	16.0	20.0	16.6	14.5	16.5	16.4	27.0
38	18.0	16.0	27.0	17.4	15.1	18.4	18.2	15.6	20.4	17.5
Avg.	17.6	17.9	30.0	21.8	18.3	20.5	17.1	17.3	19.0	16.4

to it, and the associated degree of regulation and enforcement combine to make campus parking provisions highly variable.

To illustrate: Table C-23 summarizes the diverse parking situation at six large public universities in the cross section. Although two report a significant number of curb spaces, and two report having parking garages, by far the largest numbers of spaces are provided in parking lots. The proportions of off-street spaces assigned to students, faculty, and staff, or visitors, are highly variable, as are the proportions left unassigned. When considered without regard to such assignments, the space-per-student ratios seem consistent, whereas the space-per-faculty/staff ratios do not. However, data from another source (*42*) show that space-per-student ratios, based on assignments, are actually quite variable: of 55 institutions surveyed, 13 reported a 1:1 ratio, 20 a 1:2 ratio, 9 a 1:3 ratio, and 11 a 1:4 ratio. There was somewhat less variation in the space-per-faculty/staff ratios.

Variable parking ratios might be expected, because parking demand differs with campus population and other factors. A University of Washington report (*43*), citing several studies, suggests that the number of parking spaces needed per 1,000 persons decreases as campus population increases, because proportions of resident student and time of day patterns change. A lower space ratio for a large university may thus provide the same adequacy of parking as a higher space ratio for a small college. As a very

TABLE C-23

PARKING FACILITY CHARACTERISTICS AT SIX LARGE PUBLIC UNIVERSITIES

NO. OF SPACES			PARKING SPACES ASSIGNED		VISITOR OR UNASSIGNED SPACES	SPACE RATIO	
CURB	LOTS	GARAGES	STUDENTS	FACULTY/ STAFF		STUDENTS	FACULTY/ STAFF
2000	5387	1323	433	4532	1745	0.3	0.7
—	6111	1316	178	942	5037	0.3	1.0
260	4692	—	— 3616	—	1075	0.3	0.8
11	2258	—	1371	817	70	0.2	0.6
1000	8000	—	4000	— 4000	—	0.3	1.2
250	7005	—	5469	975	459	0.7	2.4

[a] Ratio of total off-street parking spaces to the number of students, or to the number of faculty plus staff.

Source: University Facilities Research Center, *Parking Programs for Universities* (45).

general planning guide, *Parking in the City Center* (*44*) suggests 0.5 to 0.7 spaces per registered student.

Questionnaire returns tend to confirm the impression that parking is generally in short supply. Of 24 answers given concerning the general adequacy and availability of parking at the cross-section institutions, 8 specifically indicated it was inadequate, 7 indicated it was poor or very limited, and the remainder indicated that at best it was fair to good. Although such answers can hardly substitute for factual surveys, they do show how some college and university officials view their own problem.

Tripmakers' reports, summarized in Table C-24, show that the larger the institutions, the less likely that parking will be free. For campus populations under 10,000 the average percentage of paid off-street parking for work trips is under 3%; for campus populations between 10,000 and 20,000 it is 21%; for still larger campus populations it is 52%. The relationship for nonwork trips is parallel. That 86% of all work trips park off-street as compared to 60% of all nonwork trips suggests that faculty generally have some priority on off-street spaces. Practically all on-street parking was reported as free. Most of the nonwork trips that report "not parked" are the stop-and-go serve passenger trips.

Eliminating the "not parked" category, and combining trips for all purposes, the tripmakers' reports show that 17% of all parking was off-street paid, 57% was off-street free, and 26% was on-street. Variations were extensive. Some institutions had no curb parking. Others, with campuses cut by city streets, reported up to 60% of the parking on-street. Parking on lots ranged from 23 to 99%, with 15 institutions reporting more than 80% (see Table C-25).

High proportions of off-street parking probably account for the short walking distances reported. In the 13 cases where such data were available, work trips average 0.2 block walked from parking place to final destination, school trips 0.6 block, and all trips 0.4 block. These figures tend to confirm that faculty and staff parking is often more conveniently situated than is student parking.

Car Loading Factors

The average number of persons per car fluctuates more with trip purpose than with size of institution (Table C-26). The

TABLE C-24

REPORTED CHARACTERISTICS OF HOME INTERVIEW AUTO DRIVER TRIPS TO SELECTED COLLEGES AND UNIVERSITIES (PERCENTAGES)

CAMPUS POPULATION GROUP	WORK TRIPS				ALL OTHER TRIPS			
	OFF-STREET		ON STREET [a]	NOT PARKED [b]	OFF-STREET		ON STREET [a]	NOT PARKED [b]
	PAID	FREE			PAID	FREE		
I	—	92	8	—	5	64	6	25
II	3	72	25	—	12	45	28	15
III	2	91	6	—	8	60	24	8
IV	21	63	15	1	10	50	28	12
V	52	38	9	1	32	22	27	19
Average	20	66	13	1	14	46	27	13

[a] Includes parking on residential property.
[b] Auto left for service or repairs, cruised, or other not parked. For nonwork trips, this category also includes serve passenger trips (see also Table C-25).

TABLE C-25

HOME INTERVIEW AUTO DRIVER TRIPS TO UNIVERSITIES AND COLLEGES, AVERAGE CAR LOADING AND TYPE OF PARKING

UNIV.	PERSONS PER CAR BY TRIP PURPOSE TO: WORK	SCHOOL	OTHER	TOTAL	REPORTED PARKING [a] (% OF ALL AUTO DRIVER TRIPS): ON-STREET	OFF-STREET	OTHER
1	1.18	1.26	1.75	1.50	32	50	18
2	1.02	1.15	1.29	1.16	29	64	7
3	1.00	1.00	1.37	1.30	50	50	—
4	1.21	1.06	1.44	1.12	11	87	2
5	1.15	1.15	1.87	1.34	15	85	—
6	1.20	1.19	1.97	1.36	11	89	—
7	1.20	1.33	1.80	1.52	7	91	2
8	1.26	1.45	1.83	1.46	33	67	—
9	1.22	1.30	2.02	1.60	15	80	5
10	1.02	1.15	1.59	1.30	38	53	9
11	1.19	1.20	1.76	1.40	21	59	20
12	1.08	1.15	1.74	1.21	—	99	1
13	1.20	1.18	1.65	1.39	2	97	1
14	1.31	1.34	1.68	1.40	23	74	3
15	1.12	1.21	1.61	1.29	21	77	2
16	1.32	1.08	1.71	1.53	61	23	16
17	1.08	1.16	2.19	1.45	55	45	—
18	1.15	1.25	1.82	1.46	9	86	5
19	1.05	1.40	1.95	1.48	10	85	5
20	1.03	1.50	1.39	1.24	8	92	—
21	1.00	1.00	2.06	1.72	3	97	—
22	1.13	1.11	1.69	1.30	63	32	5
23	1.43	1.00	1.50	1.45	36	56	8
24	1.33	1.00	—	1.14	43	57	—
25	1.18	1.22	1.70	1.29	58	40	2
26	1.84	1.42	1.71	1.57	49	51	—
27	1.18	1.46	1.00	1.34	63	34	3
28	1.16	1.20	1.85	1.44	17	82	1
29	1.00	1.50	1.00	1.28	17	83	—
30	1.14	1.30	1.67	1.35	6	94	—
31	1.00	1.13	2.35	1.77	45	50	5
32	1.25	1.11	1.56	1.31	6	92	2
33	1.26	1.14	1.86	1.35	22	78	—
34	1.21	1.19	1.74	1.34	47	53	—
35	1.08	1.22	1.77	1.45	28	57	15
36	1.11	1.02	2.07	1.22	NA	NA	NA
37	1.13	1.50	2.44	1.76	NA	NA	NA
38	1.15	1.18	1.76	1.36	21	78	1
Avg.	1.17	1.22	1.69	1.39	27	69	4

[a] NA = not available.

TABLE C-26

AVERAGE CAR LOADING FACTORS, HOME INTERVIEW AUTO DRIVER TRIPS TO COLLEGES AND UNIVERSITIES BY CAMPUS POPULATION GROUP BY TRIP PURPOSE

CAMPUS POPULATION GROUP	TRIP PURPOSE TO: WORK	SCHOOL	OTHER	ALL
I	1.04	1.38	1.77	1.49
II	1.21	1.15	1.65	1.39
III	1.25	1.26	1.61	1.36
IV	1.14	1.18	1.76	1.36
V	1.16	1.24	1.69	1.38
Average	1.17	1.22	1.69	1.39

See also Table C-25.

all-purposes average of 1.39 persons per car includes work trips at 1.17, school trips at 1.22, and other trips at 1.69 persons per car. Although for individual institutions the all-purposes averages range from 1.12 to 1.77 persons per car, 22 institutions fall between 1.30 and 1.50 persons per car (see Table C-25). There was neither a systematic relationship between car loading and community size or community car ownership levels, nor an obvious trend when car loadings were ranked by trip survey year (1958 through 1964).

Other studies have shown that car loadings vary at different staff and student levels. The University of Washington report (*43*) shows that faculty and teaching assistant trips to school report loadings of 1.06 and 1.14 persons per car, respectively, as compared to 1.24 persons per car for nonacademic staff trips. Trips to school by freshmen average 1.67, by sophomores 1.45, by juniors 1.40, and by seniors 1.16, as compared to 1.18 persons per car for graduate students. These relationships cannot be confirmed with transportation study data, but comparable variations should exist.

Highway Design Factors

In highway design work it is customary to project a design-hour volume (DHV) and from it to determine the capacity required to accommodate that volume at some stated level of service. The DHV is the product of a projected annual average daily traffic, a two-way peak-hour percentage, and a directional tendency percentage (proportion of vehicles moving in the dominant direction of flow), weighted finally to account for the number of trucks moving in the dominant direction (*46*). In effect, Table C-27 provides typical values for the last three factors; although they would probably not be applied to any specific design, still they provide useful perspective.

Table C-27 shows, for example, that passenger car units (passenger cars, plus taxis, plus light trucks) account for 95 to 98% of daily traffic regardless of campus size. Although medium and heavy trucks account for 2 to 5% of the daily traffic, they represent only 1 to 3% of the peak-hour traffic. Total peak-hour traffic decreases somewhat with campus size (the table does not represent a "standard" peak hour, such as 5 to 6 PM, but aggregates data for whatever hour of the day was greatest at each individual institution). Peak-hour traffic at the smallest campuses averages 16.8%; at the largest, 10.2%. During the peak hour, the typical traffic flow would be unbalanced: for all campuses combined, an average of 78% of the traffic would move in the dominant direction while 22% would move in the opposite direction. The dominant direction for 26 of the 38 institutions is, in fact, toward the institution, indicating a morning peak hour (see Table C-28).

TRIP GENERATION

As used here, "trip generation" means the estimation of total tripmaking to an entire college or university—ultimately, the estimation of total vehicular tripmaking that determines highway and transit needs. This is a formidable task because daily tripmaking is so highly variable. Trips to and from the cross-section institutions range from 1,000 to 87,000 daily person trips; from 500 to 57,000 daily vehicle trips. The higher figures far surpass total trip generation at any of the other land uses examined in this project.

The uniqueness of colleges and universities makes the task more difficult. Each campus may have its own special attractions. Total tripmaking necessarily involves different types of trips to different parts of the campus, much like the variety of trips to a central business district with diverse attractions for various tripmakers. In fact, large universities may be considered cities in themselves (*47*):

> The university campus today with its dormitories, residential areas, classroom and office buildings, recreational areas, stadiums, auditoriums, hospitals, and small retail areas, is a virtual city. Like cities, the campus has parking lots, a road network and traffic signals, and traffic and parking problems that may often be complex.

Land Area and Floor Space Relationships

Institutional building designs and campus layouts vary. Sprawling campuses and scattered low-rise buildings contrast sharply with smaller campuses and centralized high-rise buildings. In the present cross section, campus size ranges from 9 acres (about two city blocks) to 1,136 acres (or about 2 square miles). Building designs are of many types, both low-rise and high-rise, and ground area ratios are accordingly diverse.

Such diversity makes land area trip generation rates highly variable. For the sample institutions rates range from 5 to 332 person trips per acre, and from 3 to 135 auto driver trips per acre. Table C-29 gives the average trip rates and the range of rates when data are aggregated by campus population group. In general, rates increase with increasing campus population, but all campus population groups have both very high and very low rates. Simple correlations between campus size (site acreage) and 14 different trip variables used in the multiple regression analysis ranged

TABLE C-27

COMPOSITION OF TRAFFIC TO AND FROM SELECTED COLLEGES AND UNIVERSITIES

CAMPUS POPULATION GROUP	DAILY TRAFFIC TO AND FROM: PASS. CARS	TAXIS	LIGHT TRUCKS [a]	OTHER TRUCKS [b]	PEAK-HOUR TRAFFIC TO AND FROM: PERCENT OF DAILY TRAFFIC	PERCENT TRUCKS [b]	DOMINANT DIRECTION
I	93.4	0.3	3.3	3.0	16.8	3.1	77
II	94.1	0.4	0.9	4.6	13.4	0.2	77
III	93.8	1.6	0.7	3.9	15.0	2.0	85
IV	97.2	0.3	0.5	2.0	11.6	1.3	85
V	93.1	0.5	3.0	3.4	10.2	0.8	68
Average	94.9	0.6	1.5	3.0	11.7	1.3	78

[a] Light trucks have four tires only. [b] Other trucks and peak-hour trucks have six or more tires (see also Table C-28).

TABLE C-28

PEAK PERCENTAGE AND DIRECTIONAL TENDENCY OF TRIPS TO AND FROM SELECTED UNIVERSITITES, ALL SURVEYS

	DAILY TRAFFIC TO AND FROM			PEAK-HOUR TRAFFIC TO AND FROM		
UNIV.	PASSENGER CAR UNITS PLUS TRUCKS [a]	TRUCKS (%)	PEAK HOUR	% OF DAILY TRAFFIC	TRUCKS IN DOMINANT DIRECTION (%)	TOTAL TRAFFIC IN DOMINANT DIRECTION (%)
1	59535	0.8	4-5 PM	9.7	0.5	52
2 [b]	9680	3.0	8-9 AM	12.3	0.4	95 [c]
3 [b]	479	8.6	7-8 AM	22.3	—	63 [c]
4 [b]	2695	1.2	8-9 AM	12.0	—	98 [c]
5	2758	4.4	8-9 AM	28.0	2.7	82 [c]
6	7719	3.3	8-9 AM	13.0	1.3	87 [c]
7	17151	2.5	5-6 PM	11.9	1.5	75
8	1313	2.7	8-9 AM	20.4	4.8	77 [c]
9	2576	—	4-5 PM	10.4	—	51 [c]
10	5453	3.0	4-5 PM	10.5	—	55
11	22370	3.1	4-5 PM	12.7	1.2	76
12	12054	0.3	8-9 AM	12.8	—	90 [c]
13	27079	0.5	8-9 AM	10.0	0.8	83 [c]
14	5468	3.9	5-6 PM	11.2	—	82
15	24745	3.6	8-9 AM	14.9	—	87 [c]
16	2406	1.7	3-4 PM	11.8	5.0	63
17	2721	4.9	8-9 AM	20.0	—	82 [c]
18	20708	1.5	8-9 AM	11.3	0.1	74 [c]
19	627	3.0	8-9 AM	13.2	0.2	76 [c]
20	710	2.4	8-9 AM	15.9	—	75 [c]
21	1101	0.7	4-5 PM	14.4	—	61
22	13097	1.4	8-9 AM	10.7	0.9	75 [c]
23	1147	—	3-4 PM	13.2	—	71
24	302	8.6	2-3 PM	28.8	—	97
25	13580	0.7	7-8 AM	13.1	—	100 [c]
26	5976	0.6	8-9 AM	14.8	—	91 [c]
27	2278	4.0	8-9 AM	20.2	5.0	100 [c]
28	21867	2.2	7-8 AM	12.5	2.9	89 [c]
29	541	—	7-8 AM	15.5	—	85 [c]
30	22499	0.2	8-9 AM	12.0	—	88 [c]
31	1094	—	3-4 PM	17.8	—	63
32	1487	—	7-8 AM	15.7	—	79 [c]
33	2305	—	8-9 AM	13.7	—	79 [c]
34	2444	—	8-9 AM	13.5	—	84 [c]
35	23058	0.2	8-9 AM	10.6	1.0	83 [c]
36	1847	2.3	12-1 PM	11.6	—	93
37	1007	1.4	7-8 PM	22.8	3.6	86 [c]
38	6914	3.1	8-9 AM	16.9	3.5	82 [c]

[a] Passenger car units include taxis and all trucks with only four tires; trucks include all vehicles with six or more tires.
[b] External trips not available.
[c] Dominant direction is to the university.

TABLE C-29

TRIPS TO COLLEGES AND UNIVERSITIES PER ACRE OF GROSS SITE AREA BY CAMPUS POPULATION GROUP

	TOTAL PERSON TRIPS PER ACRE		TOTAL AUTO DRIVER TRIPS PER ACRE	
CAMPUS POPULATION GROUP	AVERAGE RATE	RANGE OF RATES	AVERAGE RATE	RANGE OF RATES
I	11.9	5.2- 42.9	6.6	3.0- 23.7
II	21.7	8.4-214.3	13.5	6.0-134.6
III	22.3	7.0-331.8	12.1	3.5-112.4
IV	53.7	23.0-127.0	36.4	16.4- 92.7
V	55.3	26.1-137.9	33.3	18.0- 83.6

from $r = 0.19$ to $r = 0.66$, making land area alone seem a dubious indicator of tripmaking.

Floor space relationships have not been studied, because floor space data were almost totally unobtainable on a building-to-building basis. Even if they had been, transportation study trip data could not have been sorted down to a matching basis. Variations in types of space available and in space utilization among the cross-section institutions would perhaps have made comparisons difficult, in any case. The *College and University Facilities Survey* (*32*) notes that "one institution may consider itself overcrowded if it has 125 gross square feet of instructional space per student, whereas another would be glad to achieve that figure."

TABLE C-30

TOTAL PERSON TRIPS PER CAPITA (CAMPUS POPULATION) BY CAMPUS POPULATION GROUP BY COMMUNITY SIZE

CAMPUS POPULATION GROUP	COMMUNITY SIZE A	B	C	D	AVG.
I	0.80	0.98	—	—	0.89
II	0.36	0.50	0.77	0.82	0.61
III	1.34	0.52	0.71	0.67	0.81
IV	1.38	1.09	0.78	0.76	1.00
V	1.05	—	—	0.54	0.79
Average	0.99	0.77	0.75	0.70	0.82

Campus Population Relationships

PERSON TRIPMAKING

Logic would indicate that tripmaking should be more directly related to such key indicators as student enrollment and faculty and staff employment. As a starting point, the relationship of total person trips with total campus population was examined, with the results shown in Figure C-14. Trips increase linearly with campus population, with a high degree of association ($r = 0.91$).* However, the standard deviation compared to the tripmaking mean was very high: $S_{yx}/\overline{Y} = 52\%$ (see Table C-20 for further statistical details of each relationship described in the following paragraphs).

Table C-30 shows that total person trips per campus capita tend to decrease with community size, but seem to have no systematic relationship to campus size. The average trip rate of 0.82 trips per capita compares with rates published elsewhere: the *Traffic Engineering Handbook* (*48*), for example, citing rates derived by the San Diego Metropolitan Area Transportation Study, lists 0.7 trip (presumably person trips) per student for colleges without dormitories; *Access and Parking at Institutions* (*49*) gives a range from 0.23 to 0.59 auto trip per student per day.

Some improvement in trip predictability results from considering trips by trip purpose. Figure C-15 shows that total person trips to work increase linearly with total faculty and staff. The correlation is $r = 0.92$, but the $S_{yx}/\overline{Y}$ is 48%, still quite high. Using "first" work trips only, instead of total work trips, did not significantly improve the correlations, because the ratio of first work trips to total work trips was fairly constant at all institutions (Table C-31).

Table C-31 shows that the average for all institutions is 1.11 trips to work per faculty/staff. Group averages show that trip rates decrease regularly with increasing campus size. The lower rates may be the result of more part-time faculty members at large universities and faculty having more outside interests (such as attending off-campus meetings and conferences, and making out-of-town trips) and therefore making fewer trips to work on-campus; the higher rates may simply be the result of faculty at smaller colleges going home for lunch, the return trips counting as "second" work trips, in effect. Group averages show the "first" work trip rates also decrease with increasing campus size, however, and this is more certain confirmation that faculty at large universities do not work on-campus every day.

School trips have about the same predictability as work trips. Figure C-16 shows that total person trips to school increase linearly with total student enrollment. The correlation is $r = 0.92$, and the $S_{yx}/\overline{Y}$ is 45%. A plot of total person trips to school against total nonresident student enrollment showed greater scatter, as did a similar plot against total resident student enrollment.

Table C-31 shows that the average for all institutions was

* Appendix A shows that home interview surveys were taken exclusively during summer months by one transportation study, and partly during one or more summer months by ten others. Trip generation analyses generally exclude trip data from the former (representing two universities) but not from the latter. Most of the regression work, therefore, represents $N = 36$ cases instead of $N = 38$.

TABLE C-31

PERSON TRIP RATES BY CAMPUS POPULATION GROUP BY TRIP PURPOSE TO

CAMPUS POPULATION GROUP	WORK TRIPS PER FACULTY/STAFF	FIRST WORK TRIPS PER FACULTY/STAFF	SCHOOL TRIPS PER STUDENT	SCHOOL TRIPS PER NONRESIDENT STUDENT	OTHER TRIPS PER STUDENT
I	1.52	1.09	0.41	1.04	0.34
II	1.30	0.78	0.39	0.64	0.50
III	1.06	0.77	0.42	0.88	0.36
IV	0.98	0.69	0.48	0.66	0.50
V	0.71	0.54	0.36	0.59	0.44
Average	1.11	0.77	0.41	0.76	0.43

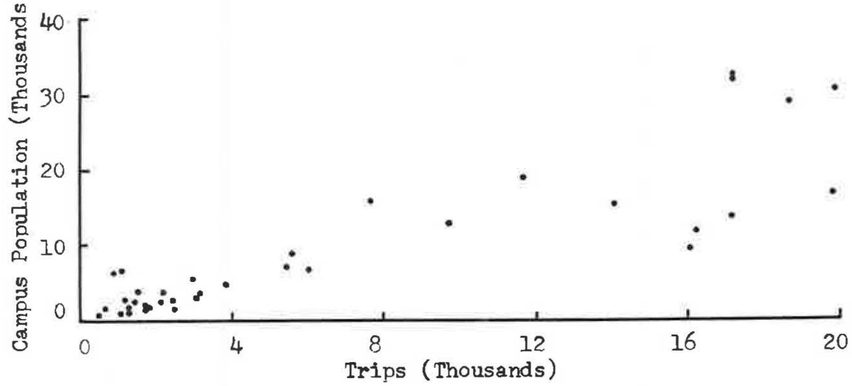

Figure C-14. Total person trips to universities related to total campus population.

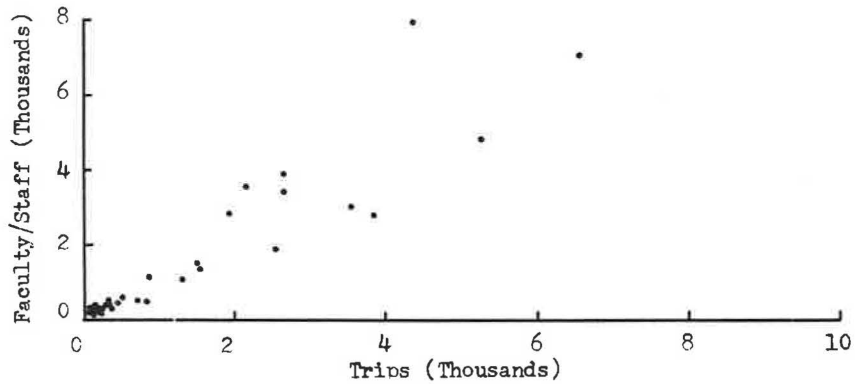

Figure C-15. Person trips to work at universities related to total faculty/staff.

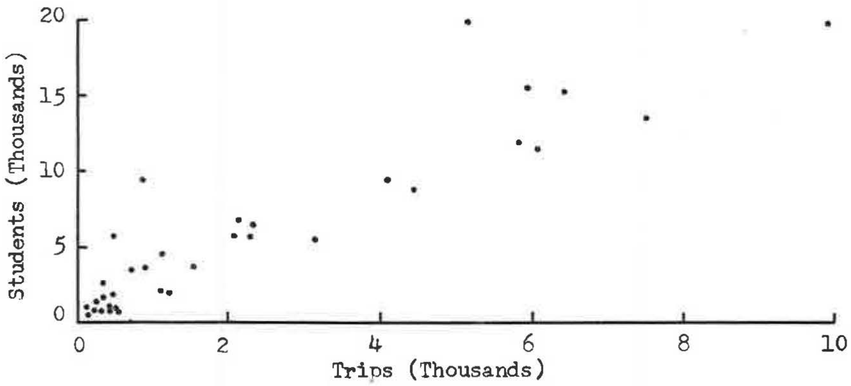

Figure C-16. Person trips to school at universities related to total students.

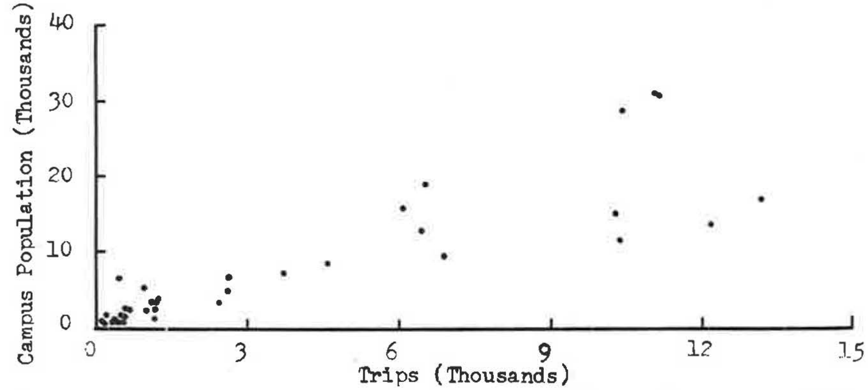

Figure C-17. Total auto driver trips to universities related to total campus population.

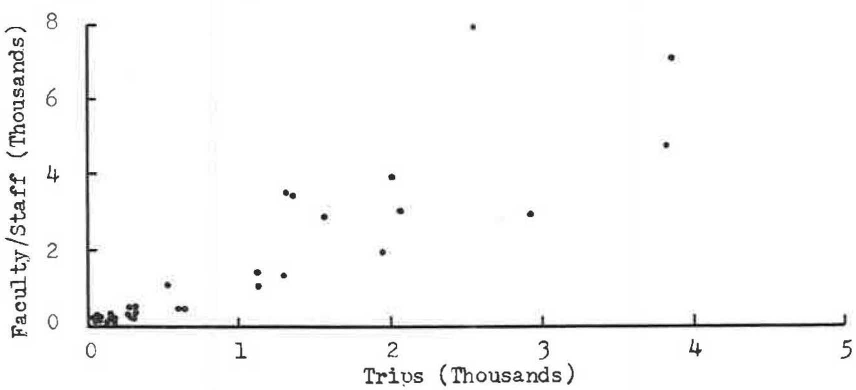

Figure C-18. Auto driver trips to work at universities related to total faculty/staff.

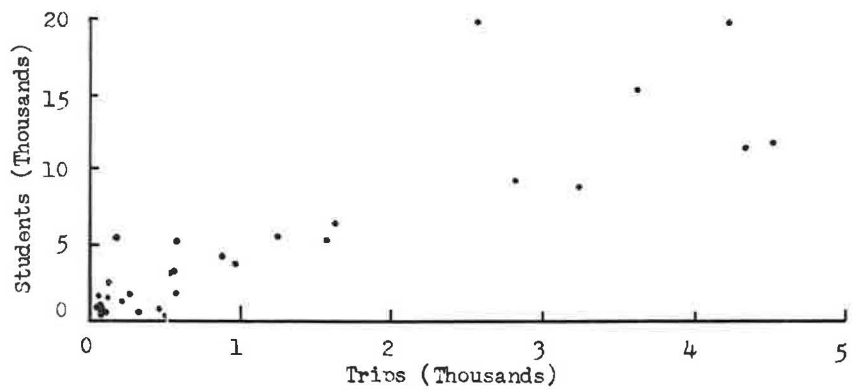

Figure C-19. Auto driver trips to school at universities related to total students.

0.41 trip to school per student enrollment. Group averages show no significant variation by campus size. Although tripmaking by graduate versus undergraduate students cannot be distinguished in the trip data, person trips to school per student for the 15 institutions having more than the mean percentage of graduate students (12% of the student body) average 0.43 trips per day, and for the 23 institutions having less than the mean, 0.36 trips per day. Whether the difference is mostly attributable to graduate student differentials, or merely reflects other factors—such as the fact that schools with low graduate student proportions are generally smaller, and have fewer part-time students and a higher proportion of resident students—cannot be precisely stated.

The remaining trip purpose groups are each rather small and difficult to predict. Home trips are perhaps the most erratic; although they relate to the resident student percentage, there is no assurance that any given resident student need leave campus on any given day (his return to campus representing a "home" trip). But social-recreation, eat meal, personal business, and the remaining purpose components of "other" trips are also erratic due to differences in the kind of public facilities and student extra-curricular activities on campus. The best approach was to treat these miscellaneous purposes as a group, excluding home trips. The correlation with total campus population was $r = 0.91$, but even so the $S_{yx}/\overline{Y}$ was 52%, and had not eight exceptional cases been dropped the results would have been much worse. The correlation with total student enrollments was no better. However, Table C-31 shows that about 0.4 to 0.5 "other" person trips per student, including home trips, is fairly typical, regardless of campus size, and this range might provide acceptable estimates.

Throughout the trip generation work just described, various average trip rates were computed after stratifying institutions by their percentage of part-time students, or their percentage of resident students, or by the size of community in which they were located. Some results suggested that further work would be rewarding, and some did not. Person trips per campus capita were found to decrease with an increase in the percentage of part-time students, but to increase with an increase in the percentage of resident students (Table C-32). It was felt, however, that with so many factors simultaneously involved, average trip rates for various stratifications would be less meaningful than the results of the multiple regression work described subsequently.

AUTO DRIVER TRIPMAKING

Relationships between auto driver trips and campus enrollment or employment are generally less consistent than are similar relationships involving person trips. Differences in the availability of transit and parking, and the regulations affecting student auto use, would be expected to increase the variability. Figures C-17, C-18, and C-19 show selected relationships. Total auto driver trips and total campus population correlate at $r = 0.90$ and $S_{yx}/\overline{Y}$ is 54%; auto driver trips to work and total faculty/staff correlate at $r = 0.92$ and $S_{yx}/\overline{Y}$ is 52%; auto driver trips to school and total student enrollment correlate at $r = 0.89$ and $S_{yx}/\overline{Y}$ is 53%. In other words, the relationships are evident, but the high standard deviations make predictions hazardous.

Table C-33 shows that total auto driver trip rates per campus capita vary both with campus and community size, but that group averages show little systematic variation. Total auto driver trip rates for individual institutions range from 0.19 to more than 2.00 trips per capita per day; auto driver trips to work per faculty/staff range from 0.24 to 1.17 trips per capita per day; auto driver trips to school per student enrollment varied from 0.12 to 0.42 trips per capita per day; and "other" auto driver trips were also highly variable.

Multiple Regression Analysis

In the sense that correlations are high, many of the foregoing relationships are quite strong. In predictive work, however, it is equally important that standard errors be kept low. So far, they have been too high. Thus, it can be said that trip generation at colleges and universities cannot be very reliably predicted from single measures such as enrollment, or faculty and staff size. Multiple regression, which can account for the effects of many variables simultaneously, was employed primarily to improve the reliability of prediction by reducing standard errors, rather than to demonstrate further the degree of association among variables.

Testing involved up to 13 independent variables to predict each of 14 dependent variables. Dependent variables represented various stratifications of tripmaking; indepen-

TABLE C-32

TOTAL PERSON TRIPS PER STUDENT BY PERCENT RESIDENT STUDENTS BY TRIP PURPOSE TO

	TRIP PURPOSE				
PERCENT RESIDENT STUDENTS	TO SCHOOL	TO SOC.-RECR.	TO HOME	TO OTHER	ALL NONWORK
0-19	0.35	0.06	0.02	0.10	0.53
20-39	0.40	0.09	0.10	0.20	0.79
40-59	0.40	0.18	0.22	0.23	1.03
60 and over	0.49	0.08	0.45	0.26	1.28

TABLE C-33

TOTAL AUTO DRIVER TRIPS PER CAPITA (CAMPUS POPULATION) BY CAMPUS POPULATION GROUP BY COMMUNITY SIZE

CAMPUS POPULATION GROUP	COMMUNITY SIZE				
	A	B	C	D	AVG.
I	0.37	0.55	—	—	0.46
II	0.23	0.35	0.48	0.62	0.42
III	0.75	0.31	0.58	0.32	0.49
IV	0.90	0.79	0.50	0.40	0.65
V	0.52	—	—	0.33	0.43
Average	0.55	0.50	0.52	0.42	0.50

dent variables mainly described institutional characteristics such as enrollments, employment, site acreage, distance from the central business district, and number of parking spaces, and urban area characteristics such as total population per square mile, population density and average car ownership per dwelling unit. Data were obtained from transportation study sources, from questionnaires, and from *Catalogs* and *Bulletins*.

The results were encouraging in that standard errors of the estimate as percentages of dependent variable means ($S_E/\overline{Y}$) for the "best" regression equations for each dependent variable ranged from 4 to 33%—under 14% for 9 of the 14 dependent variables. This was much better reliability than afforded by the simple regression equations. Correlations also were improved: coefficients of determination (R^2) exceeded 0.98 in all but one case. The most significant independent variables differed somewhat, depending on which dependent variable was considered. In general, resident and nonresident student enrollment, faculty/staff employment, campus acreage, and number of parking spaces were consistently significant for all dependent variables. (Appendix G provides details. Using for a pattern the previous discussion of hospital multiple regression work, the reader may further evaluate Appendix G for himself).

TRIP DISTRIBUTION

Trip rate curves describe the distribution of trip origins at various distances or travel times from the university or college. Rates are expressed as trips per 1,000 population. Based on home interview trips only, rates are calculated to a distance of 10 miles or a travel time of 20 min by 1-mile and 2-min increments, respectively (see footnote under "Trip Distribution," Appendix B). Problems of directional distribution also are discussed following.

Distance Rates

Auto driver and total person trips per 1,000 population by trip purpose by distance are shown in Figure C-20. These are the weighted trip rate curves for 18 institutions of various sizes. As with the trip rate curves for hospitals, weighting tends to smooth them; curves for individual institutions can be erratic, due generally to small trip samples on mile-ring or 2-min increment bases.

Trip rates for all purposes decrease with increasing distance. Of the purposes shown, work trips produce a relatively low trip rate at the 1-mile radius, and thereafter the least decrease with increasing distance. School trips produce a relatively high trip rate within the 1-mile radius; drop to a much reduced rate at about the 3-mile radius; then level off, with only a gradual decrease to the 10-mile radius. Trips for "other" purposes display a pattern similar to school trips, but with a more sustained decrease between the 3-mile and the 10-mile radius. From these curves it would appear that many students, faculty and staff may live almost anywhere in the urban area. The inference is that universities and colleges are often important regional activities that attract many trips which are relatively insensitive to travel distance.

Time Rates

Auto driver and total person trips per 1,000 population by trip purpose by travel time are shown in Figure C-21 (weighted trip rate curves for 14 institutions). As expected, trip rates decrease with increasing travel time; but, again, beyond what might be considered the institutional community and its contiguous student housing areas, the trip rates decline rather slowly.

Directional Distribution

The directional distribution of trip origins in the immediate surroundings of a university will be uniquely determined by the arrangement of land uses surrounding it. Student housing and student commercial areas are the closest and most influential of these. At McMaster University, for example, it was found that 85% of the undergraduates from out of town lived within 1 mile of the campus (*38*). Proximity not only permits the ease of walking to school, but also provides more convenience—whatever the travel mode—for students making more than one round trip to school each day.

Unlike many types of travel generators, universities and colleges may generate "repeat" automobile or transit trips by the same tripmaker at different times during the day. Although offices and other employment centers may generate repeat trips (for example, employees returning to work from lunch), as may shopping centers and other retail outlets (for example, by shoppers making second trips to buy something forgotten on the first trip), such trips are relatively uncommon, because they are wasteful of time and resources. By and large, most activity sites attract simple round trips.

By contrast, many university tripmakers are repeaters.* For one university with 7% resident students, about 15% of all home interview trips were made by repeaters; for

* Repeat tripmakers can be identified in the home interview survey data by reference to the household sample number (usually a 6- to 8-digit number), the person number, and the trip number. Because it is a rather tedious matching process, even with standard punch card equipment, only three universities were studied for purposes of illustration.

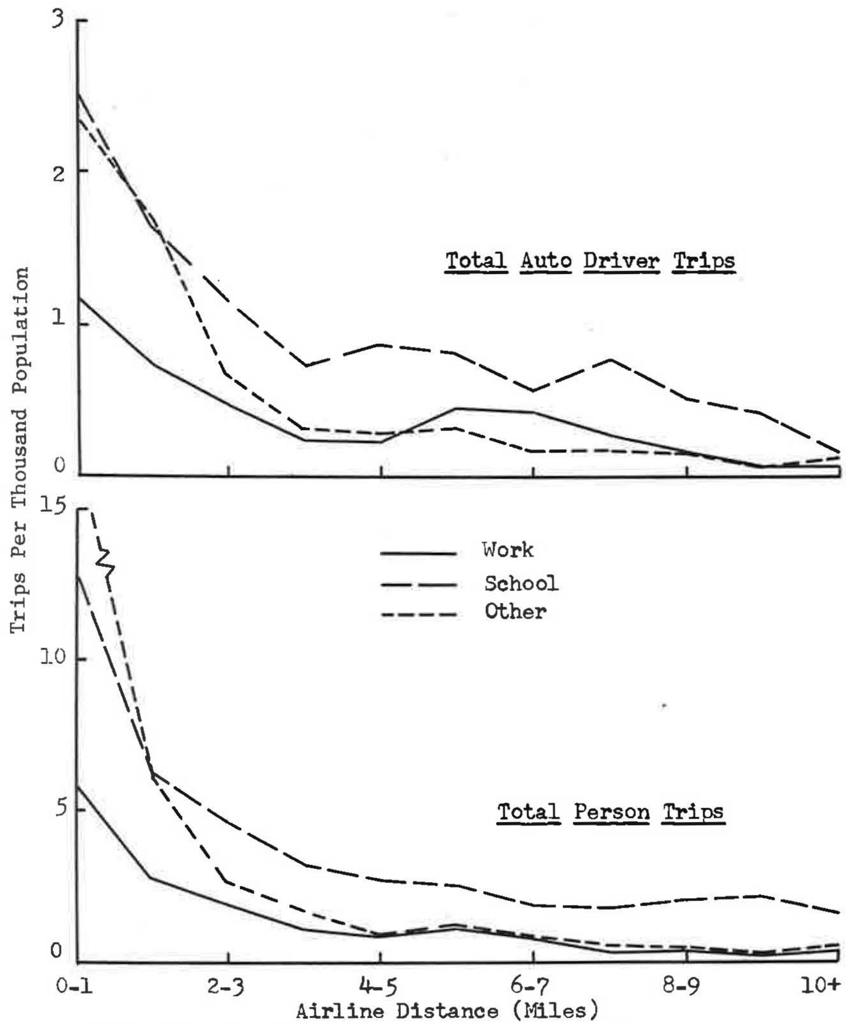

Figure C-20. Trip rates at universities, by distance and trip purpose, total auto driver trips.

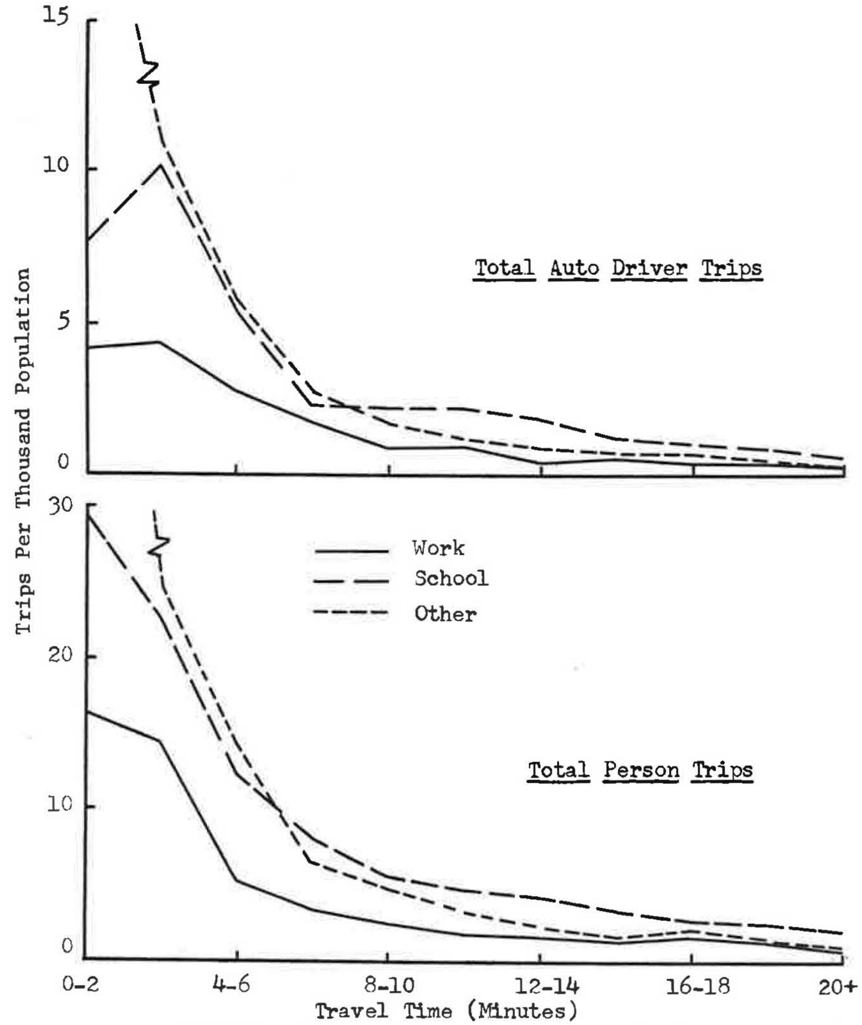

Figure C-21. Trip rates at universities, by travel time and trip purpose, total person trips.

another, with 10% residents, about 13% were by repeaters; for a third, with 34% resident students, about 4% were by repeaters. At McMaster University, with 22% resident undergraduate and 6% graduate students, surveys (*38*) show that 14% of the undergraduates made two or more round trips to the campus daily, whereas 28% of the staff and 49% of the faculty did so. Comparable findings have been reported elsewhere (*49*).

Common sense suggests that the higher the proportion of resident students, the lower will be the percentage of non-walking repeat trips. In any event, long repeat trips are unlikely, and for trip distribution purposes it might be assumed that most originate within a short radius of the university. It even seems possible that tripmaking between the campus and rented rooms or other off-campus lodgings, between classrooms and local restaurants or shops, might be the major determinant of highway loadings in the immediate vicinity of the institution. However, the different arrangements that exist suggest that the resulting directional distribution of short trips cannot be predicted on any simple probability basis.

The directional distribution for longer trips may, most simply, be based on the distribution of population. Table C-34 provides illustration: reading across for university number 25, for example, shows that sector 1 produces 18% of the trip origins and 20% of the population; sector 2 produces 19% of the trip origins and 26% of the population; and so forth. The worst example is university number 2, where the calculations did not account for racial concentrations within the general population distribution (the university was predominantly white, whereas much of the population in sector 2 was Negro, thereby producing a disproportionately low share of trips from sector 2).* Otherwise, differences between the percentages of population and trip origins by sector are generally well under 10%.

* In theory, of course, population-based trip rates would work best if throughout an urban area the "population" were homogeneous. That is, if there were comparable proportions of families by race, age, income, occupation, etc., in every neighborhood. Obviously, homogeneity seldom exists, and population based trip rates are simply an analytic convenience for making approximations of trip distribution.

Surprisingly, when only home-based trip origins are considered, instead of all trip origins, similar sector comparisons get worse rather than better. This is because the sectors containing the central business district zones and their surrounding "gray area" zones produce very few home-based university trips. With these sectors seeming to under-produce trips, the other sectors seem to over-produce trips. When all trips are considered, balance is restored by the higher levels of nonhome-based trips starting in the central business district zones.

Some discussion of tripmaking between university and CBD seems warranted: The over-all proportion is 5.7% of the person trips to and from the cross-section institutions. Averages by campus size groupings show the proportions decreasing from 6.8% at the smaller campuses to 3.8% at the larger campuses—presumably for such purposes as shopping or social-recreation the latter are more self-sufficient.† Depending on comparative campus and community sizes, and the proximity of the CBD, however, the proportions at individual institutions range from nil to nearly 20%.

The CBD-university trip interchange sometimes represents the largest single area-to-area travel volumes generated by the university (*52*). The interchange between the University of Washington and downtown Seattle, for example, is sufficient to warrant the consultant's recommendation of new bus service, on a trial basis, to serve that demand (*43*). The point here is simply that for trip distribution purposes the CBD will often require special consideration.

Special care might also be taken with intra-campus trips. Although technically they count as both trips to and trips from the campus, they do not as such appear on the off-campus highway system, and thus do not directly figure in the trip distribution problem as it is discussed here. Of

† Not all CBD-university trips are made by students, of course. Many are made by faculty and staff, as well as by visitors. The number of visitors at a major campus can be astonishing; the University of Wisconsin, for example, reputedly "draws more than one million visitors to Madison annually." (*51*).

TABLE C-34

COMPARISON OF PERCENTAGES OF POPULATION AND UNIVERSITY TOTAL PERSON TRIP ORIGINS, BY STUDY AREA SECTOR [a]

	SECTOR 1		SECTOR 2		SECTOR 3		SECTOR 4	
UNIVERSITY	POP.	TRIPS	POP.	TRIPS	POP.	TRIPS	POP.	TRIPS
2 [b]	36	67	64	33	—	—	—	—
15	38	33	44	54	18	13	—	—
25	20	18	26	19	32	40	22	23
26	20	14	26	23	32	45	22	18
27	20	16	26	32	32	32	22	20
30 [b]	53	58	47	42	—	—	—	—
35 [b]	21	26	31	38	29	21	19	15

[a] Study areas for universities 2 and 30 divided into two sectors only; for university 15, into three sectors only. Sectors do *not* correspond with study-designated sectors used for general analytic purposes.

[b] Sectors based on zones from 4 to 20 min travel time from universities; in remaining cases, sectors based on zones from 2 to 10 miles distant from universities.

course, most intra-campus trips are by pedestrians. However, for the cross-section institutions, some 4.3% of them are by auto drivers and auto or bus passengers. The percentage ranged up to 20.4% at one institution, and exceeded 10.0% at eight institutions.

Naturally the larger campuses tended to report the larger percentages of intra-campus trips. Campuses under 5,000 population averaged 2.6% intra-campus trips; campuses over 5,000 population average 6.1%. Six universities, which accounted for four-fifths of all reported intra-campus trips, were grouped to examine trip purpose and mode. After excluding trips by intra-campus bus at two institutions, where campus bus service accommodated 35 and 72% of intra-campus tripmaking, the modal distribution was: 68% auto drivers, 30% auto passengers, 2% taxi or public transit passengers. The trip purpose distribution was: 37% to home, 28% to school, 8% to work, and 27% to "other" purposes.

To summarize briefly, further work would seem to be required to predict the exact directional distribution of trips to any given college or university. Longer trips seem to be distributed in proportion to population; shorter trips seem to depend on the distribution of student housing and other student activity areas near the institution. For highway design and planning purposes, an approximation derived entirely from population distribution may be acceptable.

Accessibility Adjustments

Trip rates by travel time or distance would be more rational if tripmakers in every neighborhood had equal accessibility to all the potential trip destinations in the urban area. Where there are several travel generators of like type in the urban area, neighborhoods having a high accessibility index * may send fewer trips to any single generator than would neighborhoods at the same travel time from that generator but having a lower accessibility index. High accessibility neighborhoods simply have more choice of destinations.

Using for a test a major university in a large urban area having several other large universities, population-based trip rates for home-based work and home-based school trips were calculated and compared to weighted accessibility indices for work trips and school trips for four pairs of areas, each half of each pair incorporating all of the traffic zones falling into comparable, successive 4-min travel time increments on either side of the university. In seven out of the eight comparisons by trip purpose, it was found that the area with the higher trip rate had the lower accessibility index—generally confirming the hypothesis.

Furthermore, it was found that the average trip rates for both work trips and school trips for each 4-min travel time increment could be adjusted to reflect the trip rate differences by area associated with accessibility differences by area. That is, the average trip rates multiplied by the ratio of the average accessibility index for all areas within the travel time increment to the accessibility index for the particular area approximated the trip rates calculated for the particular area. Although work with larger samples should be a prerequisite to acceptance of such a direct association of accessibility indices and trip rates, there is little doubt that they explain part of the variability in home-based trip rates.

* The accessibility index is a computer-calculated number indicating the relative accessibility of any given traffic zone to the areawide destinations to which its trips may be sent. It is commonly derived for each of the trip purpose stratifications employed in trip distribution by the gravity model.

TRAVEL IMPACT ON HIGHWAY NETWORK

The impact of a university on the community highway system is plainly related to the size of both the university and the community. One of the cross-section universities attracted one-sixth of all the trip destinations in its urban area. In more typical cases, however, a university seldom accounts for more than 1% of the areawide trip destinations. Collectively, four institutions in Minneapolis-St. Paul generated 1.2% of the urban area daily travel, whereas three institutions in Atlanta and three more in Pittsburgh each generated less than 1.0%, respectively.

Nevertheless, the impact can be severe at the local level. Many of the cross-section institutions generate more than 2,000 vehicle trips in both morning and evening peak hours—enough to require more than three lanes of signalized arterial street capacity. Even assuming equal distribution on four approaches, the peak-hour volume on any one approach could require the exclusive use of one traffic lane.

Institutional location seems especially important, because it can determine the directional orientation of traffic. Trips to a suburban campus have the advantage, often, of running counter to the prevailing peak-hour flow—against or across the downtown movement instead of with it. This is shown in Figure C-22, which depicts the unweighted desire lines of trips to work and to school at two Buffalo institutions. Each campus draws trips from all over the urban region, and each draws trips from what might be called the market area of the "trip-shed" of the other. However, the desire lines to the institution nearer the lakefront reinforce those centering on the CBD; in the other case they do not. Other things being equal, the institution farthest from the CBD should create the lesser problems for other, through traffic, and for its own traffic as well.

General measures of highway impact cannot be established. The university traffic problem, as it relates to off-campus access highways, must be examined in light of the particular campus and its servicing highways. Obviously, smaller institutions with relatively few peak-hour trips may create no particular problem. But larger institutions, particularly if they are located in communities with inadequate street systems, or are near central business districts with existing capacity problems, may create an urgent need for special studies and remedial traffic improvements.

The executive vice-president of a large southern university privately described its problem to the researchers this way:

> We would say that our problem with automobiles lies mainly in the area of emotion and public relations. Complaints from our own people are frequent and often violent, condemning the lack of convenient parking space. Complaints from the adjacent residents are equally so, generated of course by the fact that our people—unable

to find campus parking—tend to block driveways and access roads in residential streets. The fact that our next door neighbor, ________ University, has even less on-campus parking than we do, tends to keep the emotional and public relations pot boiling in the usual town-and-gown controversy.

PREDICTING AND TESTING RELATIONSHIPS

This appendix has suggested relationships, first between traffic generation and university characteristics, and second, between trip-end distribution and urban area population characteristics. It is one thing to demonstrate that such relationships exist, and to suggest that they may have value as predictive devices. It is another to demonstrate such values. The latter can be done most effectively by applying the relationships in new situations, to institutions not in the sample from which the relationships were derived. Five colleges and universities in the Boston area were selected for this purpose.

Home interview survey trips to the five institutions provided the yardstick against which the trip generation equations were compared (see Appendix G). Trip volumes were predicted by both simple and multiple regression equations for four categories of university tripmaking. Despite the greater descriptive power of the multiple regression technique, the single independent variables of total campus population or faculty-plus-staff employment generally provide better results. The large standard errors associated with both types of equations, however, limit the effectiveness of university trip generation estimates resulting therefrom. The test of trip distribution methods produced better results. Despite the implication that consideration of accessibility and income factors would improve results, the backcheck demonstrated that trip rate curves and population distribution are sufficient for estimating approach volumes by major routes.

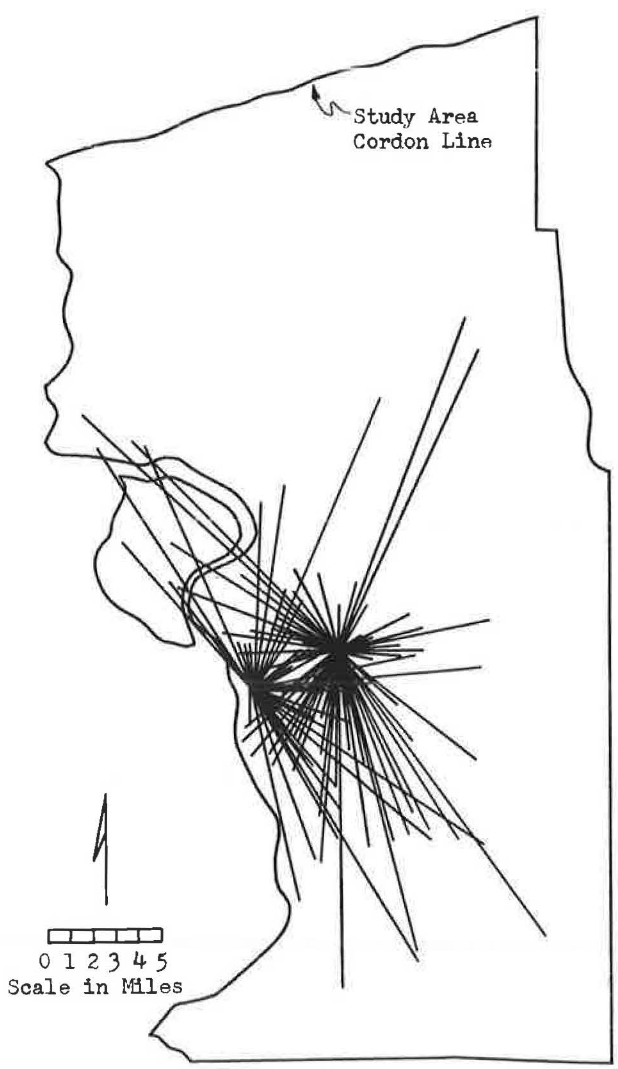

Figure C-22. Zonal interchange desire lines (unweighted by trip volumes) to two universities in the Buffalo urban area, summer weekday, 1962.

TRENDS

Total student enrollment in institutions of higher learning approximately doubled between 1955 and 1964. During the same period, with the number of institutions increasing from about 1,850 to 2,050, the average enrollment per institution increased from about 1,870 students to 2,430 students. Spectacular examples of doubling and trebling enrollments at individual institutions could, of course, be cited, along with examples of stable or even declining enrollments. Although the ratio of faculty to students decreased slightly (from 0.107 to 0.095), it is likely that faculty plus supporting staff increased as fast as student enrollment.

Despite the slowly rising proportion of students enrolled in two-year colleges, almost three-fourths of all students attended four-year universities (42%) or four-year liberal arts colleges (28%). Enrollment at public institutions accounted for an increasing share of total enrollment: 56% in 1955 compared to 64% in 1964. Perhaps this shift occurred because public institutions can better meet the capital costs of rapid expansion—expenditures for physical plant increased from $0.7 billion for all institutions in 1956 to $1.6 billion in 1962, while total expenditures increased from $3.5 billion to $7.2 billion.

Physical expansion is beset by many problems. Existing, centrally located institutions have great difficulty in acquiring additional space. Because of the rising cost of real estate, urban colleges and universities have been turning more and more to the use of high-rise structures and air-space over roads, rivers, or railroad tracks. The proposed campus for New York City's Bronx Community College, for example, is designed to use airspace over a subway yard (*53*). In other instances, sublevel space will be utilized: Brooklyn College has announced a construction program that includes an underground floor area of about 154,000 sq ft (*54*).

By and large, however, it would appear that most new campuses will be located in the suburbs, or in other outlying areas where the assembly of large tracts of land would not be prohibitively expensive. The State University of

New York at Buffalo, after thorough study of site alternatives in Buffalo, has decided upon expansion in the Buffalo suburb of Amherst, declaring that anything less than Amherst's nearly 900 acres was too "limiting" (*55*).

The implication for transportation planners is that most of the nonwalking, nonbicycle travel to suburban colleges and universities will be by automobile. This poses a dilemma. What can be done to accommodate rapidly increasing vehicular travel to and from campuses, without at the same time permitting vehicular entry into the campus in numbers that can destroy the traditional tranquility that most educators want to preserve?

The magnitude of the problem is great. Consider expectations for the University of Arizona (*56*): the Tucson Area Transportation Study, in citing the predicted increase from about 13,000 vehicle destinations in 1960 to about 40,000 vehicle destinations in 1980, has declared that "No single facility in the Study Area (expected population: 680,000) was predicted to equal the 40,000 trip destinations estimated for this 28-acre institution. To place the university in proper perspective, consider that the entire range of land uses within the central business district was expected to generate approximately the same volume of trip destinations."

There are no "solutions" to be found here. The transportation study data serve only to provide dimensions and to suggest directions of change. But in looking ahead, it is perfectly clear that campus planners must become increasingly cognizant of transportation needs both on and off the campus, and must consider especially the university's impact on the community's highway system.

CONCLUSION

Trips to and from the 38 cross-section institutions range from 1,000 to 87,000 daily person trips; from 500 to 57,000 daily vehicle trips. The higher figures far surpass total trip generation at any of the other land uses examined in this project. Major universities are virtually cities in themselves.

The kind and amount of travel attracted is more variable than might be expected on the basis of size alone. Each campus tends to be unique in terms of its proportion of resident students, its acreage and building layout, its regulations on student car use, its faculty-to-student ratio, and so forth through a long list of campus characteristics.

As a result, travel modes, trip purposes, and other travel characteristics are highly variable. Averages for the cross-section institutions show, however, that travel is highly auto-oriented. About 90% of all nonwalking trips are by auto drivers or passengers. Less than 10% are by transit passengers. Taxi use is practically nil.

Averages also show that about 40% of all nonwalking trips are to school, about 21% to work, about 10% to social-recreation, about 13% to home, and the remainder to a mixture of other purposes. Institutions with relatively few resident students report fewer home trips, of course, and therefore higher proportions of school and other trips.

Trip generation cannot satisfactorily be predicted from any single variable. Although work trips are highly associated with the number of faculty and staff, and school trips with the number of students enrolled, standard deviations are relatively high. Multiple regression equations were developed that reduce the standard error of estimate, but there is still much unexplained variation in trip generation at individual institutions.

Further work would seem to be required to predict the exact directional distribution of trips. Special problems include determining the proportion of intracampus trips, the number and origins of repeat tripmakers, and the magnitude of the university-CBD trip interchange. However, longer trips seem to be distributed in proportion to population, and for highway design and planning purposes an approximation derived entirely from population distribution may be acceptable.

University travel impact on the community highway network is plainly related to the size of both the university and the community. Small institutions may pose no difficulty. But large institutions, depending on their location and on the adequacy of the adjacent highway network, may create critical capacity problems, not only for campus-bound traffic but also for all traffic. Although providing for campus parking may be the prime concern of many university officials, it is but part of the larger transportation impact problem.

APPENDIX D

STATE CAPITOL COMPLEXES

Employment in state governments increased from about 1.2 million in 1955 to about 1.9 million in 1964, a gain of 56%. Although state capitol complexes account for only a minority of that employment, many have become crowded to overflowing. As a result, state government offices are often scattered throughout the capital city in what must be a costly and inefficient disorder.

Master plans generally call for replacing these separate, isolated offices with one totally integrated structure or complex of structures (*57*). Inasmuch as capitol buildings tend to project an image of the state, such plans spare nothing in the attempt to combine both beauty and function. Considerable effort is directed toward meeting the expanded transportation requirements resulting from consolidation.

The present study may help to assess the traffic demand not only at planned, but also at existing complexes. Travel to and from six complexes (hereafter, for convenience, simply called capitols) has been analyzed.* Except for walking trips other than to work, tripmaking by all travel modes for all purposes has been considered. Such tripmaking represents an average weekday, excluding Saturdays and Sundays, for the typical three- to six-month origin-and-destination survey.

GENERAL TRIP CHARACTERISTICS

Mode and Purpose of Person Travel

An average of 61% of all trips to the subject capitols are as auto drivers, 22% as auto passengers, 13% as transit passengers, 3% as walk-to-work, and 1% as taxi passengers (Table D-1). All told, about five out of six trips are by automobile. The travel mode distribution for trips from is basically the same as for trips to.

There are only two principal purposes for trips to capitols: to work and to personal business. The small remainder are either serve passenger or social-recreation trips (for convenience, the occasional trip for any other purpose has been counted as a social-recreation trip). About two-thirds of all trips are to work. Thus, the travel mode distributions for all trips (Table D-1) and for work trips (Table D-2) are much alike. Comparison shows only that there is more consistent transit use for work trips than for nonwork trips.

There are significant variations in the travel mode used for personal business trips (Table D-3). Auto driver trips range from 40% at Minnesota to 79% at Wisconsin; even excluding these extremes, auto passenger trips range from 11 to 30%; and transit passenger trips range from 3 to 40%. Some part of this variation results from the comparatively small number of trips represented in particular instances.

Almost all other trips are by automobile (Table D-4). Serve passenger trips consist exclusively of auto drivers picking up or dropping off passengers. Social-recreation trips, often involving visits by whole families, also generally require an automobile.

Taking all modes together, from 54 to 76% of all capitol trips are made by employees (Table D-5). Another 4 to 32% are made by other people for business purposes. Visitors for social-recreation made from 1 to 17% of all capitol trips. Drivers picking up or dropping off passengers made the remaining 7 to 15%. From the averages it is apparent that capitols are primarily centers of employment and government-oriented business activities, and not everyday tourist attractions.

On the average, about two-thirds of all trips from capitols have a trip purpose to home, 13% to work, 11% to shop or social-recreation, 5% to personal business, with the remaining 8% a mixture (Table D-6). Most of the trips to work are by drivers who have dropped a passenger at the capitol before continuing onwards to their own jobs; they are not capitol employees who are "moonlighting."

Factors Associated With Travel Mode

Each of the capitols is either in or near the central business district of its capital city, and has regularly available transit service. Although the quality of service would have some effect on the proportion of transit trips reported, quantification was not attempted for reasons previously expressed (Appendix C). Emphasis is placed, instead, on those tripmaker attributes which may most affect the demand for service.

Auto ownership would probably be a paramount factor bearing on the traveler's choice of travel mode: transit use is normally higher when an automobile is unavailable. Unfortunately, auto ownership is not recorded in the trip data for any of the subject capitols. Tripmaker occupation, sex, and race, however, are again useful indicators of travel mode choice.

Clerical-salesworker and laborer-service worker groups report the greater reliance on transit to get to work (Table D-7). About 20% of their trips are by transit, as against about 5% of the trips made by the professional-technical and craftsmen-operative groups. The last two groups report a high proportion of auto driver trips and a low proportion of auto passenger trips; the first two groups report the reverse tendency. Parenthetically, professional-technical occupations comprise 39% of the employment at the six capitols, on the average; clerical-salesworkers, 43%; and the craftsmen-operatives and laborers-service workers groups, 9% each.

Female tripmakers are twice as likely to be transit passengers as are male tripmakers (Table D-8), and three times as likely to be auto passengers. To some extent, this is a reflection of auto ownership: in one-auto families, the male head of household probably has first priority on driving. At each capitol the majority of tripmakers are male.

Of the capitols for which tripmaker race is available in the trip records, only Georgia reports any sizeable proportion of nonwhite travelers (one-sixth). It seems significant, however, that 65% of their trips are as transit passengers and only 27% as auto drivers. By contrast, white travelers make only 16% of their trips as transit passengers, and 62% as auto drivers. Race, of course, tends to reflect both income and auto ownership levels.

Truck and Taxi Travel

There were about 1,500 truck trips and 160 taxi trips to the six capitols. About 57% of the truck trips were by light trucks, 34% by medium trucks, and 9% by heavy trucks.

* In addition to the capitol building itself, they include: for Georgia, the State Office Building, the State Highways Building, and the Agriculture Building; for Indiana, the State Office Building; for Minnesota, the State Office Building and the State Highways Building; and for Rhode Island, the Roger Williams Building and the Veterans Memorial Building. For Utah, the new State Office Building was not completed until after the transportation study, hence is not included; for Wisconsin, the State Office Building is not included because located too far from the Capitol Building (all complexes as named occupy contiguous sites; although travel to the individual buildings within the complexes could have been examined, it is treated as though to a single building).

TABLE D-1

PERCENTAGE TRAVEL MODE DISTRIBUTION, HOME INTERVIEW PERSON TRIPS TO SELECTED CAPITOLS, ALL PURPOSES

	TRAVEL MODE					
CAPITOL	AUTO DRIVER	AUTO PASS.	TRANSIT PASS.	TAXI PASS.	WALK TO WORK	ALL
Georgia	55.0	18.8	22.8	—	3.4[a]	100.0
Indiana	59.0	19.8	17.7	—	3.5[a]	100.0
Minnesota	64.3	23.2	8.2	0.6	3.7[a]	100.0
Rhode Island	66.2	25.2	4.2	3.5	0.9	100.0
Utah	67.6	24.6	5.8	—	2.0	100.0
Wisconsin	57.2	22.9	7.9	2.2	9.8	100.0
Average	61.1	21.8	13.0	0.7	3.4	100.0

[a] Estimated at 5% of total work trips (see Table D-19).

TABLE D-2

PERCENTAGE TRAVEL MODE DISTRIBUTION, HOME INTERVIEW PERSON TRIPS TO SELECTED CAPITOLS, TO WORK

	TRAVEL MODE					
CAPITOL	AUTO DRIVER	AUTO PASS.	TRANSIT PASS.	TAXI PASS.	WALK TO WORK	ALL
Georgia	54.5	21.7	18.8	—	5.0[a]	100.0
Indiana	53.5	22.7	19.0	—	4.8[a]	100.0
Minnesota	68.0	18.4	8.0	0.7	4.9[a]	100.0
Rhode Island	61.7	23.4	7.4	6.1	1.4	100.0
Utah	67.2	18.0	9.1	—	5.7	100.0
Wisconsin	53.3	19.9	10.6	2.9	13.3	100.0
Average	59.4	20.9	13.6	1.1	5.0	100.0

[a] Estimated at 5% of total work trips.

TABLE D-3

PERCENTAGE TRAVEL MODE DISTRIBUTION, HOME INTERVIEW PERSON TRIPS TO SELECTED CAPITOLS, TO PERSONAL BUSINESS

	TRAVEL MODE				
CAPITOL	AUTO DRIVER	AUTO PASS.	TRANSIT PASS.	TAXI PASS.	ALL
Georgia	49.5	10.7	39.8	—	100.0
Indiana	49.4	18.6	32.0	—	100.0
Minnesota	40.0	47.3	12.7	—	100.0
Rhode Island	58.7	30.3	—	11.0	100.0
Utah	69.9	27.4	2.7	—	100.0
Wisconsin	100.0	—	—	—	100.0
Average	53.2	24.1	20.2	2.5	100.0

TABLE D-4

PERCENTAGE TRAVEL MODE DISTRIBUTION, HOME INTERVIEW PERSON TRIPS TO SELECTED CAPITOLS, TO SOCIAL-RECREATION AND TO SERVE PASSENGER

	TRAVEL MODE				
CAPITOL	AUTO DRIVER	AUTO PASS.	TRANSIT PASS.	TAXI PASS.	ALL
Georgia	78.2	21.8	—	—	100.0
Indiana	93.0	7.0	—	—	100.0
Minnesota	81.0	19.0	—	—	100.0
Rhode Island	84.4	15.6	—	—	100.0
Utah	63.2	35.2	1.6	—	100.0
Wisconsin	63.5	26.5	—	—	100.0
Average	77.3	22.3	0.4	—	100.0

TABLE D-5

PERCENTAGE PURPOSE DISTRIBUTION, HOME INTERVIEW PERSON TRIPS TO SELECTED CAPITOLS, ALL MODES

CAPITOL	TRIP PURPOSE TO WORK	PERSONAL BUSINESS	SOCIAL-RECREATION	SERVE PASSENGER	ALL
Georgia	66.3	26.0	0.5	7.2	100.0
Indiana	72.5	12.1	0.6	14.8	100.0
Minnesota	76.2	16.4	0.7	6.7	100.0
Rhode Island	54.0	31.5	7.5	7.0	100.0
Utah	54.3	16.4	17.2	12.1	100.0
Wisconsin	74.0	3.5	8.0	14.5	100.0
Average	66.8	18.8	4.3	10.1	100.0

TABLE D-6

PERCENTAGE PURPOSE DISTRIBUTION, HOME INTERVIEW PERSON TRIPS FROM SELECTED CAPITOLS, ALL MODES

CAPITOL	TRIP PURPOSE TO HOME	WORK	PERSONAL BUSINESS	SHOP OR SOCIAL-RECREATION	OTHER	ALL
Georgia	72.9	8.7	5.2	6.4	6.8	100.0
Indiana	61.4	13.2	4.7	11.4	9.3	100.0
Minnesota	61.5	12.1	8.5	8.5	9.4	100.0
Rhode Island	77.5	6.1	2.3	1.9	12.2	100.0
Utah	36.1	23.1	6.6	27.7	6.5	100.0
Wisconsin	68.7	17.8	—	9.2	4.3	100.0
Average	63.1	12.7	5.2	10.7	8.3	100.0

TABLE D-7

PERCENTAGE TRAVEL MODE DISTRIBUTION, HOME INTERVIEW PERSON TRIPS TO WORK AT SELECTED CAPITOLS, BY TRIPMAKER OCCUPATION

OCCUPATION OF TRIPMAKER	TRAVEL MODE[a] AUTO DRIVER	AUTO PASS.	TRANSIT PASS.	ALL
Professional and technical	81	13	6	100
Clerical and salesworkers	46	31	23	100
Craftsmen and operatives	86	10	4	100
Laborers and service workers	52	28	20	100

[a] Excluding walk-to-work trips and taxi passenger trips.

TABLE D-8

PERCENTAGE TRAVEL MODE DISTRIBUTION, HOME INTERVIEW PERSON TRIP TO SELECTED CAPITOLS, BY TRIPMAKER SEX

CAPITOL	TRAVEL MODE[a] AND SEX: AUTO DRIVER M	AUTO DRIVER F	AUTO PASS. M	AUTO PASS. F	TRANSIT PASS. M	TRANSIT PASS. F	ALL MODES M	ALL MODES F
Georgia	70	42	10	30	20	28	53	47
Indiana	75	44	11	32	14	24	55	45
Minnesota	87	38	12	56	1	6	69	31
Rhode Island	90	38	6	55	4	7	55	45
Utah	85	46	13	43	2	11	60	40
Wisconsin	75	43	18	43	7	14	66	34
Average	80	42	13	42	7	16	59	41

[a] Excluding walk-to-work trips and taxi passenger trips.

Many of the light truck trips were reported as for personal use, that is, a pickup or panel truck was used as a passenger car. This partially accounts for the somewhat surprising fact of more truck trips than taxi trips.

Ratios of truck and taxi trips to auto driver and total person trips are given in Table D-9. For predictive purposes, the person trip base provides somewhat more consistent ratios—on the average, about 8 truck trips and 1 taxi trip per 100 person trips. But the variation from capitol to capitol suggests that traffic counts would be desirable for design purposes.

Time Patterns

Travel to capitols probably varies somewhat by month of the year. Work and business-oriented trips would peak during months when the legislature was in session. Visitor trips would peak during the summer tourist season. Travel may also vary somewhat by day of the week. No satisfactory evidence was found on either score.

The reported travel data do show the travel variation by time of day (curves represent a typical weekday, excluding Saturdays and Sundays). Figure D-1 shows the composite total person trip patterns, all purposes, to and from each of the subject capitols. The sharp morning and evening peaks show how work trips predominate. Almost 60% of the daily trips arrive between 7 and 9 AM. Thereafter there is a fairly constant percentage of arrivals until office closing hours, with no hour exceeding 7% of the daily tripmaking. About 55% of the daily trips depart between 4 and 6PM. Only one other hour (2 to 3PM) has departures exceeding 5% of the daily tripmaking. Evenings reflect very sparse activity.

Figure D-2 shows the composite arrival and departure patterns for auto driver trips only. They differ but slightly from the total person trip patterns. The peaks are somewhat lower; in other words, offpeak travel is more apt to involve driver trips than passenger trips. Interestingly, the single morning peak for auto driver trips is 8 to 9 AM, whereas the single morning peak for all travel modes combined is 7 to 8 AM.

Figure D-3 shows the composite arrival and departure patterns for auto driver trips by trip purpose. Work trips occur when expected: the morning peak represents about 35% of the daily tripmaking; the evening peak, about 40%. Personal business trips take place throughout the working day, arriving somewhat later, and departing somewhat sooner, than work trips: morning tripmaking peaks at about 17%; afternoon tripmaking, at about 15%. "Other" trips, which will be recalled as mainly to serve passenger, have twin peaks both morning and afternoon, to drop off and pick up passengers. Each peak is around 23%. During the rest of the day, the "other" purpose curve largely depicts the arrival and departure of social-recreation trips.

Figure D-4 shows the composite arrival and departure for transit passenger. As with transit trips to and from the other land uses studied in this project, they are extremely peaked. About 63% of all transit trips to the subject capitols arrive between 7 and 9 AM; about the same percentage leave between 4 and 6 PM. A negligible number of trips arrive or depart during the rest of the day.

TABLE D-9

INTERNAL TRUCK AND TAXI TRIPS PER HUNDRED INTERNAL AUTO DRIVER TRIPS AND PER HUNDRED INTERNAL TOTAL PERSON TRIPS

	PER 100 AUTO DRIVER TRIPS		PER 100 TOTAL PERSON TRIPS	
CAPITOL	TRUCK TRIPS	TAXI TRIPS	TRUCK TRIPS	TAXI TRIPS
Georgia	11.3	2.7	6.2	1.5
Indiana	13.9	1.4	8.2	0.8
Minnesota	19.6	0.7	12.6	0.5
Rhode Island [a]	10.9	1.8	7.0	1.1
Utah	9.5	1.2	6.4	0.8
Wisconsin	4.6	1.5	2.7	0.9
Average	13.1	1.6	7.9	0.9

[a] Estimated (see Table D-19).

By contrast to person travel by auto or transit, truck travel is relatively constant during regular working hours (Figure D-5), as is taxi travel (Figure D-6). Peak hours never exceed 15% of the daily truck activity, or 13% of the daily taxi activity. Truck trips generally peak at the same hours that employees are arriving and departing.

Auto driver accumulation curves help describe the rise and fall of parking demand. Figure D-7 was derived by tabulating trips to and from the capitols, and by assuming that the minimum accumulation was approximately 5% of the maximum accumulation. For all practical purposes, the maximum accumulation of parked autos occurs by 9 AM at each capitol considered. Moreover, it ranges between 90 and 100% well into late afternoon. Parking spaces appear to empty out almost completely by 5 PM. There is relatively little parking demand in the evenings.

Travel Times and Distances

Average airline trip lengths, trips for all purposes, are directly related to the sizes of urban areas represented (Table D-10). The longest trips (5.3 miles) occur in the largest area (Twin Cities, population 1.4 million); the shortest (2.3 miles) occur in the smallest area (Madison, Wis., population 0.2 million). Trips to work are generally the longest, although personal business trips are not much shorter. "Other" trips are the shortest, with serve passenger trips more than balancing out the less frequent, though longer, social-recreation trips.

The longest trips do not necessarily require the longest travel times, although there is rough comparability (Tables D-10 and D-11). Average auto driver and auto passenger travel times of about 20 min, and average transit passenger travel times of about 30 min, compare favorably with commuting times to the other land uses studied.

Parking and Distances Walked

About two-thirds of the people who drive to work park free off-street, about 16% pay for off-street parking, and 18%

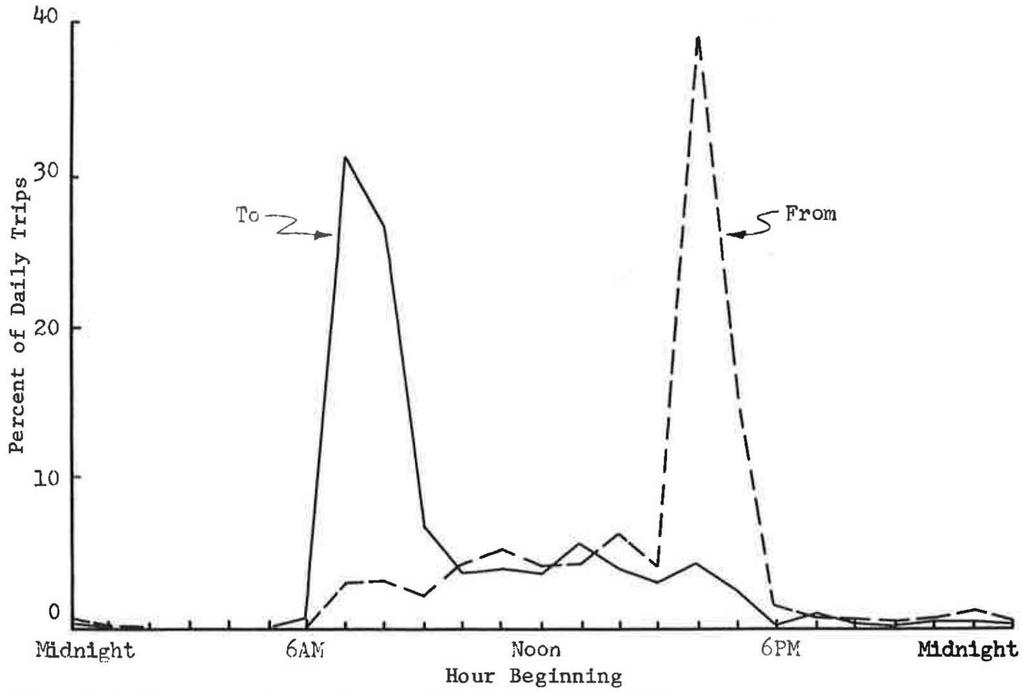

Figure D-1. Home interview total person trips to and from capitols.

park on-street, mostly free (Table D-12). About 2% report leaving autos for service and repairs (considered not parked). Excepting Georgia and Wisconsin, free off-street parking evidently is provided for between 70 and 90% of capitol employees, with consequently smaller percentages of other types of parking.*

* The Georgia capitol is surrounded by high-density urban development which would make free parking difficult to provide. The Wisconsin capitol is centrally located in the heart of the Madison CBD; although the inside of Capitol Square has unmetered street parking as a matter of public policy, the nearest off-street facilities are several blocks away (*58*). The other subject capitols have more spacious sites, as reflected by reported parking characteristics.

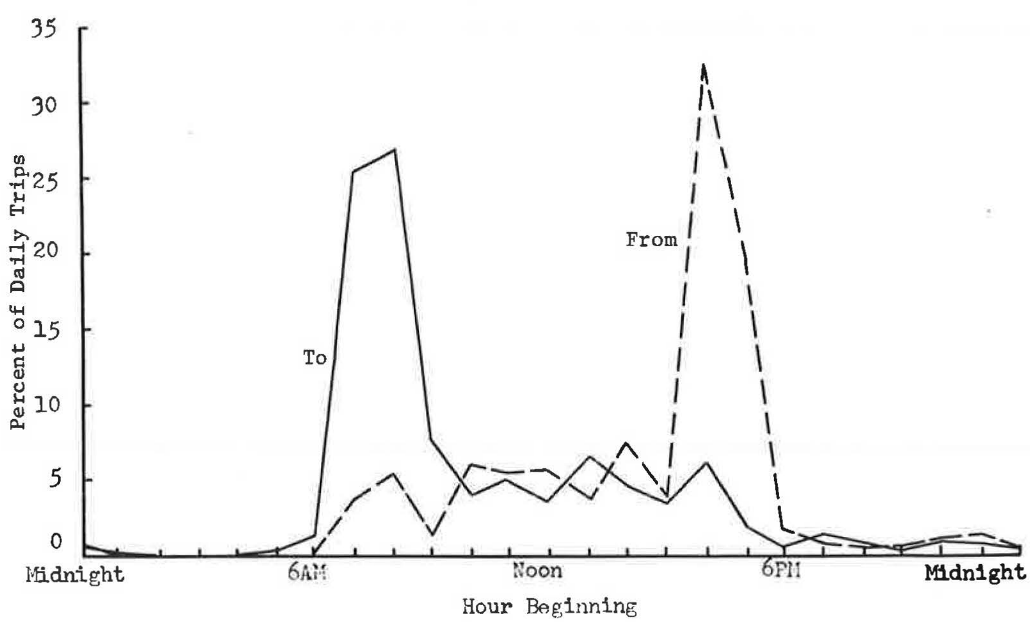

Figure D-2. Home interview total auto driver trips to and from capitols.

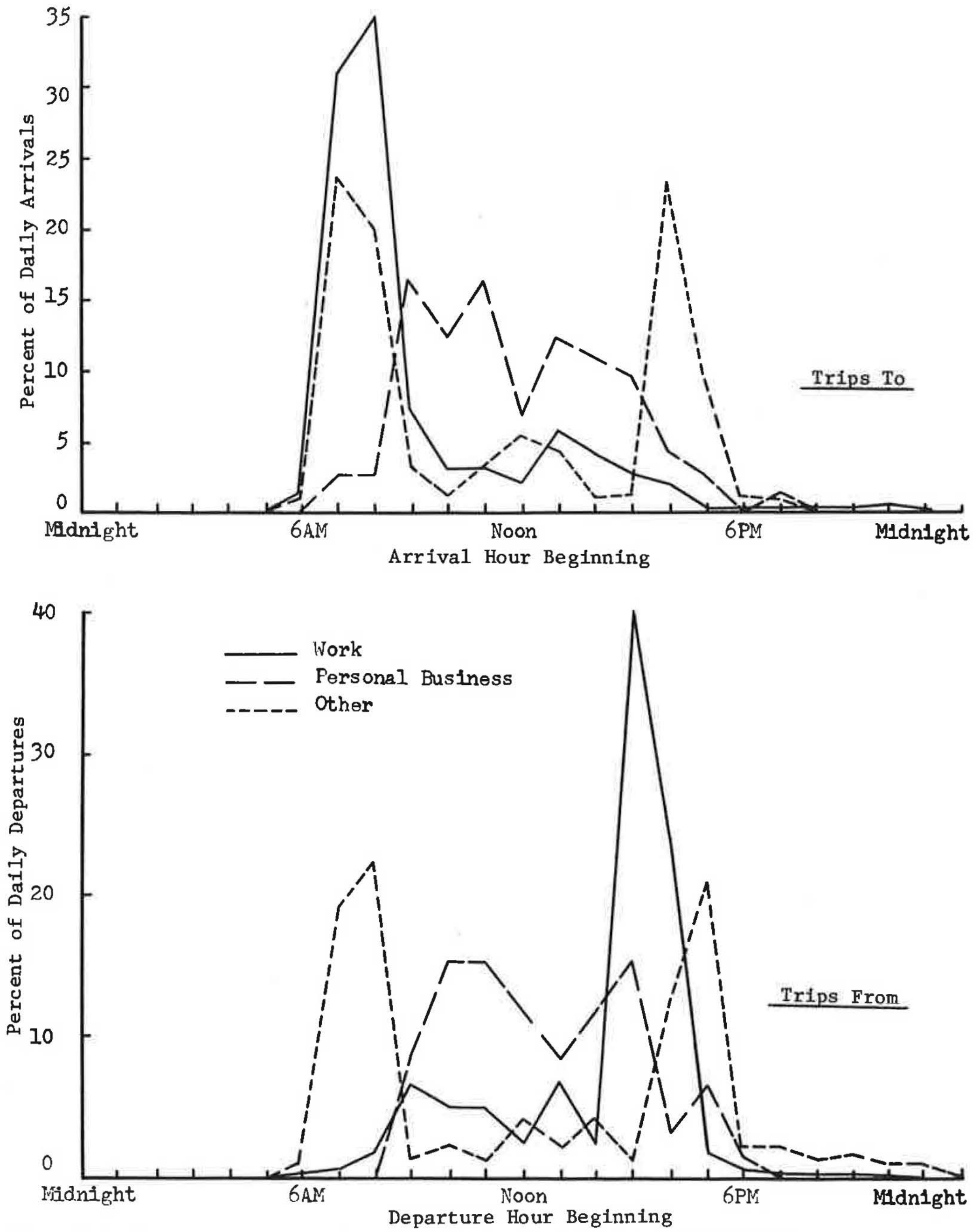

Figure D-3. Home interview auto driver trips to and from capitols, by trip purpose.

Visitors are often more likely to park on-street, as would be consistent with the shorter-stay nature of their business. Those who stay longer and need to park off-street seem, for the most part, to do so free. According to the tripmakers' reports, parking spaces are conveniently located. "Blocks walked at the destination," both for work and nonwork trips, seldom is reported as other than one or two blocks.

Car Loading Factors

As at other traffic generators, the number of persons per car (the car loading factor) varies by trip purpose. Table D-13 shows that for work trips the average is about 1.2 persons per car; for personal business trips, about 1.4 persons per car. The average for serve passenger and social-recreation trips is naturally much higher. There is considerable variation from capitol to capitol.

Highway Design Factors

Passenger car units (passenger cars, taxis, and light trucks) account for more than 93% of all daily traffic to and from the subject capitols (Table D-14). Most of the remaining

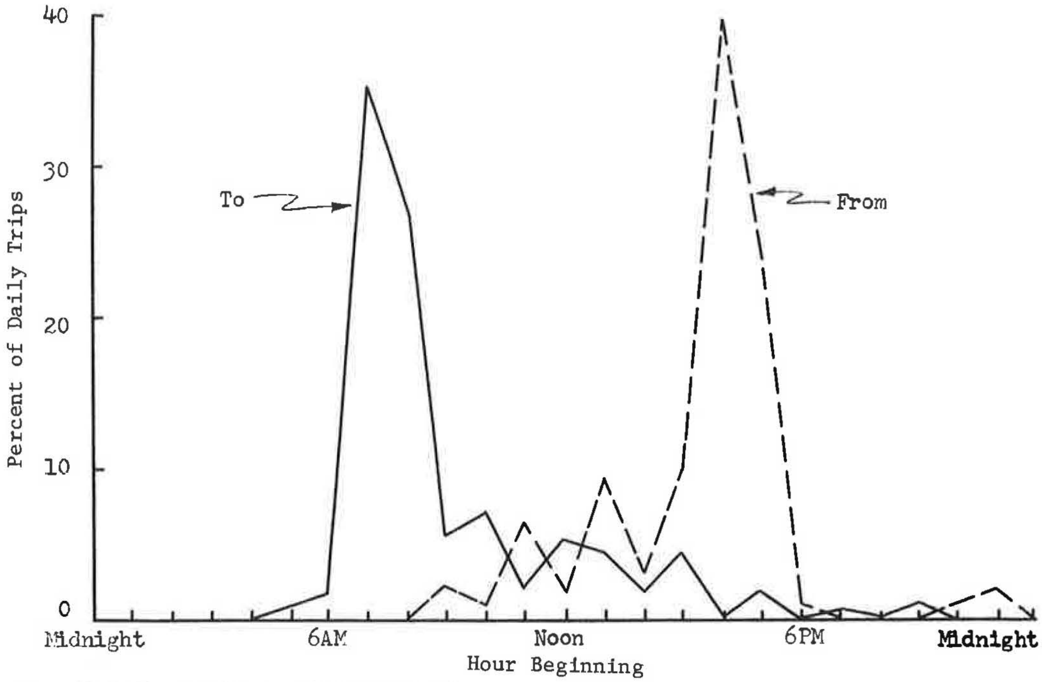

Figure D-4. Transit trips to and from capitols.

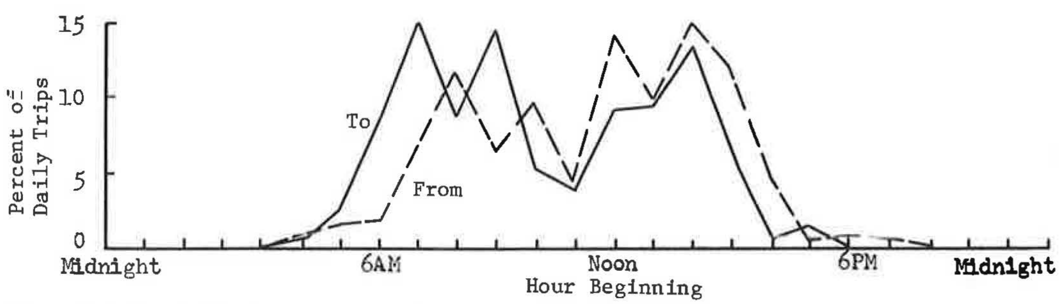

Figure D-5. Truck trips to and from capitols.

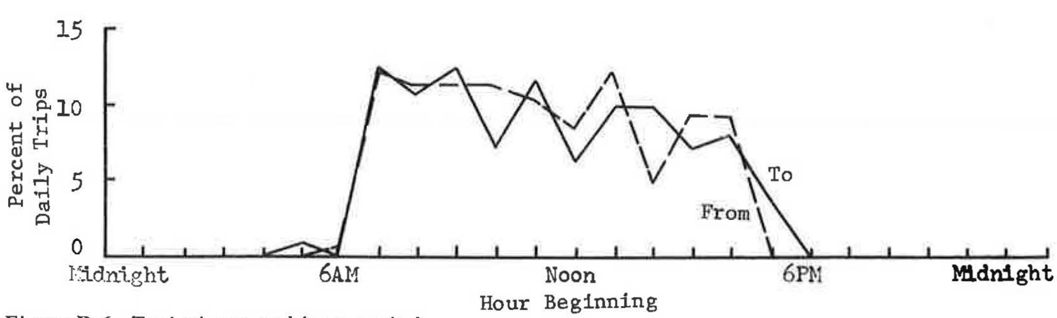

Figure D-6. Taxi trips to and from capitols.

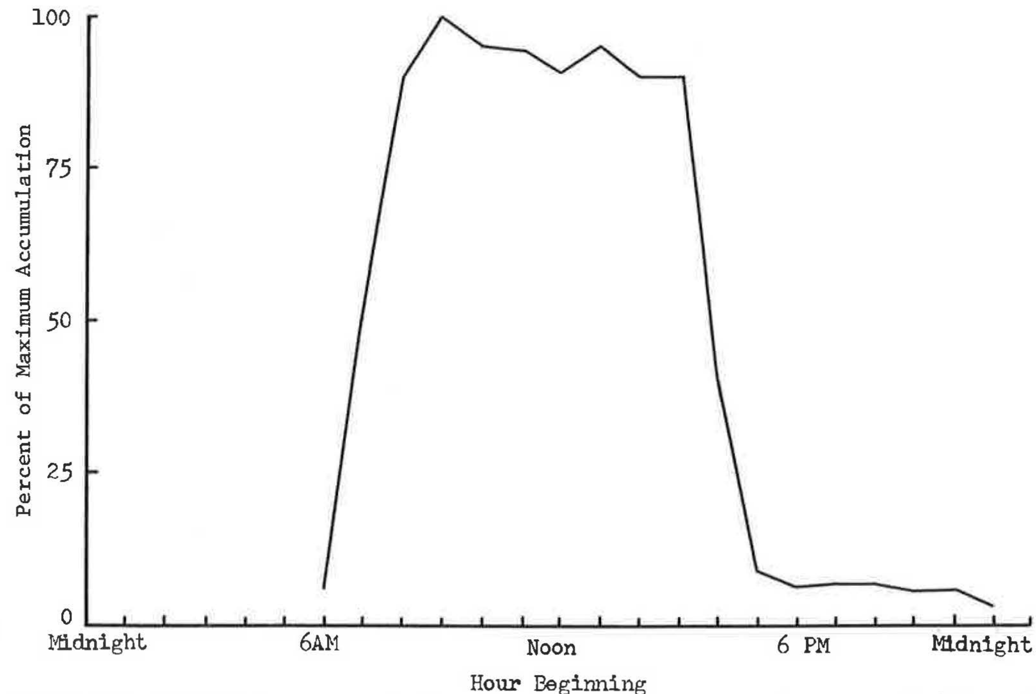

Figure D-7. Accumulation curve, auto driver trips to capitols (assuming minimum accumulation is 5 percent).

TABLE D-10

HOME INTERVIEW AUTO DRIVER AIRLINE TRIP LENGTHS (MILES) TO SELECTED CAPITOLS, BY TRIP PURPOSE

CAPITOL	TRIP PURPOSE TO: WORK	PERS. BUS.	OTHER	ALL
Georgia	4.02	3.28	3.14	3.75
Indiana	4.50	2.10	3.12	3.94
Minnesota	5.53	3.34	5.92	5.25
Rhode Island	4.48	5.38	4.01	4.64
Utah	3.02	3.13	3.75	3.24
Wisconsin	2.43	—	2.13	2.34
Average	4.16	4.00	3.54	3.99

TABLE D-11

HOME INTERVIEW AVERAGE TRIP TIMES (MINUTES) TO SELECTED CAPITOLS, BY TRAVEL MODE

CAPITOL	TRAVEL MODE: AUTO DRIVER	AUTO PASS.	TRANSIT PASS.	TAXI PASS.	ALL
Georgia	23.1	19.1	30.9	—	24.1
Indiana	21.2	22.3	34.5	—	23.8
Minnesota	23.2	18.6	33.2	18.0	23.1
Rhode Island	20.3	17.8	27.6	6.0	19.8
Utah	16.7	27.1	24.0	—	19.7
Wisconsin	10.3	9.8	15.8	7.6	10.3
Average	19.7	20.2	30.4	8.2	20.9

TABLE D-12

REPORTED PARKING CHARACTERISTICS OF HOME INTERVIEW AUTO DRIVER TRIPS TO SELECTED CAPITOLS

	WORK TRIPS				ALL OTHER TRIPS			
	OFF-STREET				OFF-STREET			
CAPITOL	PAID	FREE	ON STREET	NOT PARKED [a]	PAID	FREE	ON STREET	NOT PARKED [a, b]
Georgia	59	30	11	—	23	11	37	29
Indiana	8	79	10	3	6	19	28	47
Minnesota	5	70	22	3	5	5	37	53
Rhode Island	2	88	10	—	—	31	45	24
Utah	—	90	10	—	—	50	6	44
Wisconsin	23	9	66	2	—	—	19	81
Average	16	64	18	2	6	25	26	43

[a] Auto left for service or repairs, cruised, or otherwise not parked.
[b] Also includes serve passenger trips.

TABLE D-13

AVERAGE CAR LOADING FACTORS, HOME INTERVIEW AUTO DRIVER TRIPS TO SELECTED CAPITOLS, BY TRIP PURPOSE

	TRIP PURPOSE TO			
CAPITOL	WORK	PERS. BUS.	OTHER	ALL
Georgia	1.14	1.09	1.87	1.23
Indiana	1.25	1.36	1.81	1.41
Minnesota	1.20	1.88	2.44	1.38
Rhode Island	1.07	1.47	1.70	1.26
Utah	1.24	1.53	2.06	1.51
Wisconsin	1.25	1.00	1.75	1.34
Average	1.20	1.38	1.93	1.37

7% are medium trucks; there are very few heavy (combination) trucks.

Peak hours occur at 4 to 5 PM for Georgia, Indiana, and Wisconsin; at 5 to 6 PM for Utah; at 7 to 8 AM for Minnesota; and at 8 to 9 AM for Rhode Island—peaks representing from 13.5 to 33.6% of all daily traffic. During the peak traffic hour, the percentage of trucks is much lower. During the peak hours, the proportion of traffic moving in the dominant direction ranges from 63 to 92%. The dominant direction, except for Minnesota and Rhode Island, is obviously *from* the capitols. The variations suggest that traffic count programs would be advisable to establish design factors for any given situation.

TRIP GENERATION

Inasmuch as about two-thirds of all person trips to the six capitols are work trips, the most obvious indicator of trip generation should be employment. However, total rates for all trip purposes range from Indiana's 1.03 to Wisconsin's 2.06 person trips per employee, and from 0.61 to 1.14 auto driver trips per employee for the same capitols. These ranges confirm that work trips and nonwork trips should be treated separately.

The number of work trips, all modes, relates fairly consistently with employment. Assuming an absentee rate of 15% (about one out of seven employees away on vacation or sick leave, or for other personal reasons*), Table D-15 shows that, excluding Wisconsin, there are from 0.87 to 1.04 work trips per employee. Eliminating trips to return to work from lunch, and other second trips to work, Table D-15 also shows that there are from 0.71 to 1.00 first work trips per employee, again excluding Wisconsin.

Various factors may be responsible for variations from the average. Legislative sessions are one example: the higher Wisconsin rates may result from legislators' trips having been reported as work trips although they themselves would not have been counted as employees. Although the other state legislatures may also have held sessions during the trip survey periods, the effect on trip rates would be less apparent because of the higher employment bases at the other capitols. The availability of food service is another example: lack of an attractive capitol restaurant may literally force employees to lunch elsewhere. All things considered, it seems appropriate to allow for about 0.9 person trips to work per day per employee. Access and parking requirements computed on this basis should be adequate to meet employees' needs on most days of the year.

Floor space trip generation rates provide no predictive improvement; floor space per employee is too variable. In the present sample, the range is from Georgia's 3.3 employees per 1,000 sq ft (average for the Capitol Building plus three newer buildings) to Utah's 5.2 employees per 1,000 sq ft (Capitol Building only). Indiana and Minnesota each report 4.0; Wisconsin reports 4.4; and Rhode Island 5.0 employees per 1,000 sq ft. In terms of work trips, the range is from Georgia's 2.9 to Wisconsin's 6.0 work trips per 1,000 sq ft (Table D-16).

Nonwork trips per 1,000 sq ft of floor space also vary: Rhode Island, Utah, and Wisconsin counting 3.3, 4.1, and 3.1 trips, respectively; Georgia, Indiana, and Minnesota counting 1.5, 1.2, and 1.1 trips, respectively (Table D-16).

* Out-of-town assignments tend to create an effective absentee rate exceeding the more typical 10% rate. The 15% rate was used in the North Carolina State Capital Plan (*59*) and has been cited as ranging up to 15% in similar studies (*60*).

TABLE D-14

COMPOSITION OF TRAFFIC TO AND FROM SELECTED CAPITOLS

	DAILY TRAFFIC TO AND FROM (%)				PEAK-HOUR TRAFFIC TO AND FROM		
CAPITOL	PASS. CARS	TAXIS %	LIGHT TRUCKS [a] %	OTHER TRUCKS [b] %	PERCENT OF DAILY TRAFFIC	PERCENT TRUCKS [b]	DOMINANT DIRECTION %
Georgia	88.2	2.1	7.4	2.3	13.5	—	91
Indiana	88.4	0.9	5.2	5.5	25.9	1.9	91
Minnesota	84.9	0.6	5.1	9.4	19.3	1.9	92
Rhode Island	NA	NA	NA	NA	25.4 [c]	NA	90 [c]
Utah	88.5	1.0	9.6	0.9	13.7	—	81
Wisconsin	95.1	1.2	3.1	0.6	33.6	2.6	63
Average [d]	89.0	1.2	6.1	6.7	21.9	1.3	85

[a] Light trucks have four tires only. [b] Six or more tires. [c] Based on automobile trips only. [d] Unweighted average.

TABLE D-15

RELATIONSHIPS OF EMPLOYMENT AND WORK TRIPS TO SELECTED CAPITOLS, ALL MODES

CAPITOL	REPORTED EMPLOYMENT	EMPLOYMENT LESS 15% ABSENTEES	ALL WORK TRIPS	FIRST WORK TRIPS	TRIPS PER ADJUSTED EMPLOYMENT	
					ALL WORK	FIRST WORK
Georgia	3180	2703	2816	2690	1.04	1.00
Indiana	5257	4468	3891	3574	0.87	0.80
Minnesota	3133	2663	2353	2263	0.88	0.85
Rhode Island	1797	1527	1330	1149	0.87	0.75
Utah	1555	1322	1374	945	1.04	0.71
Wisconsin	705	599	960	850	1.60	1.42
Average	2605	2214	2121	1912	0.96	0.86

The former group also reports the highest, the latter group the lowest employee densities per 1,000 sq ft. Thus, floor space trip generation rates would seem to be too variable for the generalized prediction of either work trips or nonwork trips.

Nonwork trips appear to have no stable relationship to work trips. Ratios vary from Minnesota's 381 to Rhode Island's 906 nonwork trips per 1,000 work trips. Possibly, were all state offices in each capital city considered, nonwork trips would bear a more constant relationship to work trips. Except for differences in the number and kind of tourist attractions available (such as special exhibits, museums, historic monuments) there appears no obvious reason why, from capitol to capitol, nonwork trips would not represent some fairly consistent share of total trips attracted.

The population of the capital city's urban area may be the best indicator of the number of nonwork trips. That is, trip rates per unit of population are fairly constant: excepting Minnesota and Rhode Island, they range from Georgia and Indiana's 2.1 to Wisconsin's 2.9 trips per 1,000 population. Again, the apparent variation may result mostly from considering only trips to the defined sites, which do not consistently encompass the same governmental departments, rather than considering all state offices.

The limited evidence presented here suggests that to plan access and parking requirements for both existing or proposed state capitol complexes, it may be necessary to measure directly the actual number of nonwork trips attracted to various bureaus and departments. The unique characteristics that may exist from capitol to capitol cannot be fully accounted for in the present investigation.

TRIP DISTRIBUTION

The essential question about trip distribution relates to the highway design process: out of the total vehicular trip generation, what share of the trips will use each of the major approach routes to the generator? In general, it is known that most trips start from home; and if not from home, then more than likely from the study area "sector" in which home is located. It is also known that the probability of tripmaking per unit of population decreases with increasing distance or travel time from most generators. If an urban population has a generally random distribution—the various socio-economic family classes scattered rather than concentrated into particular sectors—then trip origins might be distributed accordingly, taking into account distance or travel time. The trip data suggest that this is sufficiently the case for highway design purposes, as this section shows.

TABLE D-16

FLOOR SPACE TRIP GENERATION RATES, AND RELATIONSHIPS OF NONWORK TRIPS TO WORK TRIPS AND TO STUDY AREA POPULATIONS FOR SELECTED CAPITOLS

CAPITOL	PERSON TRIPS PER 1,000 SQ FT			NONWORK TRIPS	
	WORK TRIPS	NONWORK TRIPS	TOTAL TRIPS	PER 1,000 WORK TRIPS	PER 1,000 POPULATION
Georgia	2.9	1.5	4.4	521	2.1
Indiana	3.0	1.2	4.2	393	2.1
Minnesota	3.0	1.1	4.1	381	0.7
Rhode Island	3.7	3.3	7.0	906	1.1
Utah	4.6	4.1	8.7	884	2.2
Wisconsin	6.0	3.1	9.1	508	2.9
Average	3.3	1.8	5.4	534	1.5

Distance and Travel Time Trip Rate Curves

Trip rates per 1,000 population decrease with increasing travel time or distance from each capitol, regardless of travel mode. Auto passenger and transit passenger rates decrease slightly faster than do auto driver trips. Considering the differences in the urban areas represented, the trip rate curves are remarkably similar.

Taking auto driver trips only, Figure D-8 shows that work trips have the steepest rate of decrease with increasing distance. This might be expected; through time, employees would tend to settle at convenient distances to work. Beyond a 2-mile radius, personal business and "other" trips are drawn to this unique land use (there can be but one capitol complex per urban area) at almost equal rates from throughout the urban area. Figure D-9 shows comparable relationships for the travel time base.

Tests show that total person trip origins and total population match fairly well for any given study area sector (Table D-17). Indiana is a good example; sector 1 accounts for 27% of the population and 31% of the trip origins, sector 2 accounts for 42% and 43%, respectively, etc. Minnesota suggests the effect of a travel barrier; sector 3 accounts for 8% of the population, but only 1% of the trip origins, possibly because that sector is beyond the Mississippi River. Wisconsin illustrates another point; the west sector accounts for 61% of the trip origins, but only 54% of the population (because of the configuration of lakes, Madison was simply divided into two sectors, east and west); this may be because a disproportionate share of professional and technical people live in the west sector (*58*).

Trip interchanges between capitols and CBD's are not significant; only 4% of all person trips to the subject capitols originate in the CBD's, and only 6% of the auto driver trips. In fact, trip origins tend to be highly scattered—no single area seems to produce any particular concentration of trips. Figure D-10, which shows the origins of total person trips to the Indiana capitol complex, illustrates how origins tend to occur throughout an incorporated, generally urbanized, area.

This is consistent with the fact that most trips are home-based. Except for Utah, something like 70 to 80% of all person trips to state capitols start from home (Table D-18). This leaves about 11% coming from work, about 4% from personal business, another 4% from shopping or social-recreation, and 10% from all other purposes. During the morning peak traffic hour, of course, a much higher percentage of trips starts from home, just as during the afternoon peak traffic hour a higher percentage than at other hours goes to home. This is another reason why, for highway design purposes, trips may be acceptably distributed simply according to the distribution of population.

Distribution of All Government Offices Trips

State capitol buildings, or even "complexes," seldom account for all state employment in capital cities; sometimes not even the majority of such employment. Government services have expanded so rapidly in the last two decades that decentralization of employment is more the rule than the exception.* The result is a growing awareness of the need for comprehensive planning for the expansion, and often the consolidation, of scattered government offices.

The extent that trip generation might increase with the consolidation of state services bears examination. In this report, only the capitol complexes have been considered, and these account for only part of the total trip generation of government offices in the subject urban areas. In Providence, R.I., for example, the present analysis deals with about 2,500 person trips, as compared to about 4,000 additional trips to state offices scattered through 34 other traffic zones. In general, the trip generation figures given herein probably could be doubled or tripled by consolidation of state services in the subject areas.

If all local, state, and federal government offices were ever centralized, the total trip generation could be very great. In the Twin Cities in 1958, for example, there were almost 40,000 daily person trips to federal, state, county, and local administration land uses (*62*). Clearly, transportation requirements at this scale would require careful planning indeed.

TRAVEL IMPACT TRENDS

Based on the six capitols examined in this report, there seems too little tripmaking to produce much of a present impact on the areawide highway network. Two-way totals range up to only 8,000 daily vehicle trips. Traffic peaks are sharp, however, and this suggests the presence of localized operational problems.

Parking is perhaps the most vexing. Most state capitol buildings are located on comparatively old sites, and through the years the capital cities have grown up around them. Frequently, the original sites have been encroached upon by high-rise office buildings and other high-intensity land uses. Sometimes so little room has been left for parking facilities that visitors and employees must compete for spaces. According to tripmakers' reports, for example, more than one-half of the employees at the Georgia state capitol complex pay for off-street parking, as do one-third of its visitors (Table D-12).

Access plans vary with the locations and characteristics of the capitol sites. The Wisconsin capitol is situated in a large central square in the heart of downtown Madison. Broad avenues provide for efficient one-way traffic movement around the square. Many of the main radial arterial streets converge on the square, and make it highly accessible. By comparison, the other subject capitols tend to be sited less advantageously for traffic purposes (although most are well sited for esthetic purposes). With the anticipated gains in employment, and the resulting increases in trip generation, adjacent streets may in several cases be hard-pressed to accommodate the traffic increase.

The dimensions of travel impact in the future can be illustrated with highlights from the recently released plan for the Connecticut Capitol Center. Preliminary information indicates that government employment in the planning

* In cases where there is no conceivable means of expanding on a central site, plans may call for peripheral city locations as a matter of policy. Wisconsin is an example (*61*).

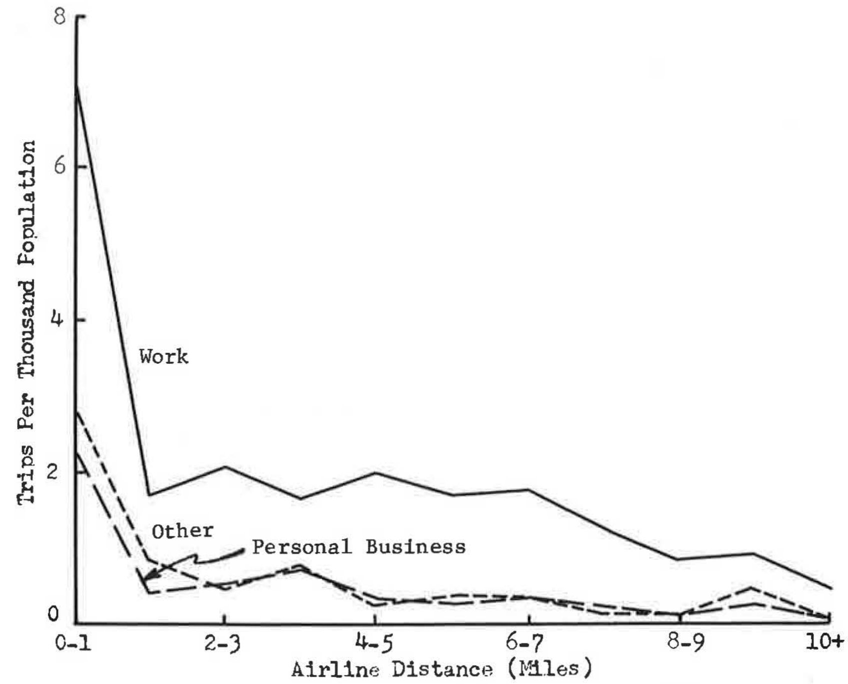

Figure D-8. Auto driver trip rates to capitols, by trip purpose and distance.

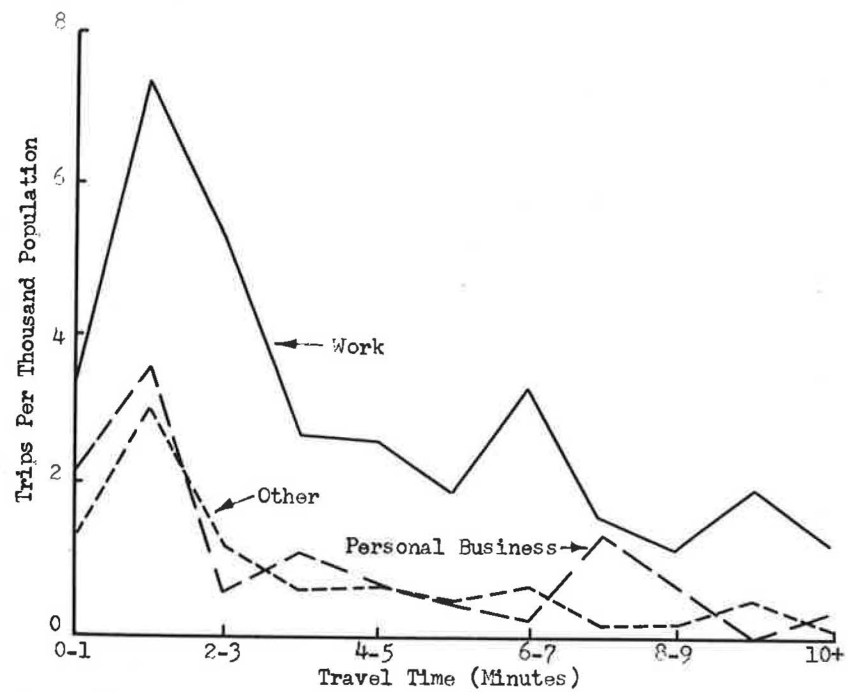

Figure D-9. Auto driver trip rates to capitols, by trip purpose and travel time.

area will increase from the current 4,000 to some 17,000 employees by the year 2000. Resnikoff (*60*) has described the resulting traffic requirements, as follows:

The projected peak-hour auto traffic to the center . . . was 4,800 by the year 2000. Approximately 45 to 55% of the traffic to the Capitol Center will approach via expressways, depending on which design concept is used. The remainder of the traffic will approach on-grade by way of the local street system. Parking facilities are planned to meet anticipated requirements of 3,700 parking spaces in 1965, 6,000 spaces in 1990, and 7,600 spaces in the year 2000.

This scale of development demands considerable space (115 acres) about one-third of which may be acquired through urban renewal planning. (Similar complexes for the states of California and New York are said to require 138 and 98 acres, respectively, and some others may be greater yet.) Where large sites cannot be assembled in the

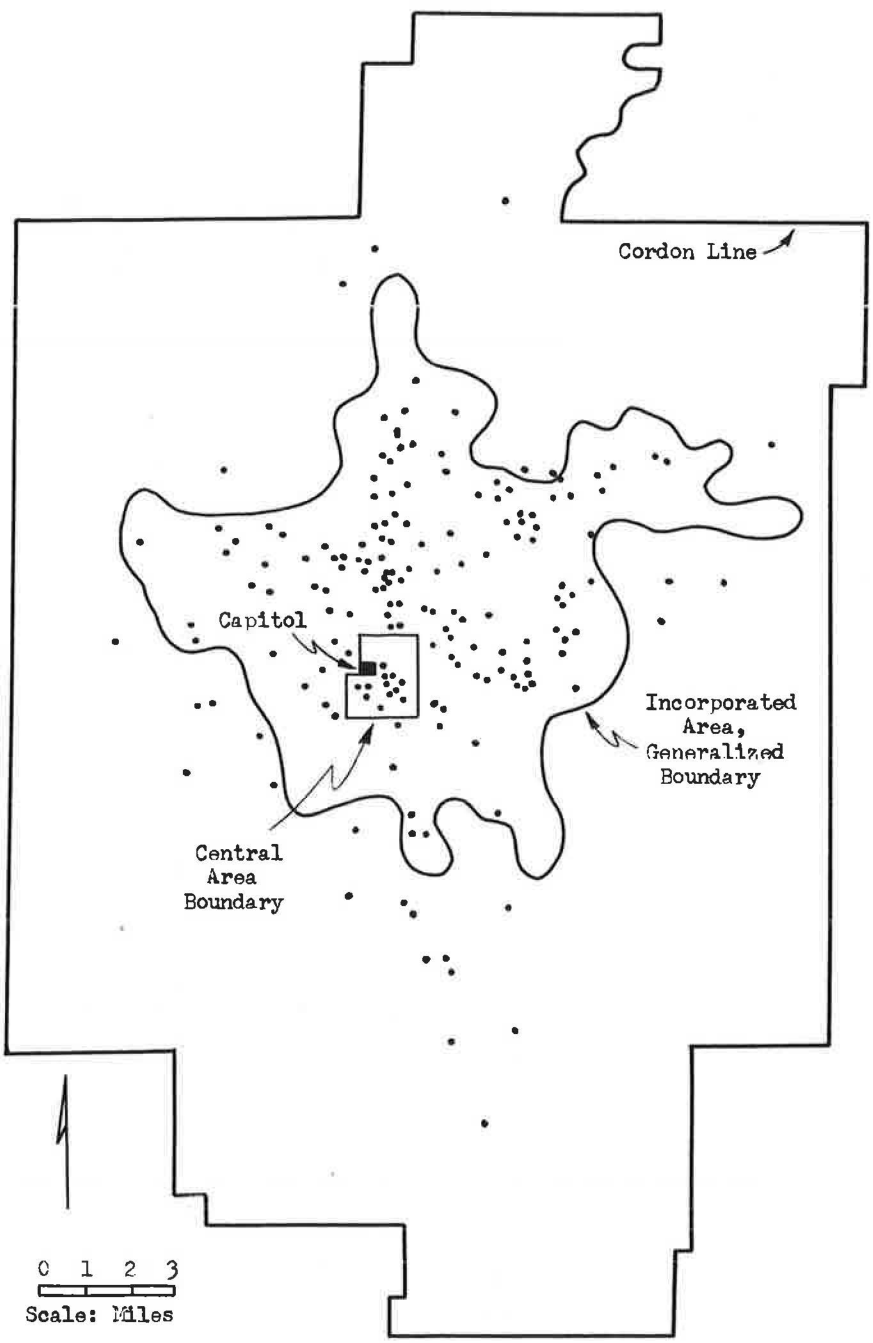

Figure D-10. Origins of home interview person trips to Indiana State Capitol complex.

TABLE D-17

COMPARISON OF PERCENTAGES OF STUDY AREA POPULATION AND STUDY AREA STATE CAPITOL TOTAL PERSON TRIP ORIGINS, BY STUDY AREA SECTOR

	SECTOR 1		SECTOR 2		SECTOR 3		SECTOR 4	
CAPITOL	POP.	TRIPS	POP.	TRIPS	POP.	TRIPS	POP.	TRIPS
Georgia	30	32	23	16	21	13	26	39
Indiana	27	31	42	43	11	13	20	13
Minnesota	27	25	16	22	8	1	49	52
Utah	9	5	25	26	45	52	21	17
Wisconsin	46	39	54	61	—[a]	—[a]	—[a]	—[a]

[a] Only two sectors designated.

TABLE D-18

PERCENTAGE OF HOME INTERVIEW TRIPS TO SELECTED CAPITOLS, BY TRIP PURPOSE FROM

	TRIP PURPOSE FROM					
CAPITOL	HOME	WORK	PERSONAL BUSINESS	SHOP OR SOCIAL-RECREATION	ALL OTHER	ALL
Georgia	77.0	6.4	4.7	2.8	9.1	100.0
Indiana	71.6	13.6	2.8	4.0	8.0	100.0
Minnesota	73.1	11.1	4.8	2.3	8.7	100.0
Rhode Island	86.3	3.2	2.5	—	8.0	100.0
Utah	48.7	23.1	4.5	10.1	13.6	100.0
Wisconsin	65.1	7.9	3.5	9.2	14.3	100.0
Average	71.5	10.9	3.8	4.1	9.7	100.0

city, suburban sites will be sought. The "State Campus" just outside Albany, N.Y., is a good example; although the legislative and judicial functions remain in the State Capitol Buildings in downtown Albany, most of the office employment has been removed to a spaciously planned site near the New York Thruway. This decentralization may be part of the new shape of things (*63*):

> Some of our state capitols, long considered citadels of conservatism, are going radical—in their architecture. Although the familiar, classic, gold-domed Capitol building will not be replaced, it will be joined by a striking array of new, subsidiary government structures, in the most advanced modern style. The bold schemes have been triggered by the pressing need for more administrative space, but they reflect a growing recognition that ambitious, long-term master plans can prove more rewarding —and practical—than the occasional haphazard construction of a building here or there.

PREDICTING AND TESTING RELATIONSHIPS

Trips to the Massachusetts State Capitol Building (State House) were examined to see how they compared to the six capitol complexes studied previously. Taking trip data from the Eastern Massachusetts Regional Planning Program as the actual situation, the objective was to determine how well trip generation and trip distribution might have been predicted from the knowledge gained about other capitols, and from State House employment and Boston area population distribution. This would suggest whether the prior findings had general application, and would help point up remaining problems.

Such examination shows that person trip generation could be predicted fairly well from known employment—work trips within 10% of actual tripmaking, nonwork trips within 20% of actual tripmaking. However, any modal split prediction would have been very poor; the Boston area's commuter railroads and rail rapid transit provide a service which was unavailable to the cross-section capitols, and the percentage of State House tripmakers using transit far exceeded that at any other capitol studied. As predicted, trip origins were generally distributed according to the distribution of population. On the whole, the results of this backcheck exercise were encouraging (see Appendix H).

CONCLUSION

Tripmaking to the selected state capitol complexes, as designated for this study, is surprisingly light. Daily two-way vehicular trip generation ranges up to only 8,000 trips. Peak hours are sharp, however, and suggest the possibility

TABLE D-19

SUMMARY OF TRIPS TO STATE CAPITOL COMPLEXES, BY SURVEY SOURCE

	TRIPS TO STATE CAPITOL COMPLEX (NO.)									
	HOME INTERVIEW					ROADSIDE			TRUCK-TAXI	
STATE	AUTO DRIVER	AUTO PSGR.	TRANSIT PSGR.	TAXI PSGR.	WALK TO WORK	AUTO DRIVER	AUTO PSGR.	TRUCK	TRUCK	TAXI
Georgia	2123	727	881	—	128 [a]	212 [b]	212 [c]	24 [d]	240	58
Indiana	2295	770	688	—	135 [a]	891	640	68	319	33
Minnesota	1924	694	244	17	111 [a]	128	131	1	378	14
Rh. Island	1482	564	95	78	19	148 [b]	148 [c]	29 [e]	148 [b]	29 [e]
Utah	1525	555	131	—	45	149	183	93	145	19
Wisconsin	646	259	89	24	111	160	160	11	30	10
Total	9995	3569	2128	119	549	1688	1474	226	1260	163

[a] Estimated at 5% of work trips.
[b] Estimated at 10% of internal auto driver trips.
[c] Estimated equal to external auto driver trips.
[d] Estimated at 10% of internal truck trips.
[e] Estimated at 2% of internal auto driver trips.

of local traffic engineering problems—particularly where parking spaces are in short supply.

About two-thirds of all trips are to work, about 19% for personal business, 10% to drop off or pick up passengers, and 4% for social-recreation. For all purposes combined, about 61% of all trips are by auto drivers, 22% by auto passengers, 13% by transit passengers, and the small remainder by taxi passengers and by persons walking to work.

Trips have widely scattered origins, following generally the distribution of population. No particular areas seem to produce trip concentrations. Trip rates per 1,000 population decrease with increasing distance or travel time from the capitols, but beyond a 2-mile radius the decrease is gradual.

With the expected rapid growth in state government employment, many states are preparing master plans to expand their capitol centers. The trip generation resulting from this consolidation and expansion of existing state services could begin to have significant impact on the highway system.

APPENDIX E

OFFICE BUILDINGS

The scarcity of literature on office building travel patterns is good reason for the present examination. Those concerned with trip generation and traffic characteristics find that relatively little is known. Considering that urban traffic congestion is centered mainly on downtown business districts, where apart from shopping and cultural pursuits the principal travel activity relates to office buildings, the value of such knowledge is evident. Increased understanding should provide guides to improved traffic circulation now, and to better transportation planning for cities in the future.

Twenty major office buildings, located in nine urban areas with from 100,000 to 1,500,000 population, were selected for study.* Nine are owned and used by city, county, state, or federal governments, and each is occupied by one or more public agencies. Eleven are privately owned, some predominantly occupied by the owners, some predominantly leased out to a multiplicity of tenants, and others with varying degrees of shared occupancy. Except for one privately owned building in a suburban setting, all are located in central business districts.

Responses to questionnaires requesting information on

* In three cases, the private office building "samples" combine two adjoining buildings of like characteristics. In effect, only common walls and different names distinguish each pair as separate buildings. Thus, counting four additional buildings examined in the backcheck, travel and site characteristics data have been assembled for a total of 27 different buildings.

physical characteristics, floor space use, and employee counts were received from all but one building management (see Fig. E-1 and Table E-1). Floor space and employment data were sometimes available as a cross-check from transportation study sources. Gross floor space was reported to range from 162,000 to 979,000 sq ft; net floor space, from 120,000 to 865,000 sq ft. The private buildings averaged slightly larger than the public buildings: 475,000 vs 405,000 sq ft, gross. Building heights ranged between 4 and 44 stories (Table E-2).

Office buildings seldom consist only of "offices." In the cross section, the proportion of net office space varied from 63 to 88% of the gross floor space. To various degrees, the private buildings all included shops, drugstores, restaurants, and other assorted activities, generally on the ground floor, whereas the public buildings included courtrooms, judges' chambers, conference rooms, et al., and occasional retail or personal service establishments.

Obviously, the number of activities per building, and the relative amount of floor space they occupy, determines trip generation. Because the present study looks only at whole buildings, it was necessary to group buildings that could be considered comparable. For working purposes, most of the following analyses deal with three groups: (1) all public buildings, where activity mixes are relatively consistent; (2) predominantly owner-tenanted private buildings, where generally at least 90% of the trip activity is accounted for by administrative corporate offices representing only one, or at most several, establishments; and (3) predominantly multi-tenanted private buildings, where generally not more than one-half the trip activity is accounted for by any single type of land-use activity, and where there may be up to

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
Project 7-1/1
Data Needs at Generator Sites
OFFICE BUILDINGS

SURVEY YEAR ________

Name: ________

Address: ________

Location: Downtown___ Intermediate___ Suburban___ Outlying___ Near Interchange___

Owner: User___ Partial User___ Developer________

Floor Space: Number of Floors_____ Total Space (sq. ft.)_______
Total Space in Offices________ Recreation________
Retail including restaurant(s)________
Other________
Number of Street Faces________ Number of Entrances________

Floor Plan and Picture Available: ________

Parking Spaces: On Site_____ Garage________ Lot________
Employer Provided______ Pay________

Off Site ________ Employer Provided______ Pay________
General adequacy of nearby street and off-street parking________

Transit Service: Type_______ Frequency________ Quality________

Employee Characteristics: % Male____ % Female________ % White Collar_______
% Other______ % Absenteeism________
Any Counts of Pedestrian Volumes________

Activities in Building: Number of Establishments________
Degree of Attraction for
Public Visits________

Types of Activity: Administrative________ Data process________
Financial (banks, brokers)________ Secretarial________
Insurance________ Public, Gov.________
Lawyers________ Restaurant________
Medical________ Retail________
Schools________ Distributors
Engr. Architect and Agents________
Services________

Figure E-1. Office building questionnaire.

TABLE E-1

OFFICE BUILDING QUESTIONNAIRE RESULTS

OFFICE BUILDING NUMBER	FLOOR SPACE (1,000 SQ FT)		NO. OF FLOORS	NO. OF EMPL.	QUALITY OF TRANSIT SERVICE	ADEQUACY OF PARKING	VISITOR ATTRACTION	EMPLOYMENT (%)	
	GROSS	USABLE						FEMALE	WHITE COLLAR
1	485[a]	412[a]	9	2172[a]	Good[a]	Fair[a]	Moderate[a]	25	70
2	979[a]	865	24	4707[a]	Fair	Good	High	50	95
3	350	270[a]	44	1615[a]	Fair	Good	Moderate[a]	33	85
4	261	225	18	—	Good	Excell.	Moderate[a]	50	100
5	416	267	11	—	Good	Insuff.	High	40	90
6	353	300	11	910[a]	Poor	Good	High	70	90
7	717	618[a]	13	2750[a]	Fair	Good	None	40	95
8	500[a]	460	32	2757[a]	Good	Good[a]	Moderate[a]	40	100
9	560[a]	450[a]	10[a]	—	Good[a]	Good[a]	Moderate[a]	40[a]	90[a]
10	172	146[a]	6[a]	—	Fair	Good	Moderate	40[a]	90[a]
11	345[a]	293	4	2330[a]	None	Excell.[a]	None	60[a]	95
12 13	1130[a]	960	14	6388[a]	Good	Good	Low	40	90
14	394	255	6[a]	849[a]	Good[a]	Fair[a]	High[a]	39[a]	90[a]
15	386	300	10[a]	2130[a]	Good[a]	Fair[a]	Low[a]	56[a]	90[a]
16	310	260[a]	11	—	Good	Crowded	Low	40	90
17	297[a]	230[a]	14	—	Good	Good	Low[a]	60	80
18	160	120	17	—	Good	Good[a]	Moderate	30	100
19	290[a]	208[a]	8	—	Good	Fair	Moderate[a]	40	100
20	565[a]	518[a]	12	—	Adequate	Poor	Normal	40	90

[a] Researchers' judgment based on building site inspection or other nonquestionnaire sources.

200 separate establishments. Two private buildings fall somewhere between these extremes, and are excluded from some (but not all) analyses.

GENERAL TRAVEL CHARACTERISTICS

Trip Purpose

Office buildings are essentially work places. Work trips account for between 46 and 69% of all person trips to and from public buildings, and between 49 and 88% of those to and from private buildings (see Table E-3). Table E-4 shows at once a difference between owner-tenanted and multi-tenanted private buildings: the former attract 85% work trips, whereas the latter attract 60% work trips. On the average, public buildings also attract about 60% work trips.

Public buildings and multi-tenanted private buildings also generate significant numbers of personal business trips: on the average, 26 and 22%, respectively. Such buildings have offices where the general public can seek advice or assistance from public agencies, or can arrange financial, legal, or other personal and professional services. By contrast, owner-tenanted private buildings generate only 4% personal business trips; such buildings have few offices to attract the general public. This basic distinction is reflected in other travel characteristics reported subsequently.

There is a miscellany of other trips. About 1 out of 10 trips to office buildings are by persons dropping off or picking up riders, with the individual sample percentages ranging between 2 and 22%—both extremes recorded at public buildings. Social-recreation, shop, medical-dental, and eat meal trips account for an average of from 1% of all person trips at owner-tenanted private buildings to 11% at multi-tenanted private buildings. The individual sample percentages reflect what is known of the activity mixes within each building.

At the other end of office building trips (that is, the origins of trips to, or the destinations of trips from the office buildings) the principal trip purpose is home. The proportions are 60% for public buildings, 62% for multi-tenanted private buildings, and 80% for owner-tenanted private buildings (Table E-5). The individual sample per-

TABLE E-2

SAMPLE OFFICE BUILDINGS SELECTED CHARACTERISTICS

BUILDING OWNERSHIP	NO. OF BUILDINGS	NO. OF CITIES	AVG. FLOOR SPACE (1,000 SQ FT)	
			GROSS	NET
Public	9	7	405	323
Private	11	5	457	386
All types	20	9	425	358

Source: Questionnaire returns (see Table E-1) and transportation study land-use inventory data.

TABLE E-3

HOME INTERVIEW PERSON TRIPS TO AND FROM OFFICE BUILDINGS, PERCENTAGE TRIP PURPOSE DISTRIBUTION

OFFICE BUILDING		TRIP PURPOSE DISTRIBUTION (%)								
		OFFICE BUILDING TRIP END				NON-OFFICE BUILDING TRIP END				
NO.	TYPE	WORK	PERS. BUS.	SERVE PSGR.	OTHER	HOME	WORK	PERS. BUS.	SERVE PSGR.	OTHER
1[a]	Pub.	77.7	22.3	—	—	89.1	4.7	3.8	—	2.4
2[a]	Pri.	97.8	2.2	—	—	94.9	2.5	1.3	—	1.3
3[a]	Pri.	94.3	3.8	—	1.8	90.4	7.7	1.0	—	1.0
4	Pri.	48.8	36.8	2.6	11.8	71.8	12.5	2.4	1.3	12.0
5	Pub.	55.6	32.3	10.2	1.9	66.8	13.3	6.0	2.5	11.4
6	Pub.	46.2	39.3	6.3	8.2	52.0	22.7	9.4	5.1	10.8
7	Pri.	88.1	2.8	8.3	0.8	80.9	6.6	2.1	5.5	4.9
8	Pri.	58.1	25.6	6.7	9.6	69.5	13.1	4.7	3.2	9.5
9	Pub.	63.9	25.6	6.0	4.5	66.4	11.5	6.9	4.0	11.2
10	Pub.	47.8	32.7	13.3	6.2	51.4	19.2	8.8	5.8	14.8
11[b]	Pri.	NA	NA	NA	NA	NA	NA	NA	NA	NA
12	Pri.	81.5	7.4	8.6	2.5	77.8	6.8	4.1	5.3	6.0
13	Pri.	84.4	1.7	12.7	1.2	80.8	9.5	2.2	2.6	4.9
14	Pub.	67.6	22.6	8.4	1.4	52.3	20.6	7.0	7.1	13.0
15	Pub.	67.2	7.9	22.1	2.8	69.7	11.4	2.6	9.2	7.1
16	Pub.	68.7	20.5	10.8	—	72.0	13.2	0.4	—	14.4
17	Pri.	73.0	12.0	9.5	5.5	67.5	17.0	3.1	6.0	6.4
18	Pri.	53.6	11.7	16.0	18.7	56.8	18.0	9.2	4.3	11.7
19	Pri.	60.6	11.5	6.1	21.8	44.0	30.0	5.3	8.8	11.9
20	Pub.	61.4	30.1	2.1	6.4	51.0	20.0	8.5	5.6	14.9
Public		59.8	26.4	9.9	3.9	60.2	16.5	6.2	4.9	12.2
Private		68.5	13.7	8.8	9.0	68.6	14.2	4.1	4.6	8.5
All		64.1	20.0	9.4	6.5	64.4	15.3	5.2	4.8	10.3

[a] Serve passenger trips lost due to linking; samples 1, 2, and 3 omitted from averages.
[b] Trips from not available.

centages range from 44 to 89%. Although not evident in Tables E-4 and E-5, most office building workers make simple round trips from home-to work-to home. Trips for other purposes are often triangular; for example, from home-to shop (elsewhere)-to personal business (at the office building)-to home. In effect, this is illustrated by the percentages of nonhome-based trips in Table E-5.

Travel Mode

Because all but one building in the cross section has a central location, connoting the best transit service available in each urban area, the proportion of trips using public transit is understandably high. The average for public buildings is 17% and the averages for owner-tenanted and

TABLE E-4

HOME INTERVIEW PERSON TRIPS TO AND FROM OFFICE BUILDINGS, TRIP PURPOSE DISTRIBUTON AT THE OFFICE BUILDING TRIP END (UNWEIGHTED AVERAGES)

OFFICE BUILDING TYPE	TRIP PURPOSE TO OR FROM				
	WORK	PERSONAL BUSINESS	SERVE PASSENGER	OTHER	ALL
Public	59.8	26.4	9.9	3.9	100.0
Private:					
Owner-tenanted	84.7	4.0	9.9	1.4	100.0
Multi-tenanted	60.0	21.5	7.7	10.8	100.0
Average	64.1	20.0	9.4	6.5	100.0

See Table E-3.

TABLE E-5

HOME INTERVIEW PERSON TRIPS TO AND FROM OFFICE BUILDINGS, TRIP PURPOSE DISTRIBUTION AT THE NON-OFFICE BUILDING TRIP END (UNWEIGHTED AVERAGES)

OFFICE BUILDING TYPE	TRIP PURPOSE TO OR FROM					
	HOME	WORK	PERSONAL BUSINESS	SERVE PASSENGER	OTHER	ALL
Public	60.2	16.5	6.2	4.9	12.2	100.0
Private:						
Owner-tenanted	79.8	7.6	2.8	4.5	5.3	100.0
Multi-tenanted	61.9	18.1	4.9	4.7	10.4	100.0
Average	64.4	15.3	5.2	4.8	10.3	100.0

See Table E-3.

multi-tenanted private buildings are 14 and 22%, respectively (Table E-6). At the one building in a suburban setting the proportion is only 4%.

By contrast with other reported experience, however, these averages are quite modest. A 1945 study of two office buildings in Baltimore found 50% transit use, naturally high because of war conditions (*64*). A 1958 study of all "general offices" in downtown Pittsburgh (*65*) also found 50% transit use. A 1959 study of four office buildings in downtown Hartford, Conn., found more than 40% of some 11,000 employees riding buses (*66*). And, of course, transit ridership in foreign countries remains at very high levels; a 1963 study of travel patterns associated with a large office building in Sydney, Australia (*67*), showed more than 90% transit use by its employees.

Transit does not seem to be favored for any particular trip purpose. In the cross section, work trips tend to utilize transit just slightly more than do trips for personal business or for other miscellaneous purposes (see Table E-7). That is, somewhat more nonwork trips than work trips are by auto drivers and auto passengers. (This is in marked contrast, for example, to central London, where in 1960 autos accounted for only 13% of work trips, but 39% of nonwork trips (*68*). Serve passenger trips are, of course, almost entirely auto driver trips—in many transportation studies, by definition.

Although it is sometimes said that many people might prefer to live downtown so that they could walk to work and avoid commuting, only about 2 out of every 100 trips to the cross-section buildings are by persons walking to work (about 3 out of every 100 work trips). Moreover, based on this relatively small sample, less than one-third are made by professional, managerial or technical personnel, the kinds of people most able to afford living downtown. Two-thirds are made by clerical personnel, service workers, and laborers, most of whom live just outside the CBD. Such figures may simply reflect a shortage of suitable downtown living quarters during the trip survey years. In any case, there are virtually no intra-CBD, home-to-work trips by other travel modes. Although there are a few such taxi trips, the total taxi tripmaking from all points for all purposes is negligible; less than 1% regardless of building type.

Thus, in the end, the automobile serves the majority of trips to the cross-section buildings: about 75% of all trips to multi-tenanted private buildings are made by auto drivers or auto passengers; to public buildings, about 80%; and to owner-tenanted private buildings, about 85%. In several instances the proportion ranges upwards of 90%, particularly in the smaller urban areas (see Table E-7).

TABLE E-6

PERCENTAGE TRAVEL MODE DISTRIBUTION, HOME INTERVIEW PERSON TRIPS TO OFFICE BUILDINGS, ALL PURPOSES (UNWEIGHTED AVERAGES)

OFFICE BUILDING TYPE	TRAVEL MODE					
	AUTO DRIVER	AUTO PASS.	TRANSIT PASS.	TAXI PASS.	WALK TO WORK	ALL
Public	60.6	18.9	17.0	0.7	2.8	100.0
Private:						
Owner-tenanted	58.6	25.6	14.0	0.1	1.7	100.0
Multi-tenanted	59.6	16.7	22.3	0.8	0.6	
Average	57.3	19.8	20.5	0.7	1.7	100.0

See Table E-7.

TABLE E-7

HOME INTERVIEW TRIPS TO OFFICE BUILDINGS, PERCENTAGE TRAVEL MODE DISTRIBUTION BY TRIP PURPOSE

OFFICE BUILDING	TRAVEL MODE DISTRIBUTION (%)											
	ALL TRIPS				TRIPS TO WORK				TRIPS TO PERS. BUSINESS			
TYPE	AUTO DRIV.	AUTO PSGR.	TRANS. PSGR.	OTHER	AUTO DRIV.	AUTO PSGR.	TRANS. PSGR.	OTHER	AUTO DRIV.	AUTO PSGR.	TRANS. PSGR.	OTHER
1 Pub.	37	11	51	1	34	10	54	2	47	13	40	—
2 Pri.	35	21	43	1	35	20	43	2	26	50	24	—
3 Pri.	23	21	52	4	20	20	55	5	100	—	—	—
4 Pri.	62	13	24	1	71	9	18	2	54	15	31	—
5 Pub.	78	16	6	—	82	15	3	—	66	22	12	—
6 Pub.	72	23	4	1	77	15	8	—	68	28	2	2
7 Pri.	52	20	28	—	48	22	30	—	34	—	66	—
8 Pri.	59	18	23	—	55	18	27	—	63	14	23	—
9 Pub.	56	17	26	1	60	16	22	2	42	13	45	—
10 Pub.	65	23	6	6	62	30	7	1	66	13	9	12
11 Pri.	65	31	4	—	65	31	4	—	67	33	—	—
12 Pri.	62	26	12	—	55	29	16	—	93	7	—	—
13 Pri.	62	29	9	—	55	34	11	—	100	—	—	—
14 Pub.	74	14	7	5	70	13	10	7	81	15	4	—
15 Pub.	53	26	13	8	38	32	18	12	68	21	11	—
16 Pub.	54	24	16	6	47	26	21	6	53	28	10	9
17 Pri.	55	19	22	4	52	18	26	4	62	20	9	9
18 Pri.	58	22	19	1	56	11	30	3	70	16	14	—
19 Pri.	70	8	20	2	74	4	22	—	38	—	62	—
20 Pri.	58	17	24	1	66	9	24	1	49	21	30	—
Public	61	19	17	3	60	18	18	4	60	19	18	3
Private	55	21	23	1	53	20	26	1	64	14	21	1
All	57	20	21	2	56	19	22	3	62	16	20	2

Factors Associated With Travel Mode

TRANSIT SERVICE

More than anything, differences in service to particular buildings reflect differences in areawide transit systems. To account for the ridership effect of service differentials, therefore, it would have been necessary to quantify and to compare whole transit systems—an undertaking deemed far beyond the scope of this project, and for that reason not pursued. In fact, every building except the suburban example was served by one or more bus routes past its doors.* Buildings in Pittsburgh and New Orleans were also served by streetcars. During the trip survey years, the Pittsburgh buildings had railroad commuter service, although with the much reduced schedules typically preceding discontinuance.

Not surprisingly, the subjective ratings of transit service by building managers were generally favorable: of 17 ratings, excluding that for the suburban building, only 1 indicated poor service, 5 indicated fair or adequate service, and 11 indicated good service (see Table E-1). Observations by the researchers tended to confirm the building managers' judgments.

* By a unique arrangement, the suburban building was linked to other suburban and city offices of the same Wilmington corporation by a privately-leased shuttle bus. Tripmakers to that building reported 4% transit use.

CAR OWNERSHIP

Car ownership consistently affects the tripmaker's choice of travel mode. Pittsburgh office building trips show a higher proportion of transit tripmaking than those of any other city; but even so, the proportion is clearly related to car ownership. Pittsburgh and Wilmington data (the only studies where car ownership was available in the trip records without recourse to the matching household characteristics records) together show that as car ownership rises, transit use decreases: Table E-8 shows that members of zero-car families report 82% transit use; members of one-car families report 37%; whereas members of multi-car families report only 10%. Based on the data used to develop Table E-8, it was found that 25% of all transit trips to the six subject buildings came from zero-car families, 64% came from one-car families, and 11% came from multi-car families.

Normally, transit riders from families without cars may be thought of as "captives," as so might be transit riders from families with cars, if the cars are not available when needed. However, CBD trips have by far the greatest propensity to attract "choice" transit riders—those travelers who might have driven automobiles had they chosen to. In Pittsburgh, for example, almost 60% of all the "choice" transit trips in the study area begin or end in the Golden Triangle (*69*). If transit trips to the subject office build-

TABLE E-8

PERCENTAGE TRAVEL MODE DISTRIBUTION, HOME INTERVIEW PERSON TRIPS TO OFFICE BUILDINGS IN PITTSBURGH AND WILMINGTON, BY FAMILY CAR OWNERSHIP CLASS

TRAVEL MODE	0-CAR FAMILIES	1-CAR FAMILIES	MULTI-CAR FAMILIES	ALL FAMILIES
Auto driver	—	40	71	46
Auto passenger	12	22	19	20
Transit passenger [a]	82	37	10	32
Walk-to-work	6	1	—	2
All	100	100	100	100

[a] Includes commuter train and taxi passengers.

Source: Pittsburgh Area Transportation Study and New Castle County (Del.) Program.

ings include a similarly high proportion of "choice" transit trips, the usual correlation with car ownership would be clouded.

TRIPMAKER OCCUPATION AND SEX

As given in Table E-9, the clerical-salesworker occupation group reports the highest transit use (23%). The professional-managerial-technical occupation group reports among the lowest transit use (12%). Together, these groups account for about 78% of all trips to the cross-section buildings; the remaining trips are almost equally distributed among the other occupation groups shown.

Women are twice as likely (33%) to use transit as are men (15%) (Table E-10). Approximately the same difference prevails at both public and private buildings. The propensity for women less often to drive and more often to be automobile or transit passengers, has been noted before: at an office building in the Houston CBD, the male-female travel mode proportions (1959) were auto drivers, 63% vs 41%; auto passengers, 30% vs 49%; and transit passengers, 6% vs 9% (*70*). The high percentage of women in the clerical labor force helps to explain why that occupation group has the highest transit use (as shown in Table E-9).

Truck and Taxi Travel

About three-fourths of the 2,600 truck trips to the 20 cross-section buildings were by pickup and panel or other light trucks. The proportion of truck trips to total trips was quite variable. Expressed as a rate per 100 auto driver trips, the mean was 9.3 for public buildings, 6.9 for private buildings, and 8.1 for the whole sample. In terms of trips per 100 person trips, the rates were 5.7 and 4.3 for public and private buildings, with 4.8 as the over-all mean (Table E-11).

Relationships between truck travel and other tripmaking or building attributes were poor. Public buildings developed 0.41 truck trips per 1,000 sq ft of gross floor space, on the average, whereas private buildings developed 0.23 trips. The combined average was 0.31 trips. (For comparison, recent London studies reported 0.38 truck trips per 1,000 sq ft for all Central Area office space). However, regression analysis showed no correlation between tripmaking and floor space. Apparently there are too many types of floor space, in terms of truck pick-ups and deliveries, for that variable to make a good predictor of truck activity.

Office buildings generate surprisingly few taxi trips; only about 750 for twenty buildings, or less than 50 per building per day. Table E-11 gives over-all rates of 2.4 taxi trips per

TABLE E-9

PERCENTAGE MODE DISTRIBUTION, HOME INTERVIEW PERSON TRIPS TO OFFICE BUILDINGS, BY TRIPMAKER OCCUPATION

OCCUPATION OF TRIPMAKER	TRAVEL MODE [a] AUTO DRIVERS	AUTO PASS.	TRANSIT PASS.	ALL
Professional and technical	70	18	12	100
Clerical and salesworkers	46	31	23	100
Craftsmen and operatives	76	11	13	100
Laborers and service workers	80	5	15	100
Students, housewives, others	59	30	11	100

[a] Excluding taxi passenger and walk-to-work trips.

TABLE E-10

PERCENTAGE TRAVEL MODE DISTRIBUTION, HOME INTERVIEW PERSON TRIPS TO OFFICE BUILDINGS, BY TRIPMAKER SEX (UNWEIGHTED AVERAGES)

SEX OF TRIPMAKER	TYPE OF OFFICE BUILDING	TRAVEL MODE [a] AUTO DRIVER	AUTO PASS.	TRANSIT PASS.	TOTALS
Male	Public	77	10	13	100
	Private	68	16	16	100
	Average	72	13	15	100
Female	Public	34	37	29	100
	Private	32	31	37	100
	Average	33	34	33	100

[a] Excluding taxi passenger and walk-to-work trips.

100 auto driver trips, and 1.4 taxi trips per 100 total person trips. Owner-tenanted private buildings attract taxi trips at much less than these average rates.

Time Patterns

HOURLY, PERSON TRIPS

Although transportation study data provide little evidence on month-to-month or day-to-day variations in office building travel—and none was found elsewhere—they do provide ample evidence of hour-to-hour variation on a typical weekday. Figures E-2 and E-3, for example, show that there are significant differences in the composite hourly patterns of total person trips to public buildings, owner-tenanted private buildings, and multi-tenanted private buildings. (Note that "composite" curves tend to average out differences in office opening and closing times; actual peak-hour percentages for individual buildings are examined later.)

Owner-tenanted buildings have higher morning arrival and evening departure peaks, and much less trip activity during the day than the other building types. About 54% of the daily trips arrive during one hour, and 77% arrive between 7 and 9 AM. Departures are similarly peaked, with about 47% leaving during one hour, and 74% leaving between 4 and 6 PM.

Public buildings, like multi-tenanted buildings, have arrival and departure peaks only about one-half those for owner-tenanted buildings, and more daytime activity associated with personal business trips. In both cases, about 45 to 50% of all trips arrive between 7 and 9 AM, and the hours from 4 to 6 PM account for a similar proportion of trip departures. Travel after 6 PM at all office building types is negligible.

Comparisons of hourly patterns *by trip purpose* show remarkable similarity regardless of building type. For example, personal business trips to owner-tenanted buildings, although fewer in number, occur during the same hours as they do at other building types. Work trips and other trips, largely to serve passenger, behave similarly. For that reason, Figures E-4 and E-5 satisfactorily portray person trips by trip purpose for all building types. The different proportions of work and personal business trips explain the different arrival and departure patterns for owner-tenanted and multi-tenanted buildings—not different time patterns for corresponding trip purposes.

HOURLY, AUTO DRIVER TRIPS

Modal split varies by hour of the day. During the peak hours, transit trips account for more than 20% of all trips in the prime direction of movement, but during the hours from 9 AM to 4 PM, less than 10%. For this reason, trips

TABLE E-11

INTERNAL TRUCK AND TAXI TRIPS PER HUNDRED INTERNAL AUTO DRIVER TRIPS AND PER HUNDRED INTERNAL TOTAL PERSON TRIPS

OFFICE BUILDING TYPE	PER 100 AUTO DRIVER TRIPS		PER 100 TOTAL PERSON TRIPS	
	TRUCK TRIPS	TAXI TRIPS	TRUCK TRIPS	TAXI TRIPS
Public	9.31	2.54	5.70	1.56
Private:				
Owner-tenanted	7.55	0.44	4.42	0.26
Multi-tenanted	6.68	2.34	4.28	1.50
Average	8.11	2.36	4.78	1.39

See Table E-24.

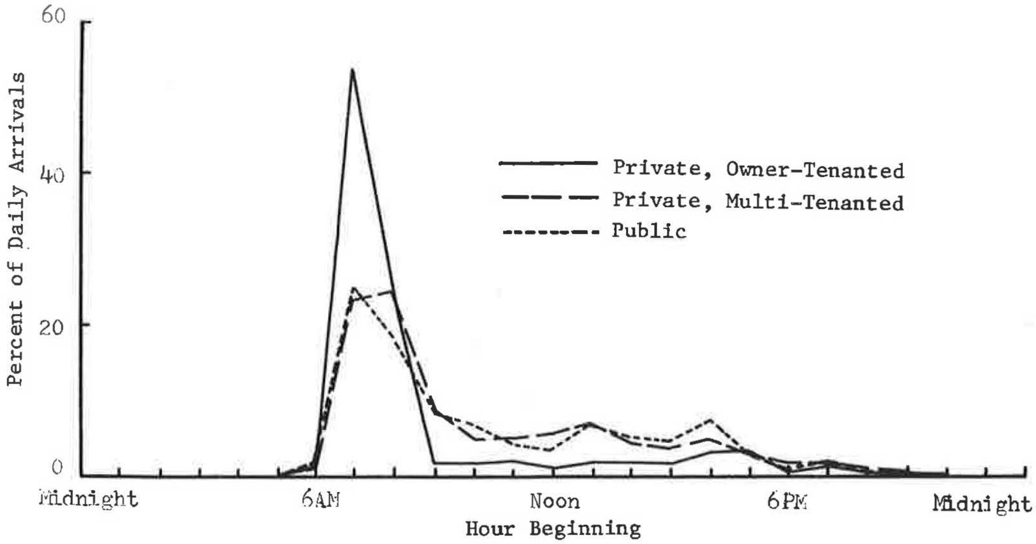

Figure E-2. Home interview person trips to office buildings, by ownership and occupancy type.

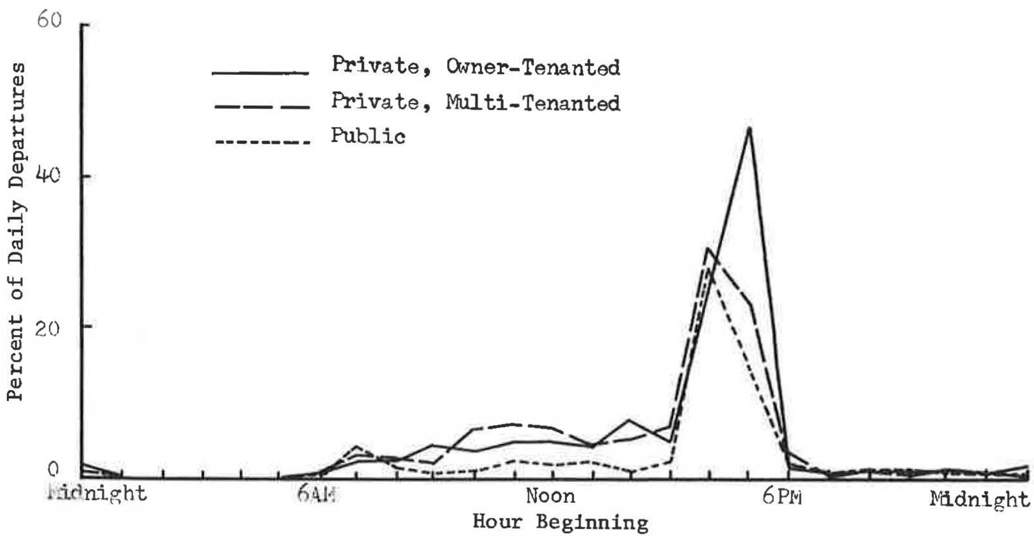

Figure E-3. Home interview person trips from office buildings, by ownership and occupancy type.

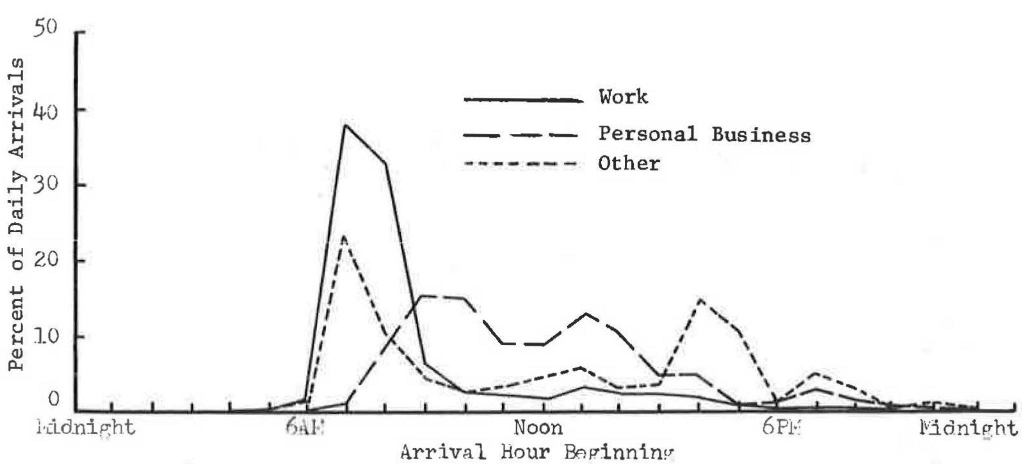

Figure E-4. Home interview person trips to office buildings, by trip purpose.

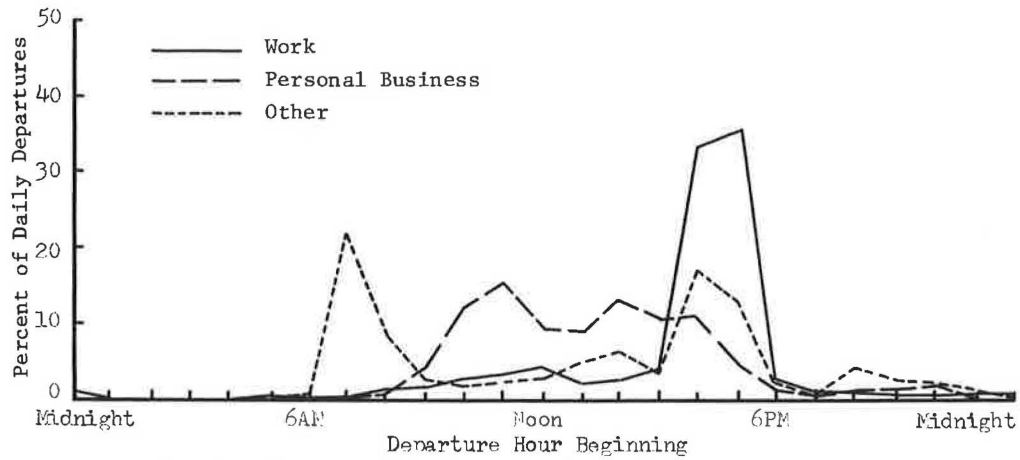

Figure E-5. Home interview person trips from office buildings, by trip purpose.

by auto drivers are less peaked than are trips by all travel modes (Figs. E-6 and E-7). Public buildings and multi-tenanted private buildings again have comparable hourly distributions, both involving fewer peak-hour trips and more off-peak-hour trips than do owner-tenanted private buildings.

HOURLY, TRANSIT PASSENGER TRIPS

By the same token, transit passenger trips are more peaked than are trips by all travel modes. At owner-tenanted buildings, from 85 to 90% of the daily transit trips occur during the four peak hours; at multi-tenanted buildings and public buildings (not shown separately in Fig. E-8 because virtually the same), the comparable proportion is 60 to 65%.

HOURLY, TRUCK AND TAXI TRIPS

Truck and taxi trips exhibit matching arrival and departure patterns because of their short-stay characteristics (Figs. E-9 and E-10). Taxi trips peak at office opening hours, at lunch, and at office closing hours. Truck trips tend to peak in the morning, and to taper off during the afternoon.

LENGTH OF STAY

The amount of time which elapses between a tripmaker's arrival at, and departure from, an office building depends on his trip purpose. Table E-12 shows, for example, that the average length of stay by employese at public compared to private buildings is 6.7 hr vs 7.2 hr; by visitors for personal business, 2.6 hr vs 1.4 hr; by visitors for other purposes (excluding serve passenger trips), 0.7 hr vs 3.0 hr. Length of stay also varies by travel mode. This was found when all trips to the Pittsburgh CBD were examined in an earlier study (*71*), and again for just the selected Pittsburgh and Seattle office buildings. Table E-12 shows that transit tripmakers have significantly longer stays than do auto drivers. In effect, length of stay relates to modal choice. Where the tripmaker needs to leave his office during the day, or where he has multiple stops to make, he will more often prefer to have his automobile at hand. Such tripmakers have been called "captive" auto drivers (*72*).

Travel Times and Distances

Most central business districts attract the longest trips in a metropolitan area. Almost all residents, regardless of where they live, occasionally visit downtown for some purpose or other. The larger the metropolitan area, the longer the average trip length becomes. Major department stores probably develop the longest CBD trips. Large, well-known private office buildings, and unique public office buildings * may also develop rather long CBD trips. Thus, travel times

* In several instances the cross section includes the then tallest and/or best known private office building in the urban areas dealt with. Seven of the nine public buildings are city-county buildings (some with and some without courtrooms), one is a state office building, and one is a federal office building.

TABLE E-12

AVERAGE LENGTH OF STAY (IN HOURS) BY TRIPMAKERS TO SELECTED PUBLIC AND PRIVATE OFFICE BUILDINGS IN PITTSBURGH AND SEATTLE, BY TRAVEL MODE AND TRIP PURPOSE CHARACTERISTICS

TRAVEL MODE AND TRIP PURPOSE CHARACTERISTIC	BUILDING OWNERSHIP	
	PUBLIC	PRIVATE
All travel modes, by trip purpose		
To work	6.7	7.2
To personal business	2.6	1.4
To other [a]	0.7	3.0
Average	5.5	6.5
Trips to work, by travel mode		
Auto driver	5.6	6.0
Auto passenger	7.5	8.8
Transit passenger	8.2	8.2
Average	6.7	7.2

[a] Excludes serve passenger trips.

Source: Pittsburgh Area Transportation Study and Puget Sound Regional Transportation Study data.

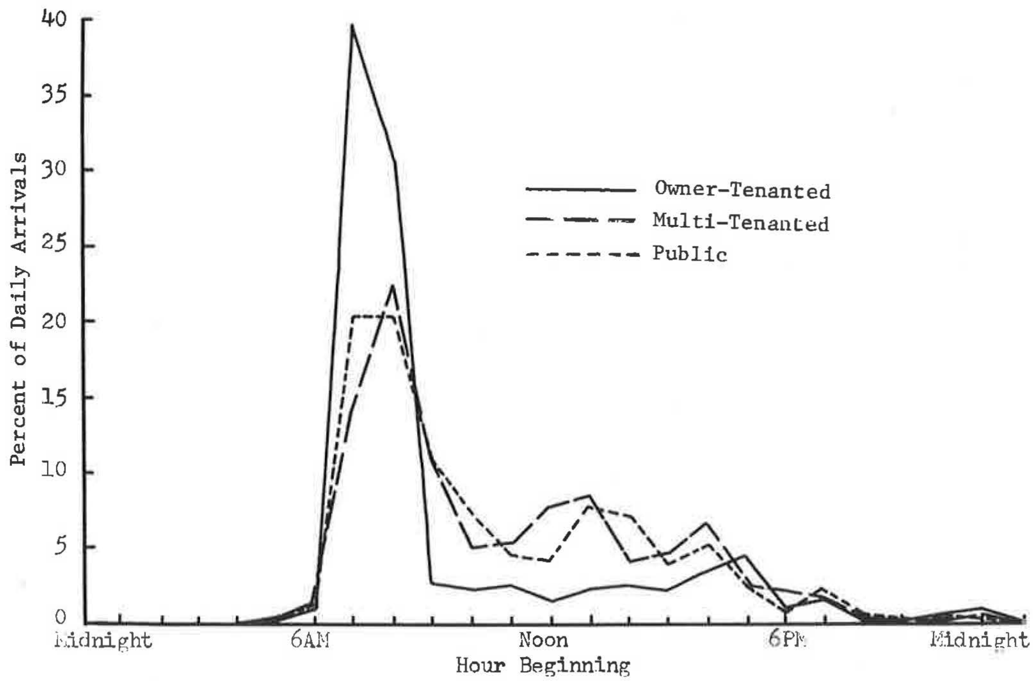

Figure E-6. Home interview auto driver trips to office buildings, by ownership and occupancy type.

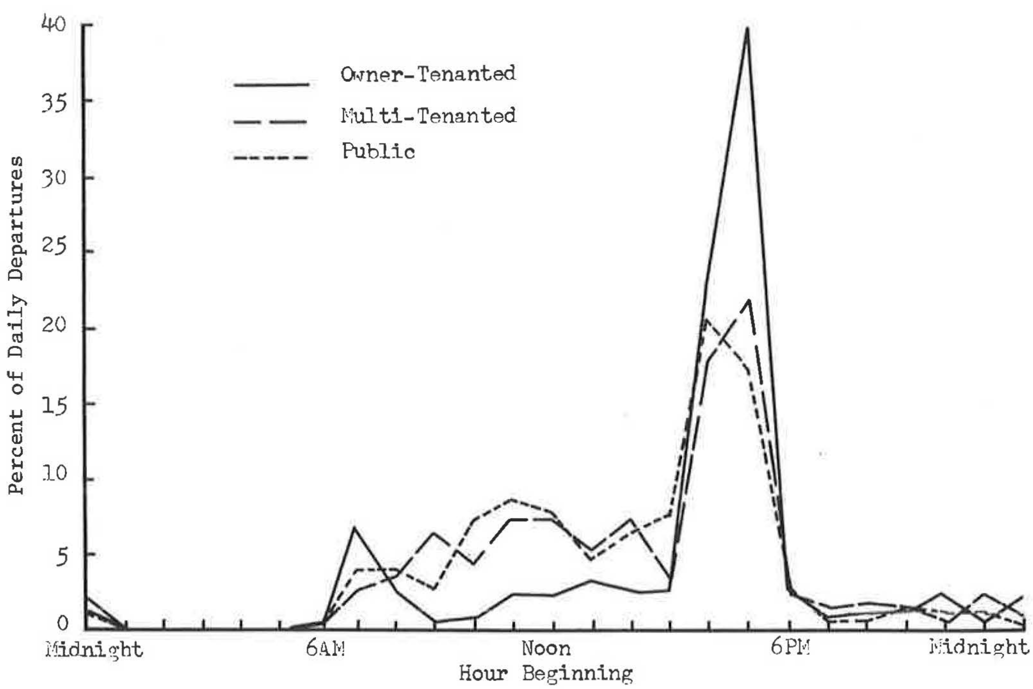

Figure E-7. Home interview auto driver trips from office buildings, by ownership and occupancy type.

and distances to the cross-section office buildings are functions both of the buildings themselves and of the sizes of metropolitan areas in which they are located.

Door-to-door travel times for all travel modes combined ranged from 11.0 to 33.4 min, the first to a public office building in Madison, Wis., the second to a private office building in Pittsburgh (see Table E-13). Differentials by building type, urban area size, and travel mode are given in Table E-14: in areas under 500,000 population, trips to private buildings take longer than trips to public buildings (not true in areas over 500,000 population, however); both classes of trips take longer in the larger urban areas; trips by transit take much longer than trips by automobile. In two cases work trips were shorter than nonwork trips. In

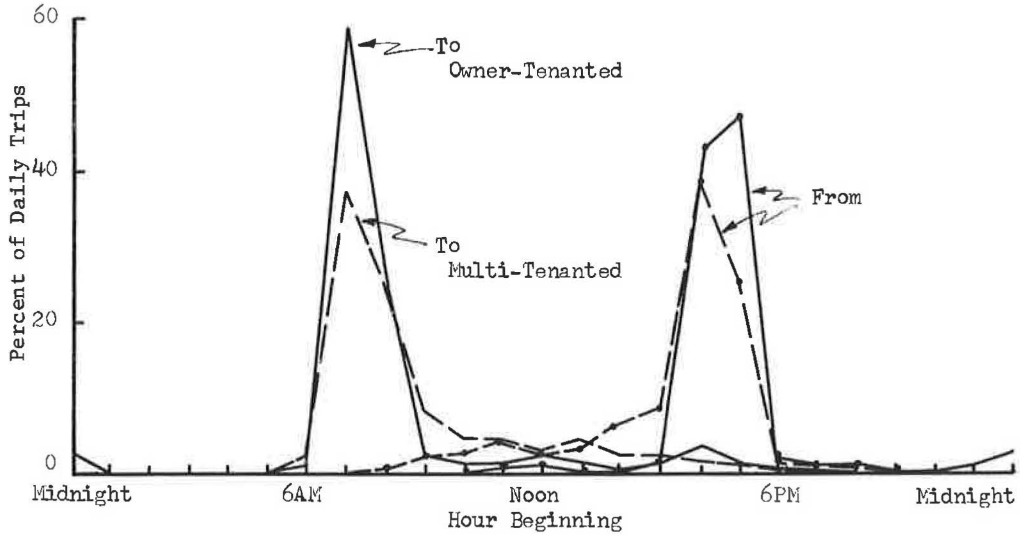

Figure E-8. Transit trips to and from office buildings.

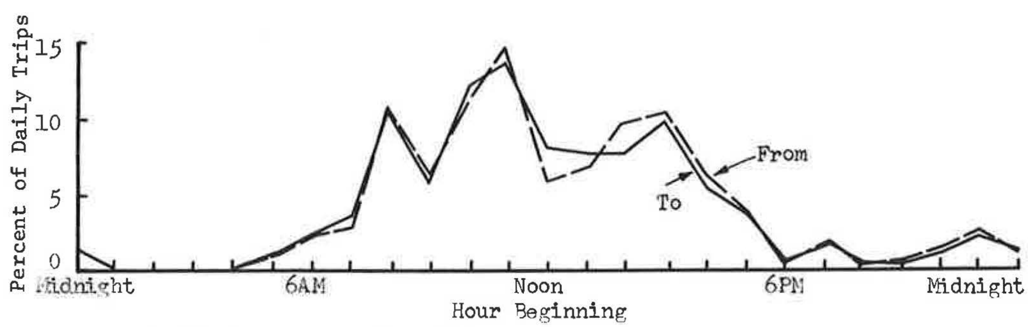

Figure E-9. Taxi trips to and from office buildings.

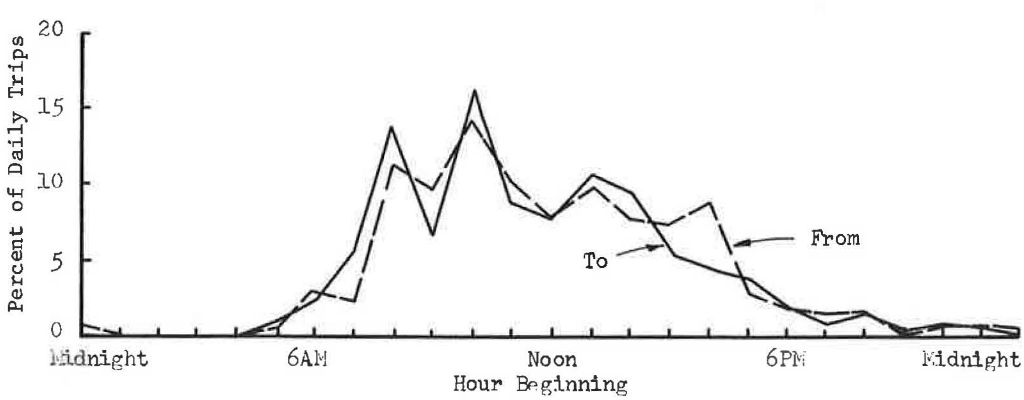

Figure E-10. Truck trips to and from office buildings.

TABLE E-13

HOME INTERVIEW TRIPS TO OFFICE BUILDINGS, AVERAGE DOOR-TO-DOOR TRAVEL TIME BY TRAVEL MODE AND TRIP PURPOSE TO, AND AVERAGE TRIP LENGTHS IN AIRLINE MILES

OFFICE BUILDING		AVG. DOOR-TO-DOOR TRAVEL TIME (MIN): BY MODE, ALL TRIP PURPOSES				BY TRIP PURPOSE, ALL MODES		AUTO DRIVER TRIPS	AVG. TRIP LENGTH (MI)	
NO.	TYPE	AUTO DRIVER	AUTO PSGR.	TRANSIT PSGR.	ALL	WORK	PERS. BUS.	TO WORK	ALL	TO WORK
1	Pub.	28.9	22.4	34.3	30.7	32.6	24.0	32.1	3.92	3.64
2	Pri.	33.5	34.1	32.9	33.4	33.6	25.5	33.5	5.42	5.39
3	Pri.	26.0	32.7	39.3	33.2	33.4	30.0	25.2	4.75	5.13
4	Pri.	22.7	28.0	29.1	24.7	26.3	22.0	25.1	5.73	4.96
5	Pub.	21.9	25.8	42.0	23.4	23.5	29.7	23.6	4.86	4.79
6	Pub.	14.2	15.0	18.0	14.8	14.6	15.6	14.2	2.69	2.96
7	Pri.	22.3	18.6	28.7	23.5	24.3	28.0	24.1	4.22	4.18
8	Pri.	21.7	21.8	28.8	23.5	26.1	19.7	26.3	4.59	4.30
9	Pub.	25.4	19.6	32.9	26.1	28.0	23.7	27.3	2.81	2.83
10	Pub.	13.1	15.5	19.7	13.8	13.8	14.4	12.8	2.40	2.56
11	Pri.	20.4	21.6	34.5	21.4	21.3	24.0	20.5	5.92	5.88
12	Pri.	20.6	20.4	26.6	21.3	22.2	19.4	21.5	3.92	3.79
13	Pri.	21.1	21.3	22.7	21.3	22.4	16.0	23.0	3.92	3.79
14	Pub.	12.3	12.0	22.2	13.0	13.2	16.2	12.5	2.36	2.33
15	Pub.	11.0	9.5	15.8	11.0	10.8	20.3	10.4	2.36	2.44
16	Pub.	29.5	30.0	27.3	28.6	31.7	20.8	32.1	5.26	4.78
17	Pri.	23.2	24.6	30.5	24.6	25.5	23.6	24.3	4.56	4.43
18	Pri.	17.0	16.5	29.2	19.9	21.8	26.2	16.3	3.62	3.19
19	Pri.	21.6	18.0	35.6	23.7	25.1	33.0	22.6	4.71	4.29
20	Pub.	24.8	25.5	29.0	25.7	26.0	26.9	22.5	4.61	4.64
Public		20.1	19.5	26.8	20.8	21.6	21.3	20.8	3.48	3.44
Private		22.7	23.4	30.7	24.6	25.6	24.3	23.9	4.67	4.48
All		21.6	21.6	28.9	22.9	23.8	22.9	22.5	4.13	4.02

three cases there was no significant difference. In 15 cases work trips were longer. This could be expected inasmuch as work trips occur predominantly at peak hours. Trips from reported higher travel times than trips to for every building examined. This is a clear reflection of greater congestion in the afternoon than in the morning travel peaks. Although the average was 5%, travel times were sometimes 15 to 20% higher.

Similarly, average trip distances also varied by urban area size and building type. For all purposes and travel

TABLE E-14

HOME INTERVIEW PERSON TRIPS TO OFFICE BUILDINGS AVERAGE DOOR-TO-DOOR TRAVEL TIME BY URBAN AREA SIZE AND BUILDING TYPE, BY TRAVEL MODE (UNWEIGHTED AVERAGES)

URBAN AREA SIZE	BUILDING TYPE	TRAVEL MODE: AUTO DRIVER	AUTO PASS.	TRANSIT PASS.	ALL
<500,000	Public	12.6	13.0	18.9	13.1
	Private	20.7	21.1	27.9	21.4
	Average	16.9	17.2	23.5	17.5
>500,000	Public	26.1	24.7	33.1	26.9
	Private	26.9	27.8	36.3	26.2
	Average	26.5	26.3	34.9	26.5

See Table E-13.

modes combined, the range was from 2.33 to 5.39 airline miles (see Table E-13). The one suburban building was an exception at 5.88 airline miles. The average for all public buildings was 3.44 airline miles; for all private buildings, 4.48 airline miles. This difference, and the corresponding difference in average travel times, may stem partly from traditional residence restrictions—city employees often must live in the city, for example—and partly from a higher proportion of intra-CBD trips both for work and personal business.

Parking, Distances Walked, and Vehicular Accumulations

More tripmakers to public buildings park free than do tripmakers to private buildings (Table E-15). Well over one-half of the auto driver trips to public buildings reported parking free, as did about one-half of those to owner-tenanted buildings, but only about 40% of those to multi-tenanted buildings. In all instances, most employees parked off-street (the shortage of long-term, on-street spaces generally dictates this), whereas most visitors parked on-street.

According to the tripmakers' reports, parking is fairly convenient; that is, blocks walked at the destination was most often reported at 0 or 1 block. With variable block lengths the precision of such responses is poor, particularly in view of various parking surveys having shown that walking distances are best measured to the nearest 100 ft. In general, however, the cross-section office buildings all tended to be located in parts of their respective CBD's that were well served by off-street parking facilities. Perhaps this is true of most major office buildings, the higher demand helping to create the necessary facilities.

Estimates of parking accumulation were made by assuming empty parking lots at 5 AM, and subtracting the hourly departures from the hourly arrivals for successive hours. Maximum accumulations, as percentages of total daily arrivals, were greatest at owner-tenanted buildings (Fig. E-11). From 9 AM to 3 PM the proportion holds steady at about 60%. Multi-tenanted buildings show a similar pattern, but with the maximum accumulation averaging about 35%. Public buildings peak in the morning at about 40%, followed by a dip at noon and an earlier decline during the late afternoon.

The composite curves mask a considerable range of values for individual samples. At private office buildings, peak accumulations range from 23% of the total daily vehicular arrivals for a multi-tenanted Seattle building to 91% for a Pittsburgh building which houses several major company headquarters. At public office buildings, peak accumulations range from 29% for a Madison building to 67% for a Pittsburgh building. The weighted average peak accumulations for public buildings, multi-tenanted, and owner-tenanted buildings are 42, 36, and 61%, respectively. Maximum accumulations occur from 9 to 10 AM at five buildings, at 10 to 11 AM for four, and at 11 to 12 AM for three. The four whose peak occurred in the afternoon showed lower than average peak percentages. Relationships between peak accumulations and building floor space or reported employment were irregular (see Table E-16).

Car Loading Factors

People most often drive to work alone. The average car loading for work trips ranged between 1.00 and 1.38 persons per car, with 15 out of 20 buildings producing values between 1.10 and 1.30 persons per car (see Table E-17). The over-all averages were 1.13 for multi-tenanted private buildings, 1.19 for public buildings, and 1.24 for owner-tenanted private buildings. Personal business and "other" trips had higher loadings, the all-buildings averages reaching 1.59 and 1.57 persons per car, respectively. With fewer of these nonwork trips, however, the average car loading for all trips to all buildings was only 1.33 persons per car, lowest of all generator types examined in this project (Table E-18).

The peak two-way traffic hour occurs at different times of the day for different buildings. It occurs three times at

TABLE E-15

REPORTED PARKING CHARACTERISTICS OF HOME INTERVIEW AUTO DRIVER TRIPS TO OFFICE BUILDINGS (PERCENTAGES)

OFFICE BUILDING TYPE	WORK TRIPS: OFF-STREET PAID	WORK TRIPS: OFF-STREET FREE	WORK TRIPS: ON[a] STREET	WORK TRIPS: NOT[b] PARKED	ALL OTHER TRIPS: OFF-STREET PAID	ALL OTHER TRIPS: OFF-STREET FREE	ALL OTHER TRIPS: ON[a] STREET	ALL OTHER TRIPS: NOT[b] PARKED
Public	28	41	29	2	10	15	43	32
Private:								
Owner-tenanted	45	38	17	—	7	8	11	74
Multi-tenanted	46	24	29	1	20	18	30	32
Balanced	73	22	5	—	—	—	—	100
Average	49	31	20	—	15	15	23	47
Average	39	36	24	1	12	14	35	39

[a] Includes parking on residential property.
[b] Auto left for service or repairs, cruised, or otherwise not parked. For nonwork trips, this category also includes serve passenger trips (see also Table F-17).

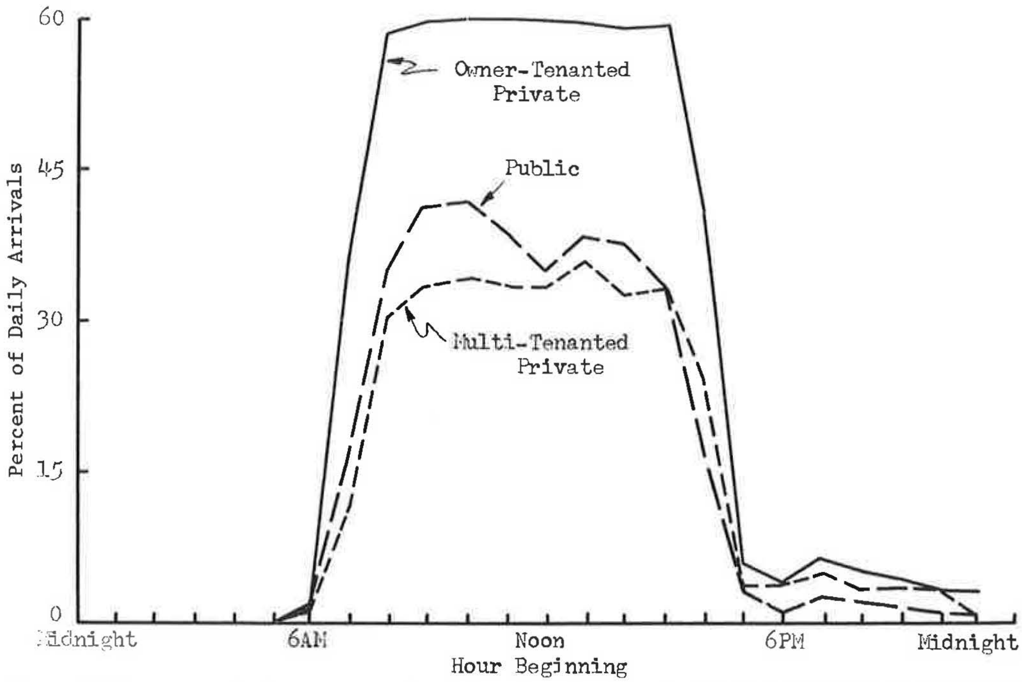

Figure E-11. Accumulation curves, auto driver trips to office buildings (assuming no accumulation at 5 AM).

7 to 8 AM, five times at 8 to 9 AM, twice at 4 to 5 PM, and six times at 5 to 6 PM. The three remaining samples whose two-way traffic could be examined showed peak hours at 9 to 10 AM, 10 to 11 AM, and 2 to 3 PM. These latter instances showed higher than average truck percentages, but lower than average total peak-hour percentages. Morning peaks are somewhat higher than afternoon peaks: in the eight cases where the two-way peak occurs in the morning "rush," the peak percentage is 22.2% of the total daily traffic and the directional tendency is 85%; in the eight cases with evening peaks, the peak percentage is 18.0%, and the directional tendency is 82%.

TRIP GENERATION

Person Trips

Of all building characteristics, floor space appears to be the most useful measure for trip generation. Two categories of floor space are considered—gross floor space, including washrooms, corridors, stairways, and other nonusable areas, and usable floor space, including only space used for offices and other activities generating trips to the building. Every sample site but one provided data on one or both of these measures. Estimates have been made of the missing figures where necessary.

Scattergrams between floor space and tripmaking generally show good correlations but rather high standard deviations. Daily person trips, for example, correlate with gross floor space (GFS) at $r = 0.79$, and with usable floor (UFS) at $r = 0.68$, but much variation is evident in Figure E-12. When public and private buildings are treated separately, public building trips show a better correlation with GFS than with UFS, whereas private building trips correlate better with UFS than with GFS. In general, floor space provides more accurate estimates of total person trip generation at private than at public buildings (see Table E-19 for statistical details of all relationships discussed in this section).

Correlations between person trips to work and floor space are somewhat better. Work trips correlate with GFS at $r = 0.64$, and with UFS at $r = 0.90$ (Fig. E-13). Public buildings work trips again correlate better with gross rather than usable floor space, but neither result is particularly good. By contrast, private building trips to work are much more predictable than are all trips, using either floor space figure ($r = 0.93$ and $r = 0.95$). Trips for nonwork purposes yielded very poor correlations for both public and private buildings.

Trip rates per 1,000 sq ft of floor space for individual buildings were quite varied. For public buildings, the average daily person trip rate was 7.43 trips per 1,000 sq ft GFS, with individual values ranging between 4.36 and 13.25 trips. For private buildings, the average was 6.44 trips per 1,000 sq ft GFS, with individual values ranging between 4.00 and 12.18 trips. The mean for all buildings was 6.86 trips. Person trips per 1,000 sq ft UFS for individual buildings ranged between 5.20 and 20.65 trips, with an average of 9.30 trips. Comparable figures for private buildings were 4.65 to 16.24 trips, with an average of 8.30 trips. The mean for all buildings was 8.75 trips.

By comparison, the London study (*68*) trip rate for all Central Area office space was 5.29 person trips per 1,000

TABLE E-16

TOTAL VEHICLE TRIPS, ALL SURVEYS, MAXIMUM PARKING ACCUMULATION CHARACTERISTICS [a]

OFFICE BUILDING	HOUR OF OCCURRENCE	PERCENT OF DAILY ARRIVALS	ACCUMULATION		
			MAXIMUM	1,000 EMPLOYEES	PER 1,000 SQ FT [b]
1	9 AM	66.6	759	349	1.84
2	11 AM	91.1	1654	351	1.91
3	9 AM	59.3	256	159	0.95
4	1 PM	51.9	856	NA	3.81
5	9 AM	42.1	1906	NA	7.14
6	10 AM	33.4	564	620	1.88
7	11 AM	61.5	1061	386	1.72
8	1 PM	38.7	1153	418	2.51
9	10 AM	49.7	1316	NA	2.93
10	10 AM	31.0	422	NA	2.89
11 [c]	NA	NA	NA	NA	NA
12	Noon	57.3	1321	467	3.11
13	10 AM	64.1	1659		
14	9 AM	29.6	433	510	1.70
15	2 PM	43.6	869	408	2.90
16	1 PM	56.5	510	NA	1.96
17	8 AM	41.6	652	NA	2.84
18	1 PM	24.9	290	NA	2.42
19	Noon	33.9	353	NA	1.70
20	9 AM	42.1	959	NA	1.85

[a] Assuming *no* accumulation at 5 AM.
[b] Usable floor space.
[c] Trips from not available.

TABLE E-17

HOME INTERVIEW AUTO DRIVER TRIPS TO OFFICE BUILDINGS, AVERAGE CAR LOADING AND TYPE OF PARKING

OFFICE BUILDING	PERSONS PER CAR, BY TRIP PURPOSE				REPORTED PARKING (% OF ALL AUTO DRIVER TRIPS)			
NO. TYPE	WORK	PERS. BUS.	OTHER	TOTAL	STREET	LOT	GARAGE	OTHER
1 Pub.	1.31	1.36	—	1.32	13	61	23	3
2 Pub.	1.26	2.00	—	1.27	3	17	78	2
3 Pri.	1.30	2.00	—	1.42	8	67	8	17
4 Pri.	1.09	1.18	1.86	1.20	13	66	10	11
5 Pub.	1.10	1.32	1.43	1.20	22	67	1	10
6 Pub.	1.05	1.46	1.92	1.32	NA	NA	NA	NA
7 Pri.	1.22	1.69	1.00	1.31	5	76	—	19
8 Pri.	1.13	1.21	1.68	1.26	22	60	5	13
9 Pub.	1.12	1.34	1.70	1.24	27	51	16	6
10 Pub.	1.22	1.72	1.91	1.53	59	24	1	16
11 Pri.	1.21	2.00	—	1.23	—	97	—	3
12 Pri.	1.15	2.11	1.00	1.26	33	52	1	14
13 Pri.	1.38	1.67	1.00	1.43	21	59	2	18
14 Pub.	1.23	1.52	1.97	1.40	45	15	29	11
15 Pub.	1.29	1.77	1.61	1.49	24	34	10	32
16 Pub.	1.22	1.40	1.50	1.31	33	46	9	12
17 Pri.	1.30	1.53	1.56	1.37	47	19	17	17
18 Pri.	1.00	2.18	2.23	1.53	35	43	6	16
19 Pri.	1.16	1.00	1.48	1.23	38	35	19	8
20 Pub.	1.18	1.27	1.22	1.21	51	31	14	4
Public	1.19	1.46	1.66	1.34	34	41	13	12
Private	1.20	1.69	1.48	1.32	21	54	13	12
All	1.20	1.59	1.57	1.33	26	49	13	12

TABLE E-18

AVERAGE CAR LOADING FACTORS, HOME INTERVIEW AUTO DRIVER TRIPS TO OFFICE BUILDINGS BY TRIP PURPOSE (UNWEIGHTED AVERAGES)

	TRIP PURPOSE TO			
OFFICE BUILDING TYPE	WORK	PERSONAL BUSINESS	OTHER	ALL PURPOSES
Public	1.19	1.46	1.66	1.34
Private:				
Owner-tenanted	1.24	1.87	1.00	1.31
Multi-tenanted	1.13	1.42	1.76	1.32
Average	1.20	1.59	1.57	1.33

See also Table E-17.

sq ft GFS (excluding bicycle and walking trips). In Chicago, 1956 rates were 4.6 and 5.7 person trips per thousand sq ft GFS for "public building" and "services" land uses in the Loop, respectively (*74*). The higher average rates reported in the present work are perhaps due to lower vacancy rates for the individual buildings studied than for these two central areas as a whole.

Looking at work trips only, the cross-section averages

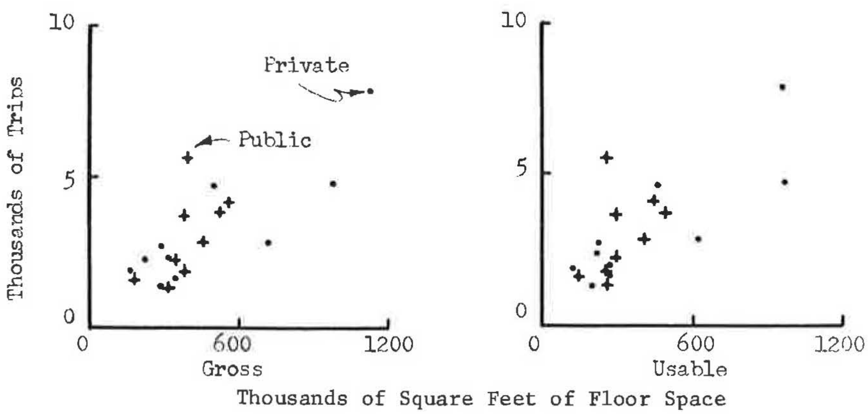

Figure E-12. Total person trips to office buildings related to floor space.

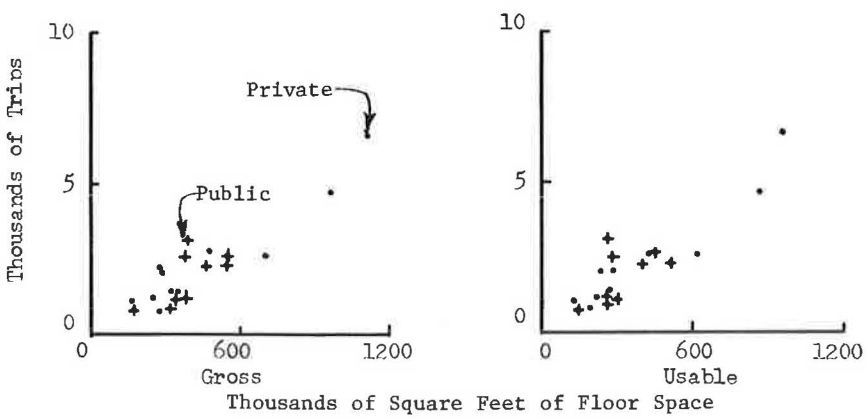

Figure E-13. Person trips to work at office buildings related to floor space.

TABLE E-19

SIMPLE REGRESSION RESULTS, OFFICE BUILDINGS

EQ. NO.	EQUATION [a]	r	N	$\frac{S_{YX}}{\bar{Y}}$
1	Total person trips to all office buildings = 715 + 5.287 GFS	0.79	19	0.32
2	Total person trips to all office buildings = 1,233 + 5.031 UFS	0.68	19	0.37
3	Total person trips to public office buildings = 269 + 6.762 GFS	0.61	9	0.34
4	Total person trips to public office buildings = 1,441 + 4.840 UFS	0.43	9	0.39
5	Total person trips to private office buildings = 599 + 5.248 GFS	0.86	10	0.30
6	Total person trips to private office buildings = 722 + 5.923 UFS	0.87	10	0.29
7	Person trips to work, all office buildings = 553 + 3.620 GFS	0.64	19	0.48
8	Person trips to work, all office buildings = 67 + 5.676 UFS	0.90	19	0.27
9	Person trips to work at public office buildings = —1,362 + 4.980 GFS	0.72	9	0.86
10	Person trips to work at public office buildings = 507 + 4.198 UFS	0.57	9	0.36
11	Person trips to work at private office buildings = —77 + 1.150 GFS	0.93	10	0.21
12	Person trips to work at private office buildings = 67 + 5.756 UFS	0.95	10	0.22
13	Total auto driver trips to all office buildings = 983 + 2.153 UFS	0.16	19	0.53
14	Total truck trips to all office buildings = 127 + 0.0268 GFS	0.07	19	6.743
15	Total truck trips to all office buildings = 52 + 0.0232 UFS	0.05	19	10.070

[a] GFS = gross floor space; UFS = usable floor space.

were 4.83 person trips per 1,000 sq ft GFS and 5.85 person trips per 1,000 sq ft UFS. For public buildings, the averages were 4.61 and 5.77 trips, respectively, with ranges from 2.97 to 7.31 trips for GFS, and from 3.54 to 11.39 trips for UFS. For private buildings, the averages were 5.00 and 5.91 trips, respectively, with ranges from 3.05 to 6.88 trips for GFS, and from 4.09 to 8.89 trips for UFS.

Work trips, as well as all trips, can also be related to employment. For the four public buildings where trip-survey-year employment could be determined, there were 0.92 first work trips per employee; for six private buildings, similarly, there were 0.84 first work trips per employee. These represent fairly typical absentee rates (allowing, also, for some under-reporting of trips). Total person trips per employee averaged 1.30 for all ten buildings, but 1.76 for the public buildings, compared to only 1.17 for the private

TABLE E-20

COMPOSITION OF TRAFFIC TO AND FROM SELECTED OFFICE BUILDINGS

	DAILY TRAFFIC TO AND FROM (%)				PEAK-HOUR TRAFFIC TO AND FROM		
OFFICE BUILDING	CARS	TAXIS	LIGHT TRUCKS [a]	OTHER TRUCKS [b]	PERCENT OF DAILY TRAFFIC	PERCENT TRUCKS [b]	DOMINANT DIRECTION (%)
Public	89.4	2.2	6.9	1.5	18.0	1.0	78
Private	92.5	2.0	4.3	1.2	20.2	0.2	84
All	90.9	2.1	5.6	1.4	19.2	0.6	81

[a] Light trucks have four tires only.
[b] Six or more tires.
See also Table E-25.

buildings. The latter average is brought down by the uniformly low rates for four owner-tenanted private buildings—1.09 trips per employee. The two multi-tenanted private buildings and the four public buildings together averaged 1.63 trips per employee.

Auto Driver Trips

Variability of transit use at individual buildings is the probable cause of poor correlations between auto driver trips and floor space (Fig. E-14). This is reflected in the wide range of trip rates; from 2.66 to 16.14 auto driver trips per 1,000 sq ft UFS for public buildings, and from 1.47 to 9.32 trips for private office buildings. Mean values were 5.67 and 4.14 trips, respectively. It is interesting to compare again Thompson and Stegmaier's (*64*) findings for two office buildings in downtown Baltimore; although person trip rates were 5.84 and 9.00 per 1,000 sq ft UFS, on the same order as rates for the present samples, auto driver trip rates in 1945 were only 0.78 and 1.71 per 1,000 sq ft UFS.

Transit Trips

Inasmuch as transit tripmaking is primarily related to transit service levels (which in turn are related to city type and size) and to tripmaker attributes, no attempt was made to relate the variable to building characteristics. Instead, transit trip percentages at the individual buildings were compared to the transit trip percentages for all trips to the CBD's in which the buildings were located (see Table B-4 for the latter). In all but one case, the percentage was less than, but strongly related to, the CBD percentage. On the average, the office buildings/CBD ratio was 0.72, and a scattergram with that slope presents a reasonable fit.

Peak-Hour Trip Generation

Trip generation ranking by building type varies by time of day; for example, although public buildings develop higher floor area trip rates on a daily basis, owner-tenanted private buildings develop higher floor area trip rates on a peak-period basis (Table E-21). Moreover, rankings may vary as between morning and afternoon peak periods: multi-tenanted private buildings develop the lowest AM trip rates, but the highest PM trip rates. Trip rates per employee, however, are fairly consistent throughout—from 0.80 to 1.03 peak-period trips regardless of building type—and for this reason represent the better approach to peak-hour trip generation.

TRIP DISTRIBUTION

Trip rate curves describe the distribution of trip origins at various distances or travel times from the office building. Rates are expressed as trips per 1,000 population. Based on home interview trips only, rates are calculated to a distance of 10 miles or a travel time of 20 min by 1-mile and 2-min increments, respectively (see footnote under "Trip Distribution," Appendix B).

Distance Rates

Trips per 1,000 population decrease with increasing distance from both public and private buildings (Fig. E-15). The principal difference is that public buildings attract more short trips—38% of all trips to the five public buildings illustrated were less than 2 miles long, compared to only 21% of all trips to the four private buildings shown. This difference is reflected in the steeper slope of the public buildings trip rate curve. Further examination showed that home-based work trip origins within 2 miles exhibited about the same distribution for each building type. However, 13% of all nonhome-based work trips and 16% of all nonwork trips to public buildings originated within 2 miles, as compared to 3 and 4%, respectively, to private buildings. In general, nonwork trip rates were less sensitive to distance (had flatter slopes) than were work trip rates, probably because such trips are made less frequently and for more specialized purposes.

Time Rates

Trip rates also decrease systematically with increasing travel time (Fig. E-16). Any difference between public and private trip rate curves largely disappears; averages for 4-min instead of 2-min time increments would bring the two curves close together. Of all public building trips, 35%

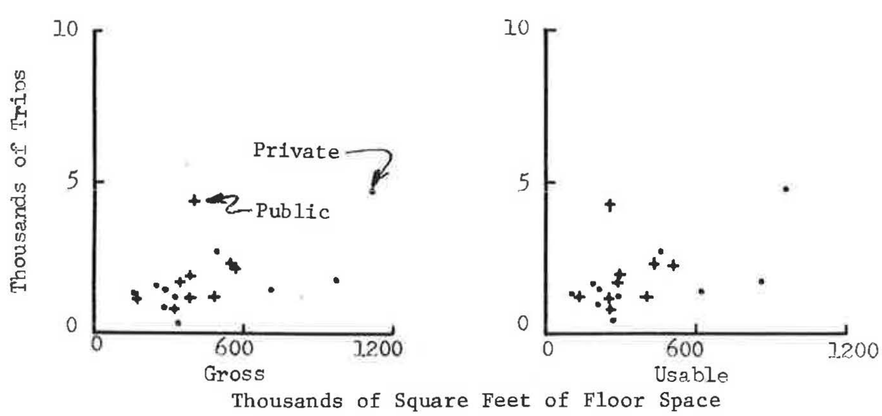

Figure E-14. Total auto driver trips to office buildings related to floor space.

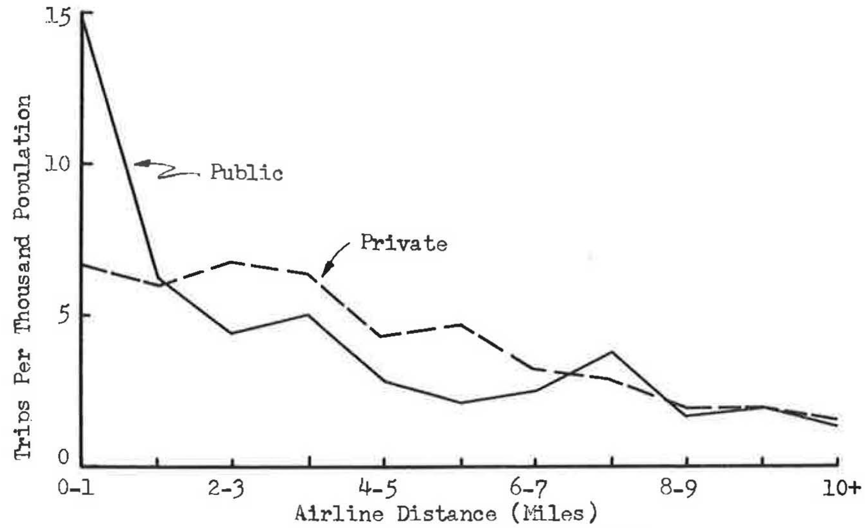

Figure E-15. Person trip rates for office buildings, by distance.

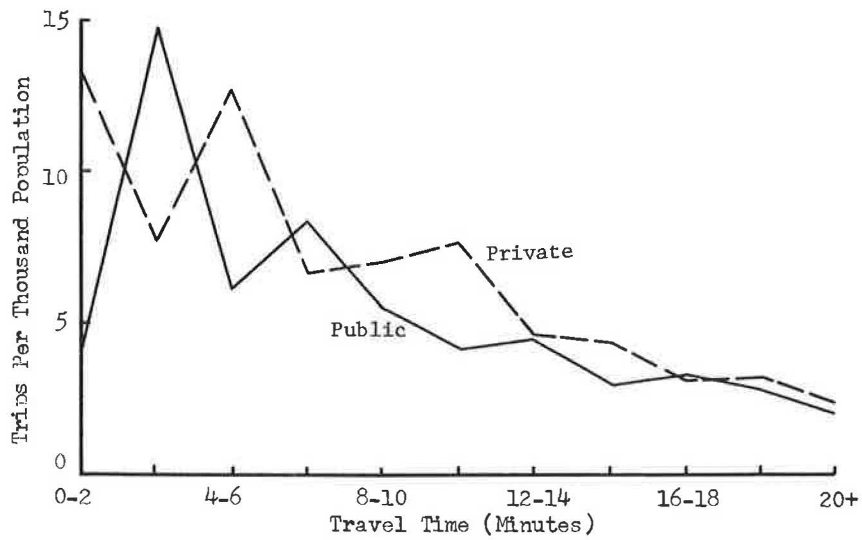

Figure E-16. Person trip rates for office buildings, by time.

TABLE E-21

PERSON TRIPS DURING THE 7-9 AM AND THE 4-6 PM PEAK PERIODS RELATED TO FLOOR SPACE AND EMPLOYMENT

OFFICE BUILDING TYPE	7-9 AM PERSON TRIPS PER 1,000 SQ FT GFS	UFS	7-9 AM PERSON TRIPS PER EMPLOYEE	4-6 PM PERSON TRIPS PER 1,000 SQ FT GFS	UFS	4-6 PM PERSON TRIPS PER EMPLOYEE
Public	3.70	4.63	1.03	3.40	4.26	0.92
Private:						
Owner-tenanted	4.53	5.31	0.87	3.93	4.60	0.80
Multi-tenanted	2.66	3.17	0.83	4.46	5.32	0.95
Average	4.10	4.89	0.89	3.88	4.70	0.88

are shorter than 10 min, compared to 30% of those to private buildings. Public and private buildings attract 21 and 20% of their trips, respectively, from areas more than 20 min away. This comparison of trip rate curves by travel time vs distance (Fig. E-16 vs Fig. E-15) shows again why travel time is usually the better basis for describing trip distribution.

Directional Distribution

The directional distribution of trip origins generally follows the directional distribution of population. That is, if 25% of the study area population falls into a sector, 25% of the office building trip origins will, also. Table E-22 gives such comparisons for public buildings in five different cities, and for private buildings in three different cities. Somewhat better matching would result were the population by sector weighted by its relative distance to the sample office buildings.

On the other hand, the more sectors that were considered, the worse the comparisons would become. Trip origins tend to bunch by area. Professional, managerial, and technical tripmakers more often live in high-income suburban communities, whereas clerical and service worker tripmakers more often live in medium-income areas of the inner city. Both bunching and occupational selectivity are illustrated by Figure E-17, which shows the location of per-

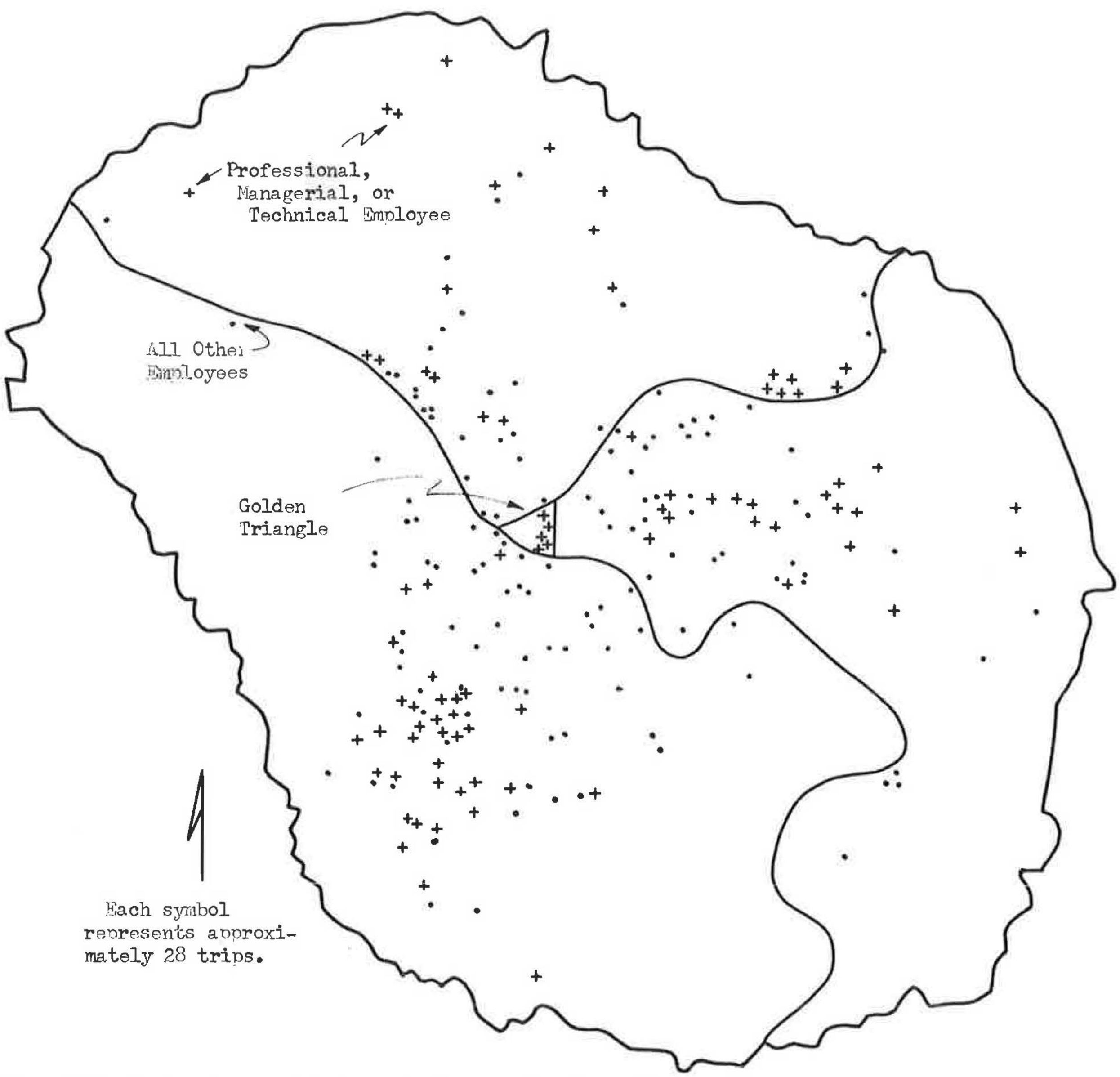

Figure E-17. Origins of person trips to work at two private office buildings in the Pittsburgh "Golden Triangle," by tripmaker occupation group.

TABLE E-22

COMPARISON OF PERCENTAGES OF STUDY AREA POPULATION AND STUDY AREA OFFICE BUILDING TOTAL PERSON TRIP ORIGINS, BY STUDY AREA SECTOR

OFFICE BUILDING TYPE	BUILDING SAMPLE NUMBER	SECTOR 1		SECTOR 2		SECTOR 3	
		POP.	TRIPS	POP.	TRIPS	POP.	TRIPS
Public	1	38	57	44	28	18	15
	5	39	41	10	11	51	48
	14	49	50	51	50	—	—
	16	59	62	41	38	—	—
Private	2	39	31	44	48	17	21
	7	76	72	17	24	7	4
	17	59	71	41	29	—	—

son work trip origins for two private office buildings in Pittsburgh. Trips by professional workers average 5.9 air-line miles—compared to the nonprofessional workers' 4.9 airline miles—and they tend to start from commonly favored residential areas.

Variability in CBD office building trip rates may be explained in part by variations in the employment accessibility of different sectors. Although the CBD, as the dominant workplace in most urban areas, may be the principal determinant of work trip accessibility from residential zones or sectors, accessibility is also influenced by the location of non-central employment centers. Thus, of several residential areas at equal travel times from downtown, some may send fewer trips to the CBD because they are more accessible to other employment. Conversely, other areas may send more trips downtown because they are less accessible to other employment.

Trip rates to Seattle office buildings provide a good example; the south sector is more accessible to all jobs than is the north sector, whereas its office building trip rates are lower. Like the university trip rates, predicted average trip rates by time increment more closely approximated the observed trip rates when they were multiplied by the ratio of the average accessibility index for all areas at that travel time to the index for the particular area. Although this was demonstrated for four out of five subareas in the Seattle sectors, the relationship held for only two out of six cases in Wilmington sectors. However, two of the non-conforming Wilmington sectors were observed to contain disproportionate numbers of low-income families.

The effect of income on office building trip rates could only be guessed at in both Seattle and Wilmington. In Seattle, auto ownership was substituted for unavailable household income data. Higher auto ownership was associated in every case with the higher trip rates by subarea. In Wilmington, where income by sector could be approximated only from income data by larger areal units, the higher-income sectors also produced higher trip rates. Similar results have been observed elsewhere. In Washington, D.C. (*75*), "low income families were not as likely to work in the CBD as were higher income families." Whether or not that is also the case for Seattle and Wilmington, the coincidence of higher trip rates, higher income, and lower accessibility suggests that higher income families are willing to pay the higher transportation costs implied by lower accessibility.

A possible solution that might explain the joint influence of both accessibility and income might be derived from accessibility indices calculated for both blue- and white-collar residential and employment locations. Even without these further refinements, however, it is clear that the distribution of office building trip origins is mainly associated with population. In determining the traffic volumes on approaches to downtown buildings, distribution by population alone does not lead to serious errors. Although the present evidence is strong enough to suggest the values of further refinement by accounting for accessibility and income differentials, it is insufficient for developing and fully testing the needed procedures here.

TRAVEL IMPACT ON HIGHWAY NETWORK

The worst congestion in urban highway systems typically develops on radial routes connecting the CBD and outlying residential districts. Office buildings are often the prime source of traffic, with unbalanced directional flows occurring in sharply defined peaks. High ratios of floor space to land area combined with shoulder-to-shoulder spacing create more intensely concentrated travel patterns than does any other type of land use.

Although an individual office building may generate but a small part of the daily travel in a metropolitan area, when more rigorous limits of time and space are imposed it may have considerable impact. By way of illustration, Table E-23 begins to narrow the focus from the metropolitan area to the streets around three Pittsburgh office buildings.* The largest generates less than 0.33% of the area's travel, and only 3% of the zonal travel. In the evening peak hour, however, some 17% of the arterial street capacity in the

* The impact on a single major access street has not been evaluated for office buildings. Although it was originally intended to study isolated office buildings, particularly those near or adjacent to highway interchanges, downtown locations had to be selected because few examples of isolated sites could be paired with travel survey data. The downtown areas' diffused pattern of trip origins and many approach streets makes the single major access street analysis inappropriate.

zone is required solely to accommodate travel from this one building. (The possibility of indirect travel necessitated by one-way streets or turn prohibitions is not considered in the calculation; this factor, unique to each location, probably accentuates the normal congestion.)

The peaking character of office building travel is even more pronounced than the usual 1-hr analysis period suggests. Study by 6-min periods shows that the vehicular arrivals and departures within such brief time spans are reported to be as high as 10 to 12% of the total daily travel. The same analysis, for buildings in Pittsburgh, Seattle, and Miami, showed that these peaks-within-peaks occur at different times from one building to another; whether planned or not, even such minor staggering of work hours is indeed a fortunate happenstance for the city traffic engineer.

PREDICTING AND TESTING RELATIONSHIPS

The effectiveness of trip generation and distribution procedures is best evaluated by applying them to a new situation. Appendix I gives the technique and results of doing so for two private office buildings in Pittsburgh and one public building in Atlanta. Predicted total person trips were higher than reported trips by 10, 2, and 25%, respectively. Inasmuch as the Pittsburgh trip data did not include serve passenger trips, and the Atlanta data did not include external trips, the results are encouraging. The prediction of trip distribution by sector was based on the distribution of population by distance within each sector. Results were extremely close to the distribution of reported trips for one Pittsburgh building, fair for the second, but considerably different for two of four sectors drawn for the Atlanta public building. The remedy in this instance is probably a population distribution after stratification by race, but these data were not available for the test.

TRENDS

Most city dwellers are well aware of the office building "boom." Although it is often identified with New York City, where one-half of the office space in the United States is located (*76*), almost all metropolitan areas have participated in it. The postwar demand has stemmed from several factors—the continued growth of population and employment, the increased share of employment housed in office buildings, the increased amount of floor space per worker, and the functional obsolescence of many older buildings (*77*). The modern buildings are also taller and better designed than ever: it has been said that if efficient buildings don't make people more productive, at least they seem to be important in attracting productive people.

Although most of the new construction has taken place in central business districts, outlying areas have also shared in the development, and for good reasons (*78*):

> With the World War II suburban boom came the national trend toward suburban office space. Not only firms or offices which might benefit directly from a suburban location near their customers (i.e., surburban real estate operators, doctors and dentists, etc.), but also, in many cities, large firms moved their regional offices from the core. The factors influencing this trend were the availability of inexpensive land for new facilities and ease of access for both employees and customers. With lower land costs it was possible to reduce construction costs (by erecting a one,- two,- or three-story building, instead of being forced to expensive high-rise within the downtown). It was also possible to provide such advantages and amenities as employee and customer parking, extensive landscaping, etc., at a relatively low capital outlay.

A recent trend is toward the suburban "office park." The Southdale Office Center in suburban Minneapolis, for example, will provide 500,000 sq ft (roughly 2,500 jobs) of office rental space in a cluster of six buildings ranging from 6 to 10 stories high (*79*). Wehrly (*80*) has said: "The office park is emerging as an identifiable land-use complex in much the same manner as the shopping center and the industrial park has during recent years." This contrasts sharply with developments toward "commuting" by elevator. Several new or proposed buildings in Pittsburgh, Miami, Milwaukee, and Chicago combine apartment units and office space, usually with office space on the lower levels (*81*). The John Hancock Center in Chicago actually puts most of the downtown elements of hotels, apartments, offices, retail stores, and parking into a single 100-story building (*82*).

How might other trends affect travel to existing downtown office buildings? First, reasonably new buildings in economically sound downtowns will continue to have relatively stable trip generation rates. Although automation

TABLE E-23

TRAVEL IMPACT OF VEHICULAR TRIPS TO SELECTED OFFICE BUILDINGS IN PITTSBURGH, BY STUDY AREA AND TRAFFIC ZONE

OFFICE BUILDING	BUILDING TRIPS VMT AS % OF STUDY AREA TRAFFIC	% OF ZONAL ARTERIAL STREET DESIGN CAPACITY USED BY BUILDING TRIPS		% OF ZONAL ARTERIAL TRAVEL REPRESENTED BY BUILDING TRIPS	
		24 HOUR	PEAK HOUR	24 HOUR	PEAK HOUR
1	0.12	1.5	2.3	4.7	10.4
2	0.29	2.6	4.1	8.0	17.6
3	0.06	0.6	0.8	1.3	2.7

Source: Pittsburgh Area Transportation Study.

TABLE E-24

SUMMARY OF TRIPS TO OFFICE BUILDINGS, BY SURVEY SOURCE

	BUILDING	HOME INTERVIEW					ROADSIDE			TRUCK-TAXI	
CITY	NO. TYPE	AUTO DRIVER	AUTO PSGR.	TRANS. PSGR.	TAXI PSGR.	WALK-TO-WORK	AUTO DRIVER	AUTO PSGR.	TRUCK	TRUCK	TAXI
Pittsburgh	1 Pub.	1064	307	1461	—	53	30	30	—	45	50
	2 Pri.	1529	93	1892	56	33	215	176	—	72	123
	3 Pri.	331	300	757	—	79	65	50	—	35	11
Miami	4 Pri.	1461	293	567	22	NA	78	23	2	108	35
	5 Pub.	4232	868	315	—	NA	77	22	—	219	—
Wichita	6 Pub.	1562	508	98	15	—	31	37	—	95	40
Minneapolis	7 Pri	1445	565	794	—	NA	28	33	—	252	10
	8 Pri.	2715	821	108	27	NA	49	40	—	216	40
New Orleans	9 Pub.	2214	660	1014	—	62	60	43	—	373	210
Salt Lake	10 Pub.	1038	368	96	90	—	29	30	7	288	28
Wilmington	11 Pri.	1154	550	61	—	—	216	95	13	111	3
	12 Pri.	1594	670	328	—	160	632	545	9	70	5
	13 Pri.	1982	916	296	15	16	564	603	8	33	9
Madison	14 Pub.	1109	212	113	24	47	206	132	5	143	21
	15 Pub.	1573	770	392	34	220	330	347	12	78	35
Seattle	16 Pub.	703	309	213	26	83	24	14	5	170	—
	17 Pri.	1462	506	599	28	102	25	11	2	79	15
	18 Pri.	1114	422	368	—	33	4	8	—	48	30
	19 Pri.	949	115	271	25	6	25	3	3	63	60
	20 Pub.	2183	627	886	—	54	36	24	10	48	15
	Public	15678	4629	4588	189	519	823	679	39	1459	399
	Private	15736	5251	6041	173	429	1901	1587	37	1087	341
	All	31414	9880	10629	362	948	2724	2266	76	2546	740

TABLE E-25

PEAK PERCENTAGES AND DIRECTIONAL TENDENCY OF TRIPS TO AND FROM SELECTED OFFICE BUILDINGS, ALL SURVEYS

	DAILY TRAFFIC TO AND FROM			PEAK-HOUR TRAFFIC TO AND FROM		
OFFICE BUILDING	PASSENGER CAR UNITS PLUS TRUCKS [a]	TRUCKS (%)	PEAK HOUR	PERCENT OF DAILY TRAFFIC	TRUCKS IN DOMINANT DIRECTION (%)	TOTAL TRAFFIC IN DOMINANT DIRECTION (%)
1	2378	1.9	8–9 AM	27.3	—	92 [b]
2	3822	1.8	8–9 AM	25.0	—	99 [b]
3	884	—	9–10 AM	18.0	—	77 [b]
4	3398	2.4	5–6 PM	15.3	—	94
5	9056	0.5	5–6 PM	13.7	—	82
6	3289	—	2–3 PM	11.1	—	72 [b]
7	3585	1.4	7–8 AM	31.7	—	84 [b]
8	5968	2.7	8–9 AM	13.6	2.0	82 [b]
9	5842	2.8	8–9 AM	14.1	—	82 [b]
10	2912	4.5	10–11 AM	13.8	3.8	52 [b]
11 [c]	NA	NA	NA	NA	NA	NA
12	4630	0.5	5–6 PM	24.7	—	86
13	5036	0.6	5–6 PM	25.2	—	96
14	2925	4.5	4–5 PM	16.2	4.9	81
15	4002	1.2	7–8 AM	32.4	—	77 [b]
16	1721	—	7–8 AM	21.2	—	74 [b]
17	3028	—	4–5 PM	19.6	—	69
18	2217	—	5–6 PM	16.3	—	70
19	2042	—	5–6 PM	12.8	—	81
20	4373	—	8–9 AM	12.0	—	89 [b]

[a] Passenger car units include taxis and all trucks with only four tires; trucks include all vehicles with six or more tires.

[b] Dominant direction is to the office building.

[c] Trips from not available.

means probable further substitution of machines for employees, there are signs that the amount of floor space per employee is leveling off. Second, if transit demand continues downward auto driver trip generation will increase. Third, average trip lengths will increase as the population decentralization creates more dispersal of office building trip origins, thus accentuating the relative impact of this segment of downtown tripmaking on the highway network.

CONCLUSION

The office buildings studied were often the biggest or otherwise most outstanding in their communities. Person trips to and from these buildings ranged from 3,200 to more than 11,000 daily. Public buildings averaged 6,000 daily trips and the private buildings 5,700 trips. Beside other land uses (except State Capitol) investigated in the present research, such volumes seem small. But because office buildings cluster together in small land areas, they may be collectively responsible for more traffic congestion than any other single land-use category.

Travel characteristics are dependent on the type of activities associated with the buildings. For this reason, three types of buildings were designated: public office buildings, private predominantly owner-tenanted, and private predominantly multi-tenanted, some with more than 100 tenants. Those public buildings which house only one agency have travel characteristics generally similar to private owner-tenanted. The different building types attract different proportions of trips by purpose, at different times of the day, at different rates per 1,000 sq ft of floor space, and with different parking accumulation characteristics.

Work trips account for most travel, but personal business and serve passenger trips, although highly variable proportions of travel at individual buildings, account for almost one-third of the travel to all the buildings examined. Three-quarters of all trips are made by automobile, with an average car occupancy of 1.3 persons for all trips, and only 1.2 persons for work trips. Transit tripmaking varies from city to city, but is strongly related to the modal split of the CBD as a whole. Travel to office buildings by trucks and taxis accounts for almost 10% of daily vehicle trips, mostly in off-peak periods.

The highest peak hours occur at owner-tenanted buildings, where as much as one-third of the daily person movements may take place in a single hour. Typically, however, for all buildings, the highest hour is 18% of the daily total travel and occurs in the morning. The evening peak is slightly lower. During the peaks, an office building may require more than 15% of the nearby street capacity to serve arriving or departing vehicles. Even though daily volumes are small, these figures illustrate the importance and impact of office building travel.

Most parking was in off-street lots. On-street parking was reported by one-third of the auto drivers to public buildings, but by only one-sixth of those to private buildings. Average peak parking accumulations were 42, 36, and 61% of daily vehicle arrivals for public, multi-tenanted, and owner-tenanted buildings, respectively. The average length of stay for auto driver trips is slightly under 6 hr for all samples, with little difference between values for public and private buildings.

Total travel can be estimated from employment or floor space. If the number of employees is known, peak-hour travel can be estimated directly. If only floor space figures are available, preferably usable floor space, total daily person trips can be estimated (more reliably for private buildings than for public buildings) and peak-hour percentages applied. Nonwork trip proportions vary greatly, and no estimation method could be found that was better than using average percentages by building type. Estimates of approach volumes by direction can be obtained by applying trip rates to population grouped by time or distance from the generator. The data suggest that measures of accessibility or income should be included in any procedure for trip allocation, but there were too few examples where a method of incorporating these added refinements could be tested and proved out.

APPENDIX F

REGRESSION AND BACKCHECK RESULTS—HOSPITALS

MULTIPLE REGRESSION RESULTS

The stepwise linear regression analysis program developed by the University of California School of Medicine was run using 18 independent and 6 dependent variables for 57 general hospitals for which comparable data could be assembled. It is impossible in this general report to reproduce the full computer outputs. What is shown in tabular form are (1) the predictive equations having the lowest standard error of the estimate (not necessarily corresponding to the highest multiple coefficient of determination), (2) the standard errors for each coefficient in the predictive equations, (3) the standard error of the estimate as a percent of the dependent variable mean ($S_E/\overline{Y}$) for each of the six "best" equations, (4) the multiple coefficient of determination (R^2) for each, and (5) all independent variables for each dependent variable listed by rank importance, showing the corresponding increase, if any, in R^2 as each variable is added to the predictive equation incorporating all independent variables. The full computer output is available to qualified researchers upon written request to the Program Director of National Cooperative Highway Research Program.

TABLE F-1

DEFINITIONS OF VARIABLES USED IN MULTIPLE REGRESSION EQUATIONS FOR HOSPITALS, AND AVERAGE VALUES FOR $N = 57$

SYMBOL	DEFINITION	AVG. VALUE FOR $N = 57$
Independent variables:		
X_1	Hospital beds	453
X_2	Hospital personnel	854
X_3	Population (in thousands) within 3-mile radius	185
X_4	Autos owned (in thousands) within 3-mile radius	49
X_5	Autos per person within 3-mile radius	0.285
X_6	Study area population (in thousands)	910
X_7	Ratio of X_3 to X_6	0.254
X_8	Years since hospital established	60
X_9	Average length of hospital stay (days)	9.03
X_{10}	Annual hospital admissions (in hundreds)	148
X_{11}	Hospitals bassinets	58
X_{12}	Hospital site gross acreage	15.7
X_{13}	Hospital total floor space (in thousands)	336
X_{14}	Ground area ratio	1.34
X_{15}	Annual outpatients (in thousands)	49
X_{16}	Net residential density within 3-mile radius	35.6
X_{17}	Ratio of X_1 to total hospital beds in study area	0.142
X_{18}	Ratio of average daily census to X_1	0.80
Dependent variables:		
Y_{19}	Transit trips as percent of total person trips	12.2
Y_{20}	Auto driver trips to work	647
Y_{21}	Auto driver trips to nonwork purposes	857
Y_{22}	Transit trips	328
Y_{23}	Total auto driver trips	1504
Y_{24}	Total person trips	2672

TABLE F-2

RANK ORDERING OF INDEPENDENT VARIABLES AND INCREASING R^2 AS THEY ARE ADDED TO PREDICTION EQUATIONS [a]

Y_{19}		Y_{20}		Y_{21}		Y_{22}		Y_{23}		Y_{24}	
RANK ORDER	R^2	RANK ORDER	R^2	RANK ORDER	R^2	RANK ORDER	R^2	RANK ORDER	R^2	RANK ORDER	R^2
3	0.46	2	0.75	2	0.71	1	0.44	2	0.78	2	0.84
9	0.61	12	0.84	14	0.74	3	0.63	3	0.83	14	0.86
17	0.66	3	0.87	18	0.78	15	0.69	14	0.85	13	0.88
5	0.71	9	0.88	13	0.79	4	0.73	9	0.86	18	0.89
15	0.73	13	0.89	12	0.80	7	0.76	13	0.88	9	0.89
2	0.74	15	0.89	5	0.81	18	0.77	18	0.89	12	0.89
7	0.76	14	0.90	9	0.81	9	0.78	15	0.89	10	0.89
12	0.76	11	0.90	1	0.81	14	0.78	1	0.89	1	0.90
10	0.76	16	0.91	8	0.81	12	0.79	4	0.89	11	0.90
11	0.76	4	0.91	15	0.82	6	0.79	16	0.90	4	0.90
8	0.77	6	0.91	16	0.82	8	0.79	12	0.90	16	0.90
14	0.77	17	0.92	7	0.82	10	0.79	7	0.90	5	0.90
13	0.77	8	0.92	6	0.82	16	0.79	17	0.90	15	0.90
1	0.77	1	0.92	4	0.82	17	0.79	5	0.90	7	0.90
16	0.77	5	0.92	10	0.82	5	0.79	11	0.90	3	0.90
18	0.77	10	0.92	17	0.82	2	0.79	8	0.90	6	0.90
4	0.77	18	0.92							8	0.90
										17	0.90

[a] Independent variables not given were not significant at the 95% confidence level.

TABLE F-3

SELECTED MULTIPLE REGRESSION RESULTS FOR 57 GENERAL HOSPITALS

R^2	S_E (% OF Y)	EQUATION AND (STANDARD ERRORS)
0.76	35	$Y_{19} = 194 + 0.048X_2 + 0.353X_3 - 475.516X_5 - 148.394X_7 + 7.311X_9 + 0.256X_{15} - 0.012X_{17}$ (0.020) (0.101) (134.338) (76.069) (1.783) (0.112) (0.113)
0.92	28	$Y_{20} = 390 + 0.838X_2 - 2.530X_3 + 6.221X_4 - 0.242X_6 - 19.425X_9 - 0.336X_{11} + 2.316X_{12} + 0.677X_{13}$ (0.109) (0.993) (3.754) (0.115) (8.042) (0.969) (1.631) (0.208) $-0.529X_{14} - 1.062X_{15} + 3.495X_{16} - 1.011X_{17}$ (0.258) (0.493) (2.637) (0.508)
0.81	32	$Y_{21} = -690 + 0.912X_1 + 0.481X_2 - 0.381X_3 + 611.955X_5 - 0.896X_8 - 29.555X_9 - 5.714X_{12} + 0.515X_{13}$ (0.857) (0.315) (0.549) (856.793) (1.650) (18.373) (2.529) (0.455) $-1.151X_{14} + 12.622X_{18}$ (0.356) (4.588)
0.79	47	$Y_{22} = -212 + 0.466X_1 + 3.043X_3 - 8.882X_4 - 464.086X_7 + 5.029X_9 - 1.671X_{12} - 0.299X_{14} + 1.556X_{15}$ (0.165) (0.590) (2.745) (164.046) (7.427) (1.367) (0.217) (0.443)
0.89	25	$Y_{23} = -262 + 1.190X_1 + 1.243X_2 - 1.528X_3 - 54.021X_9 + 0.612X_{13} - 1.503X_{14} - 1.244X_{15} + 12.413X_{18}$ (1.154) (0.436) (0.621) (24.843) (0.574) (0.430) (1.079) (6.690)
0.89	24	$Y_{24} = -913 + 2.428X_2 - 38.815X_9 + 2.065X_{13} - 2.143X_{14} + 18.185X_{18}$ (0.349) (25.599) (0.579) (0.688) (10.321)

TABLE F-4

SIMPLE REGRESSION RESULTS, HOSPITALS

EQUATION NUMBER	EQUATION	r	$\frac{S_{YX}}{Y}$
1[a]	Total person trips = —48 + 5.910 beds	0.93	0.31
2[a]	Person trips to work purposes = —129 + 2.82 beds	0.94	0.28
3[a]	Person trips to nonwork purposes = 115 + 3.391 beds	0.88	0.33
4[a]	Total person trips = —444 + 3.649 personnel	0.91	0.29
5[b]	Person trips to work purpose = —7 + 1.184 personnel	0.91	0.27
6[a]	Person trips to nonwork purposes = —142 + 2.047 personnel	0.92	0.33
7[a]	Total auto driver trips = 118 + 3.091 beds	0.84	0.38
8[a]	Auto driver trips to work purpose = —47 + 1.561 beds	0.83	0.47
9[a]	Auto driver trips to nonwork purposes = 174 + 1.519 beds	0.78	0.41
10[a]	Total auto driver trips = —101 + 1.900 personnel	0.88	0.34
11[a]	Auto driver trips to work purpose = — 154 + .952 personnel	0.86	0.17
12[a]	Auto driver trips to nonwork purposes = 40 + .963 personnel	0.85	0.35

[a] Equation for general hospitals only.
[b] Equation for all hospital types.

All dependent variable data come from transportation study sources; independent variable data come from the same sources, plus hospital questionnaires and American Hospital Association records. The variables are defined in Table F-1 with their mean values for $N = 57$ cases. Table F-2 gives the rank ordering of independent variables and increasing R^2 as they are added to the prediction equations. Table F-3 gives selected multiple regression results for the 57 general hospitals.

SIMPLE REGRESSION RESULTS

Simple regression results for various predictive equations relating to hospitals are given in Table F-4. Most of these equations are for general hospitals only, with only one being for all hospital types.

TABLE F-5

SITE AND SERVICE AREA CHARACTERISTICS FOR BACKCHECK HOSPITALS

VARIABLE	HOSPITAL A	HOSPITAL B
X_1	194	376
X_2	403	697
X_3	340,000	360,000
X_4	74,000	81,000
X_5	0.218	0.226
X_6	844,000	1,473,000
X_7	0.403	0.244
X_8	36	40[a]
X_9	5.4	10.7
X_{11}	44	40
X_{12}	4.8	7.0
X_{13}	100,000[a]	276,000[a]
X_{14}	0.50[a]	0.92[a]
X_{15}	2,000[a]	1,000[a]
X_{16}	30.0[a]	65.0[a]
X_{17}	3.6[b]	5.0[b]
X_{18}	0.84	0.74

[a] Estimated.
[b] Percent.

TABLE F-6

SUMMARY OF PREDICTIVE BACKCHECKS FOR TWO GENERAL HOSPITALS NOT IN THE CROSS SECTION STUDIED

FACTOR COMPARED	TRIP GENERATION PREDICTION EQUATION USED [a]	HOSPITAL A		HOSPITAL B	
		PREDICTED	REPORTED [b]	PREDICTED	REPORTED [b]
1. Person trips	M. R on Y_{24}	1483	1279	2082	1712
	[1]	1099		2174	
	[2] plus [3]	1191		2322	
	[4]	1027		2099	
	[5] plus [6]	1185		2103	
2. Auto driver trips	M. R. on Y_{23}	662	649	961	897
	M. R. on Y_{20} plus Y_{21}	623		877	
	[7]	718		1280	
	[8] plus [9]	719		1285	
	[10]	665		1223	
	[11] plus [12]	658		1221	
3. Transit trips	M. R. on Y_{22}	104	236	256	379
	M. R. on Y_{19} times Y_{24}	317		606	
Directional distribution, auto driver trips (%): [c]					
Sector 1		34	21	24	12
Sector 2		27	27	35	49
Sector 3		24	30	15	3
Sector 4		15	22	26	36
Directional distribution, auto driver trips (%)[d]:					
Sector 1				22	16
Sector 2				37	48
Sector 3				14	0
Sector 4				27	36

[a] M. R. indicates multiple regression equation given in Table F-3; bracketed numbers are the simple regression equations given in Table F-4.
[b] Transportation study data, not actual counts.
[c] Prediction based on distance curves.
[d] Prediction based on time curves.

BACKCHECK RESULTS

Two general hospitals not in the cross section previously studied were used to test the application of trip generation and trip distribution procedures described in the text. Hospital A is located in New Orleans; Hospital B, in Pittsburgh. The site and service area characteristics used in the various trip generation equations are given in Table F-5.

The results of the backcheck tests are given in Table F-6. External survey trips were not available for Hospital B, and are not included in the "reported" column; assuming that 10% of the internal survey trips were added to represent the missing external trips, the predicted trip totals would look nearly as acceptable as for Hospital A. The predicted trip distributions are less encouraging. Hospital B showed no significant difference resulting from application of the time trip rate curve rather than the distance trip rate curve. (The travel time tree was not available for Hospital A.) Clearly, this very limited test supports the text's finding that trip generation can be predicted better than trip distribution.

APPENDIX G

REGRESSION AND BACKCHECK RESULTS—UNIVERSITIES

MULTIPLE REGRESSION RESULTS, UNIVERSITIES

The stepwise linear regression analysis program developed by the University of California School of Medicine was run four times, each run incorporating a different number of sample cases. Run 1 ($N = 38$) included all the institutions in the cross section, and employed 10 independent variables to predict each of the 14 dependent variables common to all four runs. Run 2 ($N = 25$) employed

13 independent variables, including the parking variables X_7, X_8, and X_{13}, which were not employed in Run 1 because they were not available for the full cross section. Run 3 ($N = 27$) altogether dropped various institutions because the values of one or more variables were suspect for various reasons, and again employed only the 10 independent variables excluding those relating to parking. Run 4 ($N = 16$) employed 13 independent variables for those institutions in Run 3 where the parking variables could be included. Thus, correlation results generally were improved from Run 1 through Run 4, but at the expense of decreasing the number of sample cases.

The large number of predictive equations (well over 300) and the mass of supporting output are impossible to report fully here. For illustration, the following results are provided for Run 4 only: (1) that predictive equation for each of the 14 dependent variables having the lowest standard error of the estimate (this is because the emphasis is on providing a predictive tool, rather than on explaining degrees of association among variables; such equations will not usually correspond to the equations producing the highest multiple coefficient of determination), (2) the standard errors for each coefficient in these predictive equations, (3) the standard error of the estimate as a percent of the dependent variable mean ($S_E/\overline{Y}$) for each of these predictive equations, (4) the multiple coefficient of determination (R^2) for each, and (5) a summary recapitulation of independent variables as they were entered (or removed) in successive steps leading up to the equation incorporating all the independent variables which meet the preselected level of F values for inclusion or removal—in effect a rank ordering in terms of significance—and showing the corresponding increase, if any, in R^2 as each variable is added or removed. The full computer output is available to qualified researchers upon written request to the director of the National Cooperative Highway Research Program.

All dependent variable data come from transportation study sources; independent variable data come from the same sources, plus university questionnaires, *Catalogs,* and *Bulletins.* The variables are defined in Table G-1 with their mean values for $N = 16$ cases. Table G-2 gives the rank ordering of independent variables and increasing R^2 as they are added to the prediction equations. Table G-3 gives selected multiple regression results for the predictive equations for universities (Run 4, $N = 16$).

BACKCHECK RESULTS

Five colleges and universities in the Boston metropolitan area (whose transportation study data had not been employed before) were selected to test the trip generation and trip distribution procedures. The diversity in sample characteristics is evident in Table G-4.

TABLE G-1

DEFINITIONS OF VARIABLES USED IN MULTIPLE REGRESSION EQUATIONS FOR UNIVERSITIES AND COLLEGES, AND AVERAGE VALUES FOR $N = 16$

SYMBOL	DEFINITION	AVG. VALUE FOR $N = 16$
Independent variables:		
X_1	Study area population density, persons per sq mile	190
X_2	Study area cars per 100 dwelling units	107
X_3	Study area population (in thousands)	880
X_4	Distance from university to CBD (in 0.1 mi)	34
X_5	Age of travel data, years from 1967	6.1
X_6	Site (campus) acreage	219
X_7	Faculty parking spaces	960
X_8	Student parking spaces	1675
X_9	Campus population density (persons per acre)	59
X_{10}	Total faculty plus staff	2684
X_{11}	Total resident students	2661
X_{12}	Total nonresident students	5774
X_{13}	Visitor parking spaces	120
Dependent variables:		
Y_{14}	Truck plus taxi trips	361
Y_{15}	Total person trips	9819
Y_{16}	Person trips to work	1935
Y_{17}	Person trips to school	3669
Y_{18}	Person trips to "other" purposes	4215
Y_{19}	Total vehicle trips	6687
Y_{20}	Total transit trips	646
Y_{21}	"First" person trips to work	1390
Y_{22}	Peak parking accum., % of daily arrivals (0.1%)	346
Y_{23}	Total auto driver trips	6326
Y_{24}	Auto driver trips to work	1396
Y_{25}	Auto driver trips to school	2420
Y_{26}	Auto driver trips to "other" purposes	2510
Y_{27}	First auto driver trips to work	914

The tests compare reported trips, from the home interview survey, with those predicted by the regression equations. Because walk-to-work trips were not reported, and because external and the truck and taxi survey data are not included, the reported trips are low by perhaps 10 to 15%. Had all such data been added, the comparisons on the whole would be improved (see Table G-5).

For the most part, the simple linear regressions provide better trip generation predictions than the multiple regression equations. This is partly because values for certain independent variables sometimes fall beyond the range of values in the data employed to develop the equations. For example, college B, which produces negative results for most trip generation predictions, has a population density ten times the mean of the original sample data. Even when the multiple regression equations are applied to subcomponents of total trip generation, such as to auto driver work trips, the results are generally no better than those from the simple regression equations. In sum, the comparisons point up the difficulty of generalizing college and university trip generation—this land use has a range of different attributes that makes almost every site unique.

The trip distribution results are better. A curve of trip rates by time increment, applied to population data arrayed by time increments within sectors, produces a close match between estimated and reported trips. In all but 9 of the 38 sector comparisons given in Table G-5, the predicted trips and reported trips agree within 10% of the university trip total. Differences were less than 5% in 16 cases. Reasons for the few major differences can only be speculated upon. Sector 1 for college C, containing two of the three largest universities in the region, probably has higher accessibility for school trips than any other sector. Sector 4 for colleges D and E is possibly a lower-income area with higher employment accessibility than other sectors. Although neither accessibility nor income data by area were available for this analysis, these appear to be the most likely influences.

TABLE G-2

RANK ORDERING OF INDEPENDENT VARIABLES AND INCREASING R^2 AS THEY ARE ADDED TO PREDICTION [a]

Y_{14}		Y_{15}		Y_{16}		Y_{17}		Y_{18}		Y_{19}		Y_{20}	
RANK ORDER	R^2	RANK ORDER	R^2	RANK ORDER	R^2	RANK ORDER	R^2	RANK ORDER	R^2	RANK ORDER	R^2	ORDER RANK	R^2
10	0.88	11	0.90	11	0.87	10	0.92	11	0.84	11	0.90	10	0.74
12	0.95	10	0.95	6	0.94	8	0.97	7	0.89	10	0.93	11	0.82
7	0.98	8	0.96	9	0.96	4	0.97	13	0.91	8	0.95	9	0.86
3	0.98	7	0.96	13	0.97	1	0.98	8	0.93	12	0.95	12	0.90
11	0.98	13	0.98	12	0.98	5	0.99	6	0.95	13	0.98	13	0.97
8	0.98	12	0.99	4	0.98	2	0.99	5	0.96	2	0.99	6	0.98
13	0.98	2	0.99	7	0.98	3	0.99	12	0.97	4	0.99	5	0.99
5	0.98	3	0.99	8	0.98	(1)	0.99	10	0.98	7	0.99	2	0.99
2	0.99	9	0.99	10	0.99	9	0.99	4	0.99	9	0.99	1	0.99
(7)	0.99	6	0.99	3	0.99	6	0.99	2	0.99	3	0.99	4	0.99
6	0.99	4	0.99	5	0.99	13	0.99	9	0.99	6	0.99	3	0.99
7	0.99	5	0.99	1	0.99	11	0.99	3	0.99	5	0.99	8	0.99
9	0.99	1	0.99	(6)	0.99	7	0.99	1	0.99	1	0.99	7	0.99
4	0.99			2	0.99								
1	0.99												

Y_{21}		Y_{22}		Y_{23}		Y_{24}		Y_{25}		Y_{26}		Y_{27}	
RANK ORDER	R^2	RANK ORDER	R^2	RANK ORDER	R^2	RANK ORDER	R^2	RANK ORDER	R^2	RANK ORDER	R^2	ORDER RANK	R^2
11	0.85	5	0.26	11	0.89	11	0.88	10	0.83	11	0.83	11	0.89
5	0.97	10	0.32	8	0.93	6	0.97	8	0.92	7	0.87	6	0.97
6	0.97	7	0.42	2	0.94	4	0.98	11	0.94	13	0.91	5	0.98
13	0.98	9	0.48	9	0.95	3	0.98	2	0.96	8	0.93	7	0.99
7	0.98	8	0.55	10	0.96	12	0.99	4	0.97	6	0.96	8	0.99
8	0.99	2	0.59	7	0.97	8	0.99	5	0.98	5	0.96	4	0.99
4	0.99	1	0.60	13	0.99	7	0.99	13	0.98	12	0.97	13	0.99
3	0.99	4	0.62	12	0.99	5	0.99	7	0.98	10	0.98	1	0.99
10	0.99	3	0.64	3	0.99	10	0.99	3	0.99	4	0.99	9	0.99
1	0.99	13	0.65	6	0.99	2	0.99	9	0.99	2	0.99	3	0.99
(11)	0.99	12	0.66	4	0.99	(11)	0.99	6	0.99	9	0.99	10	0.99
2	0.99	6	0.66	5	0.99	9	0.99	1	0.99	3	0.99	12	0.99
9	0.99	(9)	0.66	1	0.99	(4)	0.99			(8)	0.99	(13)	0.99
		11	0.67			13	0.99			1	0.99		
						4	0.99						

[a] Independent variables not given were not significant at the 95% confidence level. Parentheses indicate variable removed at indicated step, and may or may not be re-entered in subsequent steps.

TABLE G-3

SELECTED MULTIPLE REGRESSION RESULTS FOR UNIVERSITIES, PREDICTIVE EQUATION FROM RUN 4 ($N=16$)

R^2	S_E (% OF Y)	EQUATION AND (STANDARD ERRORS)
0.98	26	$Y_{14}= -53+0.080X_3+0.139X_7+0.229X_{10}-0.070X_{12}$ (0.059) (0.033) (0.015) (0.010)
0.99	13	$Y_{15}= 14{,}413-106.464X_2+1.552X_3-17.999X_6+0.409X_7+1.349X_8-57.890X_9+3.424X_{10}+1.866X_{11}$ (42.515) (0.976) (10.597) (2.022) (0.754) (30.504) (0.790) (1.036) $-1.182X_{12}+23.387X_{13}$ (0.344) (5.304)
0.99	14	$Y_{16}= 145-3.432X_4-0.616X_6+1.073X_7+0.364X_8+2.298X_9+0.258X_{10}-0.119X_{11}-0.047X_{12}$ (5.784) (1.738) (0.375) (0.124) (4.346) (0.155) (0.194) (0.069) $-0.883X_{13}$ (0.987)
0.99	13	$Y_{17}= 7{,}629-50.394X_2+1.591X_3-23.485X_4-154.309X_5-4.922X_6-0.810X_7+0.702X_8-30.044X_9$ (16.994) (0.787) (20.590) (138.261) (3.505) (0.612) (0.222) (14.927) $+0.823X_{10}+0.577X_{11}+3.850X_{13}$ (0.161) (0.360) (1.656)
0.98	28	$Y_{18}= -1{,}714+22.958X_4+175.996X_5-5.462X_6-1.466X_7-0.391X_8+1.861X_{10}+2.199X_{11}$ (22.333) (230.157) (5.985) (1.712) (0.537) (0.714) (0.961) $-0.985X_{12}+18.327X_{13}$ (0.301) (4.112)
0.99	12	$Y_{19}= 14{,}190-97.475X_2+2.465X_3-50.902X_4-11.822X_6-1.095X_7+0.715X_8-67.233X_9$ (27.128) (1.097) (32.887) (6.450) (1.392) (0.462) (24.597) $+1.847X_{10}+2.214X_{11}-0.716X_{12}+18.004X_{13}$ (0.488) (0.755) (0.210) (3.386)
0.99	13	$Y_{20}= 1{,}393-0.986X_1-10.449X_2+2.510X_4-98.395X_5+2.611X_6+7.406X_9+0.024X_{10}$ (0.623) (4.515) (1.924) (21.024) (0.504) (2.104) (0.029) $-0.226X_{11}+0.176X_{12}-3.542X_{13}$ (0.023) (0.015) (0.334)
0.99	6	$Y_{21}= -48-5.321X_4+30.644X_5+1.169X_6+0.429X_7+0.147X_8+0.077X_{11}+0.090X_{12}-1.753X_{13}$ (1.286) (14.887) (0.275) (0.061) (0.031) (0.028) (0.010) (0.230)
0.74	33	$Y_{22}= -17+42.551X_5+0.054X_7+0.031X_8+1.480X_9-0.044X_{10}$ (15.243) (0.033) (0.024) (0.996) (0.018)
0.99	12	$Y_{23}= 14{,}024-96.931X_2+2.266X_3-47.489X_4-11.296X_6-1.149X_7+0.733X_8-64.987X_9$ (26.108) (1.056) (31.651) (6.208) (1.340) (0.445) (23.673) $+1.614X_{10}+2.157X_{11}-0.643X_{12}+17.549X_{13}$ (0.470) (0.726) (0.202) (3.258)
0.99	11	$Y_{24}= 718-6.054X_2-0.193X_3+55.963X_5-0.080X_6+0.836X_7+0.311X_8-2.381X_9+0.133X_{10}$ (4.103) (0.137) (34.308) (0.646) (0.068) (0.053) (2.857) (0.033) $-0.063X_{12}$ (0.023)
0.99	12	$Y_{25}= 6{,}291-49.246X_2+1.583X_3-29.158X_4-146.796X_5-2.788X_6-1.146X_7+0.440X_8-28.848X_9$ (10.187) (0.472) (12.343) (82.881) (2.101) (0.367) (0.133) (8.948) $+0.310X_{10}+0.840X_{11}+4.007X_{13}$ (0.097) (0.216) (0.993)
0.99	19	$Y_{26}= 6{,}817-45.531X_2+1.139X_3-19.608X_4-20.812X_5-7.626X_6-0.699X_7-32.266X_9$ (15.194) (0.781) (19.940) (141.044) (2.789) (0.457) (14,032) $+1.259X_{10}+1.187X_{11}-0.609X_{12}+13.109X_{13}$ (0.242) (0.303) (0.103) (1.932)
0.99	4	$Y_{27}= -74+1.086X_1+0.192X_3-7.090X_4+31.532X_5+0.198X_6+0.314X_7+0.095X_8-5.007X_9$ (0.148) (0.052) (1.298) (9.497) (0.172) (0.058) (0.018) (0.732) $+0.055X_{10}+0.139X_{11}-0.011X_{12}$ (0.020) (0.033) (0.008)

TABLE G-4

CHARACTERISTICS OF BACKCHECK UNIVERSITIES

UNIVERSITY	FACULTY AND STAFF	STUDENTS: RESIDENT	STUDENTS: NON-RESIDENT	TOTAL CAMPUS POP.	CAMPUS AREA (ACRES)	POP. DENSITY (NO./AC)
A	1450	1150	8179	10779	130	83
B	4055	5227	16531	25813	45	570
C	1100	1380	598	3078	200	15
D	9205	7300	5054	21559	287	75
E	7158	2696	4455	14309	115	124

TABLE G-5

SUMMARY OF PREDICTIVE BACKCHECKS FOR FIVE UNIVERSITIES NOT IN THE CROSS SECTION STUDIED

FACTOR COMPARED	PREDICTION EQUATION USED [a]	VALUES [b]: UNIV. A P	UNIV. A R	UNIV. B P	UNIV. B R	UNIV. C P	UNIV. C R	UNIV. D P	UNIV. D R	UNIV. E P	UNIV. E R
1. Person trips	M. R. on Y_{15}	2851	6944	−18775	12896	11814	1845	43787	14310	26961	19647
	[1]	8903		21291		2558		17787		11813	
	[2]+[4]+[6] [c]	8506	5555	20562	11129	2097	1341	15756	12651	10129	9727
2. Auto driver trips	M. R. on Y_{23}	3749	3603	−18981	4901	8531	1077	30283	8173	15216	6423
	[7]	5545		13197		1625		11032		7341	
	[8]+[9]+[10]	6343		15463		1817		13754		9239	
3. Transit trips	M. R. on Y_{20}	762	716	4676	4730	−781	117	−760	3386	0	2933
	M. R. on Y_{20}										
4. Auto driver work trips	M. R. on Y_{21}	−146	841	−1492	1053	418	414	2736	3266	2185	3903
	[8]	884		1926		744		3986		3167	
Directional distr. person trips (%)[d]:											
Sector 1		57 [e]	47	35 [e]	31	50	34	34 [e]	45	30 [e]	30
Sector 2		21	23	26	33	25 [e]	25	24	26	18	26
Sector 3		22	30	27	26	13	25	22	24	35	34
Sector 4		—	—	12	10	12	16	20	5	17	10
Directional distr. auto driver trips (%)[d]:											
Sector 1		61 [e]	50	35 [e]	30	56	30	31 [e]	31	29 [e]	20
Sector 2		22	24	30	27	22 [e]	22	26	34	18	27
Sector 3		17	26	27	33	12	33	22	27	38	40
Sector 4		—	—	8	10	15	10	21	8	15	13

[a] M. R. indicates multiple regression equation given in Table G-3; bracketed numbers are the simple regression equations given in Table C-20.
[b] P = predicted; R = reported in home interview survey.
[c] Both predicted and reported values exclude trips to home.
[d] Based on time curves.
[e] Sector includes CBD.

The reader will recognize that, as for all of the backchecks described in this report, alternative methods of prediction could have been applied. Essentially, the backcheck predictions were made "at arm's length"; that is, without any on-the-ground studies and without taking full advantage of more detailed data on students and staff characteristics normally available in university business offices. With such additional information, for example, simple trip rates per student or per staff member might have been used, instead of regression equations. The merit of the backcheck, as applied, is perhaps that it points up the difficulty of making approximations without just such minimal information.

APPENDIX H

BACKCHECK RESULTS—CAPITOLS

Trips to the Massachusetts State Capitol Building (State House) were examined to see how they compared with the six capitol complexes studied previously. The 1963 employment at the State House was about 2,500 persons. According to the rule of approximately 0.9 person trips to work per day per employee (Appendix D), there should be about 2,250 trips. In fact, there were 1,882 trips reported in the home interview survey (excluding walk-to-work trips, which were not recorded). If walk-to-work trips are assumed at 5%, and external work trips are assumed at another 5%, the check would be about 2,100 reported trips against 2,250 predicted trips.

However, the rule of approximately 2.5 nonwork trips per 1,000 study area population (Appendix D) grossly overstates that component of total person trip generation; with about 3.6 million people in the study area, some 9,000 trips would be predicted. In fact, there were only 807 trips. Alternatively, if the six-capitol average of 534 nonwork trips per 1,000 work trips had been used (see Table D-16), the prediction would have been 1,005 trips—fairly close to the actual 807 trips (which may be low because of excluding external trips for nonwork purposes).

The modal split in Boston would be expected to differ from that in any of the six capital cities studied. The State House is less than a mile from commuter railroad service at North Station, and within a few blocks of several rail rapid transit stations. Accordingly, about 49% of all person trips were by some form of public transit. This compares with about 19% at the Indiana State Capitol complex, the highest percentage of the six capitols previously studied (see Table D-2). Obviously, any prediction from the prior data would have been very poor, even had tripmaker occupation, sex, race, and auto ownership factors been accounted for.

The directional distribution of person trips might have been predicted fairly accurately on the basis of the distribution of population. The proportion of population and person trip origins paired up for each of four sectors as 25 and 36%, 16 and 18%, 32 and 28%, and 27 and 18%, respectively. The distribution of auto driver trip origins, however, was not as good, pairing up 25 and 33%, 16 and 7%, 32 and 46%, and 27 and 14%, respectively. This test simply added all the population and actual trip origins by sectors, incorporating all zones from 0- to 32-min travel time away without taking into account the comparative proximity of populations to the State House. Alternatively, auto driver trip origins were predicted by application of the trip rate curves in Figure D-9; results were nearly the same.

APPENDIX I

BACKCHECK RESULTS—OFFICE BUILDINGS

The effectiveness of suggested trip generation and distribution procedures are here evaluated for two multi-tenanted private buildings in Pittsburgh (cases A and B) and one public building in Atlanta (case C), none of which are in the original cross section. Table I-1 gives selected factors required for the backcheck.

Work trip generation is based on the regression equation for person trips to work vs usable floor space given in Table E-19. Total person trips are then estimated for cases A and B by assuming that work trips represent 60%, and for case C by assuming they represent 84% (the latter, actually more typical of owner-tenanted private buildings, is chosen because the public building in question houses only a single public agency). The proportion of transit trips is assumed to be 0.72 times the known CBD modal split percentages (that is, for cases A and B, $0.51 \times 0.72 = 0.37$; for case C, $0.28 \times 0.72 = 0.20$). Applying these percentages to total person trips, and subtracting the estimated transit trips, leaves trips by auto drivers and auto passengers. Automobile trips are then determined by applying estimated car loading factors. The distribution of trip origins by sector is derived by summing known populations by mile increment within each sector, and applying trip rates shown in Figure E-15. This produces approximations of the proportions of trip origins by sector (trip totals so produced do not equal trip generation). Comparisons of predicted vs reported tripmaking are given in Table I-2.

The trip generation results are encouraging, particularly because the reported tripmaking is probably low (cases A and B do not include an estimated 10% serve passenger trips; case C does not include an estimated 20% external trips). If reported tripmaking were increased by those percentages, the auto driver trip predictions would all check to within ±18%. There are, of course, offsetting predictive errors in each case, so that pinpointing of the source of error is impossible. The trip distribution results are fair. For the Atlanta test, it seems reasonable to assume that race-stratified sector summaries of population distribution would have improved the outcome, but such data were not readily available.

TABLE I-1

CHARACTERISTICS OF BACKCHECK OFFICE BUILDINGS

BUILDING	USABLE FLOOR SPACE (1,000 SF)	NO. OF EMPLOYEES	WORK-NONWORK SPLIT [a] (%)	CAR LOADING FACTOR [a]
A	438	3043	60-40	1.34
B	429	2615	60-40	1.34
C	143	701	84-16	1.25

[a] Estimated.

TABLE I-2

SUMMARY OF PREDICTIVE BACKSHECKS FOR THREE OFFICE BUILDINGS NOT IN THE CROSS SECTION STUDIED

FACTOR COMPARED	BUILDING A		BUILDING B		BUILDING C	
	PRED.	REPORTED	PRED.	REPORTED	PRED.	REPORTED
Person trips to work	2553	3087	2588	3258	880	725
Total person trips	4255	3860	4171	4080	1047	839
Transit trips	1562	1807	1531	1101	214	157
Auto driver trips	2010	1549	1970	1927	667	464
Directional distribution (%):						
Sector 1	36	33	36	45	29	28
Sector 2	44	45	44	41	26	18
Sector 3	20	22	20	14	21	10
Sector 4	—	—	—	—	24	44

APPENDIX J

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Presents, in part, travel data based on questionnaire surveys of tripmakers to the 950-bed hospital of the University of Pennsylvania. Shows differences in patterns of trip origins, average trip lengths, and modes of travel, as among inpatients, clinic outpatients, private outpatients, visitors, medical staff, and other employees.

10. de Visé, P., "Hospital Study Districts for Metropolitan Chicago: A Geographic Analysis and Methodology." *Tech. Rep. No. 2,* Hospital Planning Council for Metropolitan Chicago (Apr. 1966).

Deals with accessibility and travel to medical and hospital centers, the residential origins of patients, the mapping of patient origins, the delineation of hospital study districts, and other factors directly bearing on hospital trip generation. Presents Chicago Area Transportation Study Cartographatron prints of total hospital tripmaking in the metropolitan area. Statistical data and a 42-item bibliography make this a highly useful reference on the subject of service areas.

11. de Visé, P., "The Chicago Regional Hospital Study: Objectives, Research Strategy and Methods." The Hospital Planning Council of Metropolitan Chicago (Sept. 1966).

The Chicago Regional Hospital Study is the short title of the $168,000 research project titled "Computer Simulation Model—Metropolitan Hospital Use," funded by the U. S. Public Health Service. The study employs multiple regression techniques to determine the number and distribution of hospital patients in a systems context.

12. Drosness, D. L., Reed, I. M., and Lubin, J. W., "The Application of Computer Graphics to Patient Origin Study Techniques." *Pub. Health Rep.,* 80:33 (Jan. 1965).

Described how, in metropolitan areas, graphic displays are necessary in analyzing and understanding the patterns of patient origins.

13. Drosness, D. L., and Lubin, J. W., "Planning Can Be Based on Patient Travel." *The Modern Hospital* (Apr. 1966).

Describes how birth records can be used to synthesize all patient travel, and thus to establish planning service areas.

14. Georgopoulos, B. S., and Mann, F. C., *The Community General Hospital.* Macmillan (1962).

A very useful text.

15. Godlund, S., "Population, Regional Hospitals, Transport Facilities, and Regions: Planning the Location of Regional Hospitals in Sweden." The Royal University of Lund, Sweden, Dept. of Geography (1961).

Presents concept of hospital location minimizing patient travel time.

16. Goodrich, D. K., and Smith, C. L., "Progress Report on Trip Ends Generation Research Counts." California Div. of Highways, District 4, San Francisco (Dec. 1965).

This study was designed to gather factual data on trip generation for use in traffic projections. Statistical results are provided for 27 sites, including four hospitals.

17. Hall, E. M., "Traffic Generator Studies in San Diego." *Traffic Eng.,* Vol. 30 pp. 13-16 (Feb. 1960).

Includes trip rates per hospital bed at various San Diego sites.

18. "Health and Hygiene, Drugs and Sanitation." *Price List,* Supt. of Documents, U. S. Govt. Printing Office, Washington, D. C. 20402.

Updated periodically, this price list is an extensive bibliography of publications available from the USGPO, many of which deal exclusively with hospital problems, including those related to traffic. Useful to the researcher.

19. "Hill-Burton Publications." U. S. Pub. Health Service. Pub. No. 930-G-3.

An annotated bibliography available free from Division of Hospital and Medical Facilities, Public Health Service, U. S. Department of Health, Education, and Welfare, Washington, D. C. 20201.

The Hospital and Medical Facilities Series is especially pertinent to various hospital planning problems. The highway planner will find the Public Health Service publications among the most complete and thoughtful references available; they are too numerous to itemize in this brief space.

20. "Hospital Service Areas in Allegheny County." Hospital Planning Association of Allegheny County, Pittsburgh, Pa. (July 1963).

Defines techniques of establishing service areas based on patient trip origins, relating, in part, differences in hospital services available.

21. *Huntington Memorial Hospital, Traffic and Parking Study;* and *Hospital Parking, Buffalo, New York: Buffalo General and Roswell Park Memorial Institute, Deaconess, Millard Fillmore.* Wilbur Smith & Associates, New Haven, Conn. (1965).

Further examples of a consultant's work to establish access and parking requirements by various direct surveys. Extensive traffic data provided.

22. Jackson, L. G., *Hopital and Community: Studies in External Relationships of the Administrator.* Macmillan (1964).

Long (822 pp.) text covering all aspects of hospital administration. Describes current publications (all magazines and other periodicals, the *Hospital Literature Index,* etc.) and provides a lengthy bibliography. Like similar texts, however, access and parking problems are hardly mentioned.

23. London, M., and Sigmond, R. M., "How Weekends and Holidays Affect Occupancy." *The Modern Hospital.* (Aug. 1961).

Discussion of daily and seasonal variations in hospital admissions, discharges, and average length of stay.

24. Lubin, J. W., Drosness, D. L., and Wylie, L. G., "Highway Network Minimum Path Selection Applied to Health Facility Planning." *Pub. Health Rep.,* 80:771 (Sept. 1965).

How travel time "trees" can be used in optimizing hospital location.

25. Lubin, J. W., Reed, I. M., Worstell, G. L., and Drosness, D. L., "How Distance Affects Physician Activity." *The Modern Hospital* (July 1966).

This study suggests that doctors' travel time is a critical consideration and should encourage plans for fewer but larger hospitals.

26. *Noise in Hospitals Located Near Freeways.* Consultant report to the Washington State Highway Commission (Jan. 1964).

A study to determine whether traffic noise affects the economic status of a hospital, and the effect of this noise on those inside the hospital.

27. *Oakland Study: Medical Institutions* (preliminary report), Pittsburgh Regional Planning Association, Pittsburgh, Pa. (Nov. 1960).

Example of a planning agency's report on future hospital development, in which access and parking requirements are given detailed examination. Parking space standards discussed and proposed.

28. Osborne, H. W., "Transporting the Sick and Injured in Niagara Frontier Plan." *Traffic Quart.*, The Eno Foundation for Highway Traffic Control (Oct. 1960).

Emphasis on the operational regulation affecting ambulance services in Buffalo, N. Y.

29. *Publications Catalog.* American Hospital Assn., Chicago, Ill. 60611.

Updated periodically, this catalog provides a prodigious list of publications by AHA, many dealing with factors which bear on any investigation of hospital trip generation. Most publications available free or at nominal cost. They are far too numerous to list even the most pertinent in this brief bibliography.

30. *Report on the Feasibility of the Proposed University Hospitals Parking Facility, University of Wisconsin, Madison.* DeLeuw, Cather and Company (July 1962).

Example of a consultant's work, describing the parking structure, its location, financing, and general feasibility. Extensive traffic data provided.

31. Roth, M. D., "Hospital Locations and Future Needs." Paper presented at Twentieth Annual Regional Plan Conference, New York (Nov. 1965).

A look ahead, with direct implications for access and parking requirements.

32. Shuldiner, P. W., Berry, D. S., and Montgomery, J. M., Jr., "Traffic and Parking Requirement of Off-Center Medical Office Buildings." Hwy. Res. Record No. 49 (1964) pp. 1-12.

Concerned with parking demand at relocated medical office building.

33. Smith, W. S., *Access and Parking for Institutions.* The Eno Foundation for Highway Traffic Control (1960).

Discusses access and parking requirements at colleges and universities, schools, stadiums, auditoriums, coliseums and hospitals; how problems developed with advent of the automobile; changing trend; and what can be done to smooth institutional expansion in the urban setting. Some trip generation rates provided.

34. Souder, J. J., Clair, W. E., Elkind, J. I., and Brown, M. B., *Planning for Hospitals.* American Hospital Assn., Chicago (1964).

Excellent example of a systems approach, using computer-aided techniques, to plan the internal layout and operations of a modern hospital.

35. Wheeler, E. T., *Hospital Design and Function.* McGraw-Hill N. Y. (1964).

Excellent basic text, engineering-oriented, on all phases of hospital operations.

COLLEGES AND UNIVERSITIES

1. Ackroyd, L. W., "Vehicle-Trip Generation Studies in Nottingham, 1964-66: 2. Industrial and Educational Land Use." *Traffic Eng. and Control,* London (Nov. 1966).

Second of a series on trip generation, describes study of University of Nottingham (3,550 students, 1,838 staff) and five "Colleges of Further Education."

2. Barton, Aschman and Associates, "Access, Circulation, and Parking: University of Minnesota, Minneapolis Campus." Chicago (Oct. 1963).

Comprehensive study of future needs at a major university.

3. Bennett, W., "University Campus Parking," and "The Car and College Campus." *Traffic Quart.* The Eno Foundation for Highway Traffic Control (Jan. 1956 and Oct. 1958).

General discussions of the development of campus parking problems with regard to facilities and procedures at selected universities. Suggests what must be done to reconcile continued campus growth with parking and circulation.

4. "Cars on Campus." A Report on Circulation and Parking Policies for the University of Wisconsin Campus in Madison, prepared by the Campus Planning Committee, Subcommittee on Cars on Campus, Madison (April 1964).

Discussion of problems and presentation of 27 proposed policies necessary to provide for proper parking and circulation within over-all University planning objectives. Extremely interesting for ramifications of policy questions which must be settled before parking policies can be established.

5. C. C. Parker & Parsons, Brickerhoff, Ltd., "McMaster University, Hamilton, Ontario, Traffic and Parking Plan." (Apr. 1964).

Example of a full-scale study to determine future parking needs and arterial street improvements to provide for campus circulation. Planning based on questionnaire returns, traffic counts, and parking surveys.

6. "College Area Parking." San Diego State College (Apr. 1960).

Study relating classroom use to parking lot occupancy.

7. Csanyi, L. H., "Parking Practices on College Campuses in the United States." *Bull. 181,* Iowa Eng. Exper. Station, Ames (Oct. 1958).

Presents results of questionnaires sent to 53 land grant colleges and universities, 88 private colleges and universities, and 25 colleges in Iowa having an enrollment of more than 200 students.

8. Davinroyd, T. B., "Travel Pattern Study of the State College-Bellefonte, Pennsylvania Area." *Res. Rep. No. 6,* Pennsylvania State Univ. (May 1965).

Considers patterns of business trips beyond a 50-mile radius generated by Penn State personnel (and employees of 15 other major traffic generators) by all travel modes. The frequency of such trips can be significant.

9. Drosendahl, R. G., and Smith, C. L., "Second Progress Report on Trip Ends Generation Research Counts." State of California Transportation Agency, Dept. of Public Works, Div. of Highways, District 4, San Francisco (Dec. 1966).

This study was designed to gather further factual data on trip generation for use in traffic projections (see entry 16 under "Hospitals"). Statistical results are provided for 19 additional sites, including one grammar school, three high schools, and a junior college.

10. Elmer, C. E., and Holzer, F. J., "University of Utah Traffic Study." B.S. thesis in cooperation with Utah State Dept. of Highways and U. S. Bur. of Public Roads (May 1961).

Long (110 pp.) factual description of 1959 traffic generation and traffic distribution at a large (8,762 day students) university. Student registration data on punch cards are compared with traffic counts and travel time studies. Includes recommendations.

11. Harland Bartholomew and Associates, "Long-Range Parking Plan for the University of Illinois." Memphis (Dec. 1962).

Comprehensive study of parking requirements.

12. Higgins, E. E., and Jones, D. M., "Campus Parking Bibliography." College and University Physical Facilities Series, U. S. Dept. of Health, Education, and Welfare, Office of Education (Aug. 1962).

Thirty-seven entry bibliography, thirteen from *College and University Business,* a monthly controlled circulation magazine published by McGraw-Hill.

13. Kelly, D. C., and Ward, H. A., "Campus Transportation Study: Part I. A Study of Bicycle Facility Needs." B.S. thesis, Univ. of Kentucky (May 1965).

Questionnaire returns indicate 22 percent of student body would "ride a bicycle to campus and/or between classes if safe and convenient bicycle riding and parking facilities were available." Cites comparable 24 percent at Michigan State University.

14. Mel Conner and Associates, "Florida State University Campus Traffic Study." Conducted for the Florida State Road Dept. (July 1962).
Comprehensive study of parking and street needs (including requirements for sound traffic engineering generally); controls on automobile registrations, parking fees, and fines; enforcement; and relationships to long-range planning.
15. *Newsletter.* Nat'l. Assn. of College and University Traffic and Security Directors, Security Office, Northern Illinois Univ. DeKalb.
Published bimonthly, this official publication of the Association carries up-to-date news of parking regulations, parking and traffic surveys, etc. Useful indicator of current problems and trends.
16. *Oakland Study: Carnegie Institute of Technology and University of Pittsburgh* (preliminary report). Pittsburgh Regional Planning Assn. (1961).
Example of a planning agency's report on future university development, in which access and parking requirements are given detailed examination. Parking space standards discussed and proposed.
17. Sato, N. G., "Estimating Trip Destinations By Purpose—School Trips." *Res. News,* Chicago Area Transportation Study (Dec. 31, 1965).
Discusses prediction of trips to all types of schools, including colleges and universities, on bases of urban area school age population, the percentage of this population enrolled in school, and average daily attendance.
18. "Transportation to and from The Campus." A Report to the President and the Executive Planning Committee on the Physical Plant, University Planning Office, Univ. of Pennsylvania (Mar. 1964).
Example of an excellent report (104 pp.) by university staff. Detailed analyses of results of 2-page questionnaires distributed to students, faculty and staff, university employees, and hospital employees (each questionnaire slightly different). Includes projections of parking needs and estimated capital costs.
19. "University of Pittsburgh Parking Study, 1962." Prepared by the Director of the Physical Plant, Univ. of Pittsburgh (Jan. 1964).
Another example of a parking needs study conducted by university staff. Reviews past, present, and future situations, with regard to the announced building program and plans for the Oakland area of Pittsburgh.
20. "Student-Staff Parking and Traffic Questionnaire." *Tech. Memo. C,* Physical Plant Dept., Univ. of Mississippi (July 1963).
Relates results of questionnaire returns.
21. "Parking Programs For Universities." University Facilities Research Center (with the Educational Facilities Laboratories), Madison, Wis. (Nov. 1961).
Monograph (noted as largely the work of DeLeuw, Cather and Company) aimed at aiding university and college administrators, and their planners, architects, and engineers. Presents results of survey of parking practices at Western Conference universities and selected universities throughout the country (38 completed questionnaires). Discusses on-street parking, and site selection criteria and financing of off-street parking.
22. Wilbur Smith and Associates, "Parking Studies Nashville, Tennessee: Central Business District and University Center Area." (May 1961).
Detailed parking survey and study of the Vanderbilt University and Peabody College campuses and contiguous area.
23. Wilbur Smith and Associates, "Parking Needs Knoxville, Tennessee: Central Business District and University of Tennessee." (Oct. 1963).
Similar study of the University of Tennessee.
24. Wilbur Smith and Associates, "Traffic and Parking Report, University of Washington." (Jan. 1966).
Similar study of the University of Washington, but considerably more comprehensive than the two preceding.
25. Zack, R. J., "Faculty and Staff Parking Requirements on the University Campus: An Evaluation and Analysis." M.S. thesis, Univ. of Illinois (1964).
Study of reserved faculty-staff parking spaces. Thirty-seven entry bibliography.

OFFICE BUILDINGS AND STATE CAPITOL COMPLEXES

1. "A New Context for the Office Tower." *Arch. Rec.* (Nov. 1966).
Describes changing patterns of office building design, and how new construction incorporates parking, retail stores, hotels, and even apartments.
2. Carlson, D. B., "The Low Cost of Fine Buildings." *Arch. Forum* (July 1961).
Discusses the economics and reasons behind development of large corporate-owned office buildings in comparison with speculative building trends.
3. Fisher, R. M., "The Boom in Office Buildings." *Tech. Bull. 58,* Urban Land Institute, Washington, D. C. (1967).
Comprehensive study of office building development since World War II. Relates trends in demand and supply of office space, and in financing and leasing arrangements, as well as indicating growth in office worker employment.
4. "Guide Plan: Central Offices for the Executive Branch of State Government." *Rep. No. 5,* Rhode Island Statewide Comprehensive Transportation and Land Use Planning Program, (Apr. 1966).
Describes recommended plan to be carried out from 1966 to 1965. This 117-page report is unique for having been developed in part from transportation study data.
5. Harper, B. C. S., and Edwards, H. M., "Generation of Person Trips by Areas Within the Central Business District." *HRB Bull. 253* (1960) pp. 44-61.
Explores the relationship of three categories of floor space, measured by traffic zones rather than by individual sites, to travel generated by central business districts. Seven major cities were examined, with the idea that if such relationships could be determined they could be used to forecast travel from estimates of future floor space use.
6. Horwood, E. M., and Boyce, R. R., *Studies of the Central Business District and Urban Freeway Development.* Univ. of Washington Press (1959).
Extensive examination of central business district growth trends between 1946 and 1956 in retail and office activities. Points up difficulties in isolating impact of highway systems from other influences on CBD development.
7. Kneebone, D. C., and Munro, R. D., "Work Trips Generation by a Large City Office Building." *Proc. Second Conf.,* Australian Road Research Board (1964).
Describes a survey of employees in Sydney office buildings, and the subsequent intensive analysis of travel by mode, areas of origin, and travel time.
8. Larry Smith and Company, *Economic Analysis of Land-Use Requirements, Wichita-Sedgwick County (Kansas) Metropolitan Area.* Seattle (1961).
Future land-use needs are estimated on basis of present utilization and intensities of use. Section on office space contains useful background on typical

urban area requirements. Similar reports are often available for other metropolitan areas.

9. "North Carolina State Capital Plan." North Carolina State Capital Planning Commission (1965).
Provides present floor space-employee relationships, and projects needs to 1980 and again to 2000. Good example of presently dispersed employment (41 buildings around downtown Raleigh) and planning required to regroup and rehouse that employment for effective functional relationships. Traffic pattern changes carefully considered.

10. O'Kane, L., "115-Acre Connecticut Capital Center Is Urged For Hartford." *New York Times* (Mar. 26, 1967).
Reviews plan to replace separate, isolated buildings with "one totally integrated structure." A pedestrian promenade bridging all streets would separate pedestrians from the vehicular traffic below.

11. *Parking Needs Related to the Sedgwick County Courthouse Area.* Wichita-Sedgwick Metropolitan Area Planning Department, Wichita, Kans. (1964).
Parking survey findings related to number of employees and visitors at major office building. Discusses lengths of stay, peak accumulations, and procedures for estimating parking demand.

12. Preswood-Smith, P., and Lamb, G. M., *Traffic Generation Rates for Small-Scale Development Schemes Within the Central Area of London Based on the London Transportation Study.* Greater London Council, Dept. of Highways and Transportation, Research and Development Group, London (Mar. 1967) (unpubl.)
Trip generation rates based on employment and floor space are developed for various land-use categories, based on London Transportation Study data. Peak-hour, daily, and mode split characteristics are discussed.

13. Seligman, D., "The Future of the Office Building Boom." *Fortune* (Mar. 1963).
Traces the growth in office building space in several major cities since World War II. Identifies the major differences between development trends in New York and in other cities.

14. Shultz, E. and Simmons, W., *Offices in the Sky.* Bobbs-Merrill (1959).
History of the office building as "a tool of commerce and a prime factor in the growth of cities." Semi-popularized, with statistics on unit costs and economic arguments for skyscraper development.

15. *Skyscraper Management.* Nat. Assn. of Building Owners and Managers, Chicago.
Monthly periodical, published since 1931, devoted to office building management problems and techniques. Occasional articles on parking needs.

16. "State Capitols Go 'Radical.'" *New York Times* (Sunday Magazine) (May 12, 1963).
Pictorial discussion of modern "state capitol complex" designs in several states.

17. Thompson, J. T., and Stegmaier, J. T., "The Effect of Building Space Usage on Traffic Generation and Parking Demand." *Proc. HRB,* Vol. 28 (1948) pp. 320-339.
Pioneer study of travel associated with specific sites of various land uses, based on a 1945 O-D study in Baltimore, Md. Emphasizes the value of standard O-D studies in determining interrelationships between land use and travel.

18. "Traveling to Work by Elevator." *Bus. Week* (Apr. 2, 1966).
Discusses trend toward combining apartment units with high-rise office buildings. Describes examples in Pittsburgh, Miami, Milwaukee, and Chicago.

19. Wheeler, R. J., "Employee Transportation Habits and Commercial Land-Use Activity: Vol. 1. City of Columbia." Preliminary report (Apr. 1966).
Extensive computer tabulations of employees and floor space, developed from interviews with 991 commercial firms, and from travel questionnaires distributed to employees (Volume 2 presents comparable data for the University of Missouri).

20. Wilbur Smith and Associates, "Parking Needs, Knoxville, Tennessee: Central Business District and University of Tennessee." (Oct. 1963); and "Parking Studies, Nashville, Tennessee: Central Business District and University Center Area." (May 1961).
Detailed parking surveys, parts of which are concerned with parking demands associated with individual office buildings.

21. Wilbur Smith and Associates, *Parking in the City Center.* New Haven, Conn. (1965).
Reviews the factors contributing to downtown parking needs and shows, by example, how several cities have solved parking problems. Parking demands associated with different types of buildings are discussed.

22. Wright, P. H., "The Relationship of Traffic Attracted to Zones in a City's CBD to Intrazonal Floor Space Use." Georgia Inst. of Technology (1964).
Report on research sponsored by the Institute of Traffic Engineers, similar to that of Harper and Edwards (entry 5). Floor space-travel relationships were developed through multiple linear regression techniques for several metropolitan area central business districts. The results relate to area analyses, not to individual building trip generation.

23. "Traffic, Traffic Generators in Central Business District." *Traffic Eng.* (Mar. 1965).
Summarizes the preceding report and suggests areas for further research.

GENERAL

1. Campbell, M. E., and Schmidt, R. E., *Highway Traffic Estimation.* The Eno Foundation for Highway Traffic Control (1956).
A basic text interesting for its treatment of the broad aspects of trip generation and traffic estimation.

2. Chicago Area Transportation Study, *Final Report: Volume 1, Survey Findings; Volume 2, Data Projections;* and *Volume 3, Transportation Plan* (1959, 1960, 1962).
Together, these three volumes detail the transportation planning process developed to attack the transportation problem in America's second largest metropolitan area, and are "must" reading for any student of transportation planning. Includes thoughtful analysis of land-use trip generation.

3. Falk, E., "Traffic Generation Rates." Wichita-Sedgwick County (Kansas Metropolitan Area Planning Dept. (1963).
Ranks among the more detailed descriptions of the trip generation methodology used to project by major land uses the vehicular travel for future years. Does not, however, provide actual floor space or land-use area rates.

4. Hall, E. M., "Traffic Generator Studies in San Diego." *Traffic Eng.* (Feb. 1960).
Based on factual studies of 1952-1953 travel characteristics in San Diego, this articles presents various trip generation rates used by the San Diego Metropolitan Area Tranportation Study.

5. Hamburg, J. R., and Sharkey, R. H., "Land Use Forecast." *Tech. Manual 32:610,* Chicago Area Transportation Study (1961).
Book-length account of the procedures used to forecast and distribute spatially the additional land to be brought into use between 1956 and 1980 in the 1,250-square mile Chicago study area. Important to trip generation, since the determinants of where and how land will be used are also, generally, the determinants of its level of trip generation.

6. "Origin and Destination Survey, Tables Supplement." *Tech. Rep. No. 9,* Madison Area Transportation Study (1962).

Provides study area trip/acre rates for 80 distinct land uses; also the actual number of trips and acres. Excellent example of thoughtfully prepared data from a smaller transportation study.

7. PITTSBURGH AREA TRANSPORTATION STUDY, *Final Report: Volume 1, Study Findings; Volume 2, Forecasts and Plans* (1961, 1963).

Styled after the Chicago report, the Pittsburgh volumes contain detailed studies of trip generation with special attention to land-use area trip generation rates and their shortcomings for the prediction of future travel production.

8. PENN-JERSEY TRANSPORTATION STUDY, *Final Report: Volume 1, The State of the Region; Volume 2, 1975 Projections—Foreground of the Future; Volume 3, 1975 Transportation Plans* (1964, 1965).

Generally confirming the basic relationships with land use found by predecessor studies, the Philadelphia experience also shows that differences in trip generation persist from city to city.

9. ROW, A. T., "Land Use Planning Related to Traffic Generation and Estimation." *Proc. 28th Annual Meeting,* Inst. Traffic Engineers (1958).

Reviews the inseparableness of land use and transportation planning and cites certain implications of planning vs predicting land uses.

10. SHULDINER, P. W., DESALVO, J., DICKEY, J., and HORTON, F., *Non-Residential Trip Generation Analysis.* Northwestern Univ. (Nov. 1965).

A research project sponsored by the U. S. Bur. of Public Roads exploring the role of land use in trip generation analysis, variables used in generation analysis, methodological approaches (particularly multiple linear regression), and various other aspects of trip generation. Excellent review of techniques used by selected transportation studies. Extensive bibliography.

11. SULLIVAN, S. W., "Land Use Trip Generation Rates." *Tech. Paper No. 12,* Pittsburgh Area Transportation Study (1961).

A summary presentation of all two-digit person and vehicle land-use area trip generation rates, by ring, for the Pittsburgh area, 1958. Explains calculation of rates.

12. TWIN CITIES AREA TRANSPORTATION STUDY, *Final Report: Volume 1, Study Findings* (1962).

Chapter IV, "Trip Generation and Land Use," provides trip generation rates by both floor area and ground area. Another important report for comparison purposes.

13. WILBUR SMITH AND ASSOCIATES, *Future Highways and Urban Growth.* New Haven, Conn. (Feb. 1961).

Chapter on "Characteristics of Urban Travel" includes much factual information on trip generation and many references. Comparative data based on some dozen transportation studies.

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