It is known, of course, that an early start will usually give better and cheaper results. Present thinking in Missouri indicates that an earlier use of asphalt underseal following the first signs of initial slab movement, will result in control of slab pumping at the lowest cost. Early use of the other methods of control will pay dividends in the cost of maintenance and the life of the pavement. Especially is this true if the use of bituminous decking is indicated, because the early use of decking will certainly help to hold down the cost of preliminary mudjacking, undersealing, and full depth concrete replacement. It will, in addition, result in a better and longer lasting road surface. It should be added, of course that proper shoulder and drainage maintenance should always be practiced, regardless of the presence of other corrective or preventive operations.

The problem discussed in this paper has been approached from the maintenance point of view. All tools and processes described have been developed to provide corrective or preventive relief. The opportunity should not be passed, however, without giving due credit to the design, construction, and material engineers, who have steadily altered and modernized their designs and methods, to take advantage of maintenance findings. Improved subgrade material gradation and compaction, the elimination of joints, better shoulder design and more adequate drainage, to mention only a few, all illustrate the good that can come from close cooperation between all branches of highway engineering. Such shoulder-to-shoulder efforts cannot help but make the maintenance load lighter. While it is not anticipated that slab pumping will ever be ruled out completely, it now appears that its occurrence will be less general, and its effects less expensive to correct. When that happens, however, the maintenance engineer will still have plenty of other needy projects upon which to spend the money saved.

DEPARTMENT OF TRAFFIC AND OPERATIONS

WILBUR S. SMITH, *Chairman*

THE EFFECT OF BUILDING SPACE USAGE ON TRAFFIC GENERATION AND PARKING DEMAND

J. TRUEMAN THOMPSON AND JOSEPH T. STEGMAIER, *The Johns Hopkins University*

A method is demonstrated of using urban origin and destination survey material for information concerning the power of buildings of various types to attract traffic and create parking demand. Fifteen buildings such as department stores, schools, theatres, factories, hospitals, etc. and one shopping community are analyzed as generators in such a way as to bring out the purposes of trips made to them, the mode of travel used, the time-of-day distribution of the travel, and where the trips originated. In two cases information about the sex and color of those making trips is also provided. These data are then translated in terms of vehicular attraction of the several generators.

A second method is presented which uses origin and destination data to secure mass information about the parking demands created by various generators. By segregating the trips of those who drove passenger cars and by assuming that each such trip represented a potential parker, the total daily parking demand of each generator is established. The purposes of the trips and the hour they were made are then taken into account and turnover factors developed for each trip purpose for each generator. These turnover factors are used to establish parking space requirements. These, in turn, are related to physical properties of the generators to produce such basic units as the number of square feet of department store selling space per parking space required, the number of theater seats per parking space required, etc.

Recommendations are made for modifications in collecting and filing O and D survey data to facilitate their use in generator study.

The paper emphasizes the validity of the suggested methods of analysis, not the data derived in the present investigation. Indeed it warns that they should be used cautiously, if at all, until further applications of the method have substantiated or modified them.

The purpose of this paper is to demonstrate the practicability of using urban origin and destination survey data as a source of information on the traffic attraction and parking demand of different kinds of building use. The investigation was carried on by Dr. Stegmaier under the direction of his co-author, as a dissertation requirement for the degree, Doctor of Engineering, at Johns Hopkins.

The material examined had been collected in the Baltimore O and D Survey conducted in the autumn of 1945 and in the Parking Survey of the following spring. These surveys were financed jointly by the Public Roads Administration, the Maryland State Roads Commission, and the City of Baltimore. The authors are deeply grateful to these sponsors and to members of their staffs too numerous to name, not only for permission to use the data but for their advice and generous cooperation throughout the study.

METHOD

It is assumed that the reader is generally familiar with the methods of urban O and D surveys. They have been made in scores of our cities and have been extensively reported.[1] The Baltimore Survey followed the conventional pattern.[2] But perhaps it would be well to recall that this survey was accomplished by questioning people in a five percent sample of their homes regarding the details of their travel on the day before, which was always a weekday. The questions took the form—"From where did you leave and at what hour? Where did you go? By what means? For what purpose?" This part of the study was known as the internal survey. Much larger truck and taxicab samples, i.e., 20 percent, were drawn from the records of the Commissioners of Motor Vehicles and Public Service respectively. Trip information was gotten from the owners of the trucks and from the taxicab manifests required by the Public Service Commission. Because of the small number of truck trips to the selected buildings they have been omitted from this report.

Trip information regarding the vehicles and the people moving in and out of the study area was gotten by establishing interview stations at the intersection of all important highways with the study area boundary. These highways carried over 94 percent of the vehicles entering and leaving the area. This part of the study was known as the external survey.

Three control points and a screen line were established to count and classify the traffic. These figures were compared with the expanded interview data in order to check their accuracy and completeness. For the 16-hour period from 6 A.M. to 10 P.M. the checks were 89 percent accurate, while during the peak hours the accuracy mounted to 98.5 percent.

The information thus obtained for each trip was coded and transferred to business machine punch cards. These could be sorted by small local areas which corresponded to those into which the metropolitan study area had been subdivided. The smallest of these was a sector, which in the downtown district was equivalent to a city block but which grew in size outwardly to include several blocks.

Fifteen buildings and one neighborhood shopping community were selected for study as generators of traffic and parking demand. In a few cases these occupied an entire sector, but generally this was not the case. The selected generators were as follows:

Department Store "A"

Department Store "B"

[1] For example: J. T. Lynch, "Origin and Destination Surveys in Urban Areas." *Proceedings*, Highway Research Board, Vol. 24, p. 239 (1944).

W. F. Childs, Jr., "Origin and Destination Survey Methods as Applied to the Transportation Study—Baltimore Metropolitan Area." *Proceedings*, Highway Research Board, Vol. 25, p. 422 (1945).

[2] Report of the Transportation Study—Baltimore Metropolitan Area, "*Transportation Needs*," Vol. 1. Also Manuals of Instruction, ed. Maryland State Roads Commission in cooperation with Baltimore City and the Public Roads Administration, Federal Works Agency. (Baltimore, 1945-1946).

A Railroad Passenger Station
A Retail and Mail Order Store
A Neighborhood Shopping Community
A General Market
Department Store "C"
An Industrial Plant
Office Building "A"
Office Building "B"
A Theater
A Public High School
A University Campus
A Hotel
A Bus Terminal
A Private Hospital

Having sorted out all of the punch cards for the sectors which contained the generators, it was necessary, for most of them, to identify the trips which were made to the generator. This was because, in the majority of cases, the sectors contained not only the selected generator but other buildings as well.

This was no easy task. Except in the few cases where the sector contained no other buildings, all of the internal survey cards, which had been sorted on sector of destination, had to be individually inspected and their information listed according to trip, person, serial number and tract. Since the original questionnaires had been filled out, arranged, and filed in this sequence, such a listing greatly facilitated the search to determine the actual building of destination within a given sector. A search was then made of the original questionnaires, and only those cards pertaining to trips to the selected generators were retained.

Similarly, for the external survey, the cards sorted on sectors of destination were individually inspected and a listing made of the information on them which tallied with the method used in filing the original questionnaires, namely, serial number, hour, direction of travel (inbound or outbound), and interview station number.

In dealing with trucks and taxicabs a somewhat similar process was employed to identify actual generator trips.

While investigating the original internal survey questionnaires it was noticed that in about 16 percent of the cases the destination had been recorded as a street intersection rather than as the name or address of a particular building. This practice was, of course, satisfactory for the purposes of the origin and destination survey, but it sometimes posed a serious problem in this study of individual traffic generators. But fortunately, the compass quadrant or corner of the intersection had been recorded in every such instance. This assured proper coding as far as the sector of destination was concerned but still the information was inadequate for the purposes of this study. However, it is believed that by scanning each questionnaire which fell into this category and by examining the purpose, time, and other data regarding the trip, a reliably accurate determination was made as to whether or not the selected building had in reality been the trip destination. The same disturbing element was also discovered in the case of the external and the truck and taxicab surveys but was less important in these.

Notwithstanding the fact that this difficulty could be dealt with as explained, if in the future this type of generator study is contemplated as a supplement to an origin and destination survey, a determined effort should be made to record in every case the address or name of the selected building as the trip destination, rather than to record the street corner or intersection.

In addition to this source of possible error, there are inaccuracies inherent in the methods of the original survey and particularly in the application of its basic sample size, 5 percent, to the analyses of trips to specific buildings. Unfortunately no reliable method was discovered by which a definite check on the accuracy of the analysis could be established. It can only be said that the results hang together with remarkable consistency. The data show that shoppers, industrial workers, students, office building employees, and other groups 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. Such applications of the method would be particularly expedient in view of the fact that O and D studies, similar to the one conducted in Baltimore, are considered the best means thus far developed of getting the facts of urban travel and will probably be made in many other municipalities in addition to being applied for periodical re-surveys. The resulting informa-

tion should go a long way toward answering many of the questions concerning traffic generation which are now merely matters of speculation.

PRESENTATION OF RESULTS—TRAFFIC GENERATION

The trips to each of the 16 generators have been analyzed so as to reveal the relationships of such factors as time of day, mode of transportation, and trip purpose. These are displayed in graph form. In addition, for each generator a map of the study area showing the distribution of trip origins is presented. These are represented by circles whose sizes indicate the number of trips originating daily in the several zones of the metropolitan area or from the external survey interview stations. The accompanying scale, which applies to all the maps, was necessarily adjusted in order to satisfy the diverse trip groupings which were adopted for each generator. The circles are sectored so as to show by the black sector the proportion of trips by mass transportation and by the white sector the proportion of trips by automobile and taxicab. The generator location, in each case, is marked by a star. These graphic materials are accompanied in each instance by a brief discussion of the data.

Department Store "A"

Department Store "A" is one of Baltimore's largest buildings of this type, located in the downtown area. The total number of trips generated daily by the store slightly exceeded 8900. From Figure 1 it can be seen that the majority (51.6 percent) were by mass transportation for the purpose of shopping. The peak period of travel was from ten o'clock in the morning until noon, reaching an average rate of 17.7 percent of the total number of daily trips per hour. Since the store opened at 9:30 A.M., practically all of the employees reached the store during the 7 to 10 A.M. interval, and 88 percent of them were mass transit passengers. It appears that each mode of travel was used fairly regularly throughout the day. Of interest is the fact that almost 15 percent of the total trips were by automobile drivers. Figure 2 shows that nearly 84 percent of the persons were white females and by far the largest portion of them came to shop. Only 4.3 percent were colored and 84 percent of these were employees. Less

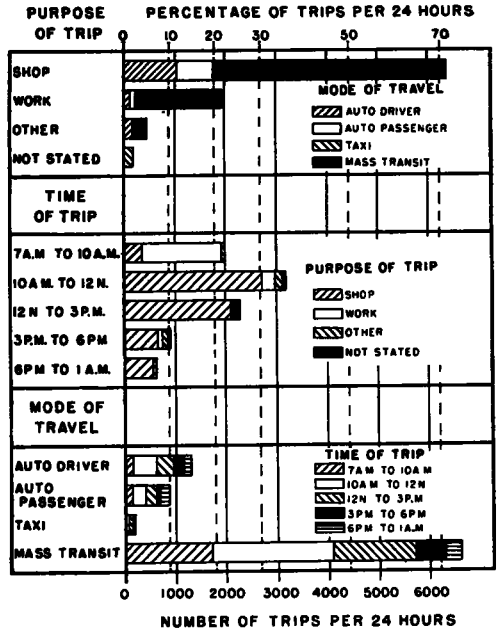

Figure 1. Analysis of Trips to Department Store "A" by Purpose, Time and Mode of Travel

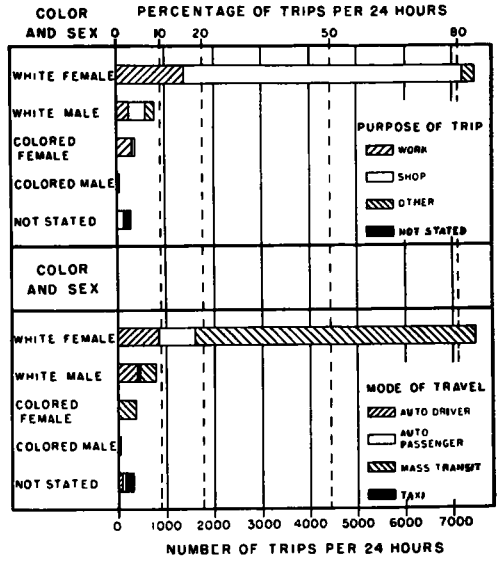

Figure 2. Analysis of Trips to Department Store "A" by Purpose and Mode of Travel and Color and Sex

than 76 percent of the whites traveled by mass transit whereas all of the colored persons used

these facilities. Sex and color data are presented only for this store and for Department Store "B" as examples of the kind of information that may be procured. Figure 3 reveals the fact that the majority of the people came from the western, northwestern, and northern sections of the area, while the heaviest concentration of passenger car and taxicab trips originated in the north. This is, generally, the area of highest economic status.

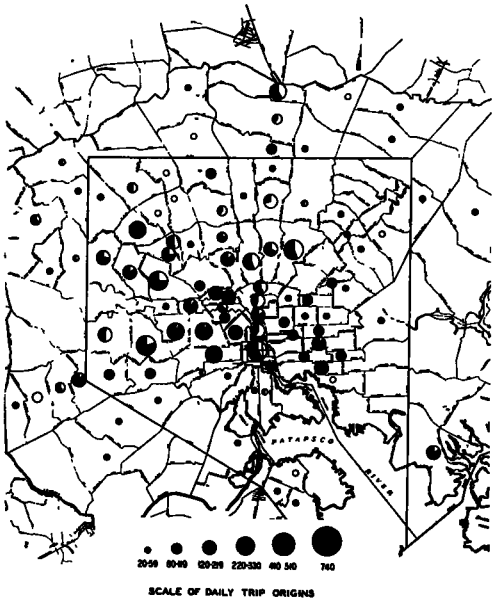

Figure 3. Origin of Trips to Department Store "A"—*Note*: The Scale of Daily Trip Origins shown applies also to all other origin maps in this paper

Department Store "B"

Department Store "B" is also one of the city's largest retail stores in the central business district. It daily generated an average of nearly 6300 trips. Figure 4 reveals that the character of the traffic was very similar to that of Department Store "A", the most noticeable exception being a decreased percentage of automobile drivers. This is perhaps due in part to the fact that "A" operated a nearby garage and was also closer to the nearest public parking lot. The decrease, amounting to about 6 percent of the total number of daily trips, is accounted for by an equivalent increase in mass transit passengers. Figure 5 also shows but one major divergence

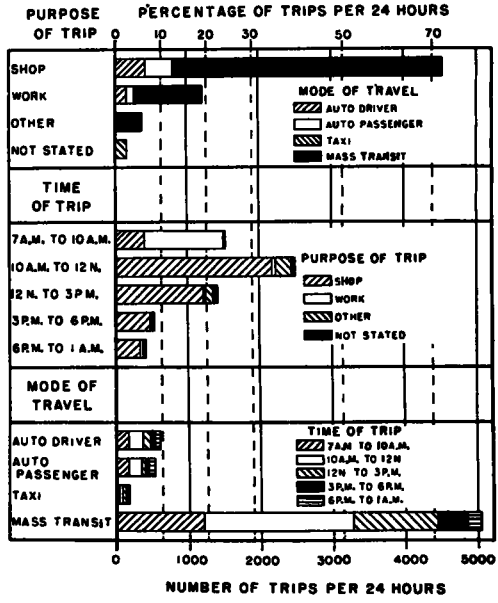

Figure 4. Analysis of Trips to Department Store "B" by Purpose, Time and Mode of Travel

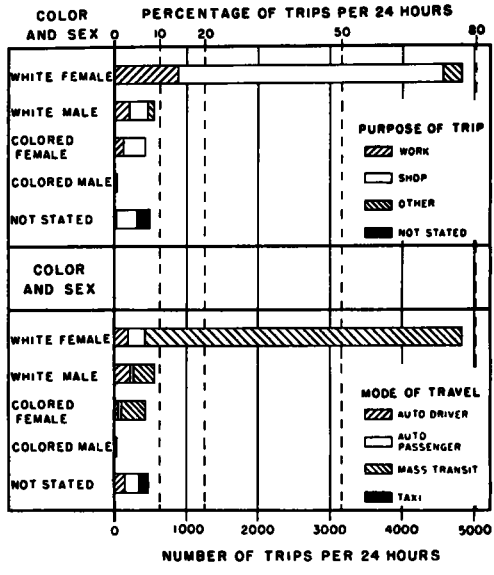

Figure 5. Analysis of Trips to Department Store "B" by Purpose and Mode of Travel and Color and Sex

from the type of traffic generated by Department Store "A". This is the fact that over 7 percent of the people were colored and of

these more than 72 percent were shoppers. From Figure 6 it may be seen that, while the trip origins were somewhat scattered throughout the western, northwestern and northern districts, a large portion were in a rather concentrated section of the east-central area. Automobile and taxicab travel was markedly less prevalent from zones lying to the east and to the west of the store. These are areas of much lower economic status.

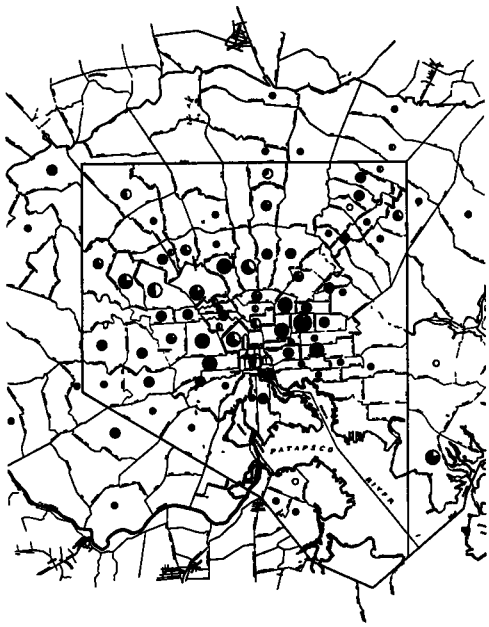

Figure 6. Origin of Trips to Department Store "B"

Railroad Passenger Station

The station studied is perhaps the largest single traffic generator in the City of Baltimore, having attracted an average of more than 9200 trips daily. Figure 7 shows that nearly one-quarter of these trips were made between 6 and 9 A.M., many of them, presumably, by commuters working in nearby Washington, D. C. Almost 45 percent of the travel was by taxicab and, probably because of luggage, only 26 percent by mass transit. The remainder was split fairly evenly between automobile drivers and passengers. Trip purpose was not included in the analysis because the purpose given in the questionnaires was confused as between those who left by train and those who did not. Figure 8 shows that the trips originating in the suburbs were relatively insignificant compared with those having their origin in and around the downtown

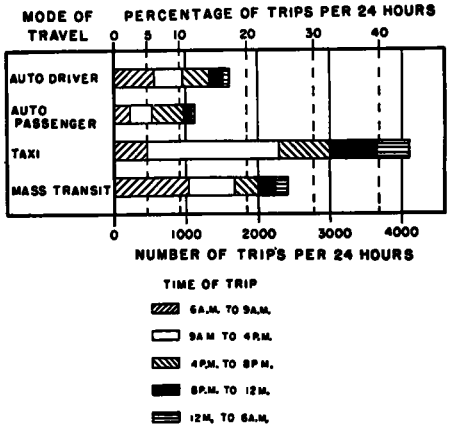

Figure 7. Analysis of Trips to A Railroad Passenger Station by Mode and Time of Travel

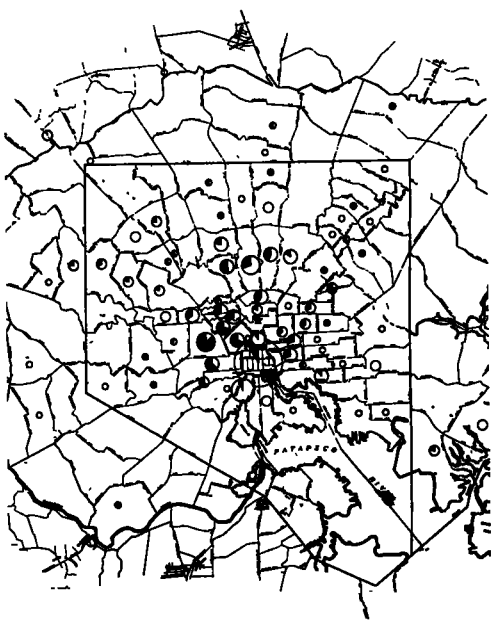

Figure 8. Origin of Trips to A Railroad Passenger Station

area. Only in the west-central area did mass transit travel exceed that by taxicab. This area is predominantly occupied by negroes and presumably their lower economic status was responsible. The very great concentration of trips from the downtown area, only a

small portion of which was by mass transit, was influenced no doubt by the presence in the downtown area of hotels and business houses which serve as origins for guests and out-of-town businessmen who would be expected to be large if not almost exclusive users of taxicabs.

Retail and Mail Order Store

This store, a very large retail and mail order outlet in the southwestern section of the city, attracted in the neighborhood of 5570 trips

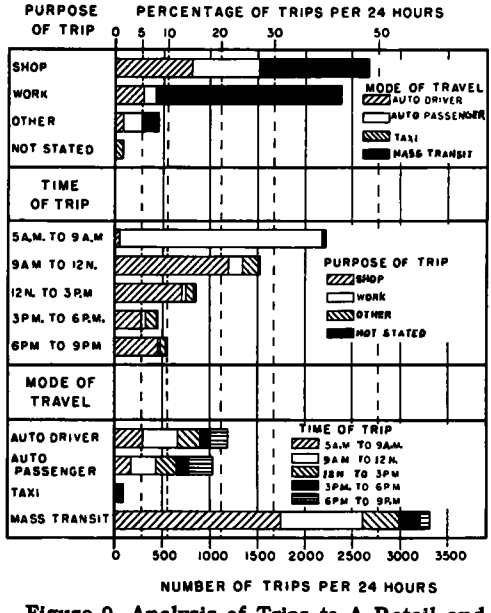

Figure 9. Analysis of Trips to A Retail and Mail Order Store by Purpose, Time and Mode of Travel

well dispersed in the outlying sections, seem to have been more pronounced in the central area of the city. Also there was a marked degree of traffic, originating outside of the area, which traveled through stations located around the southern rim of the cordon line.

Neighborhood Shopping Community

This shopping community is the Waverly area, just west of the Baltimore Stadium. It will be familiar to those who have attended Navy football games there. It lies outside

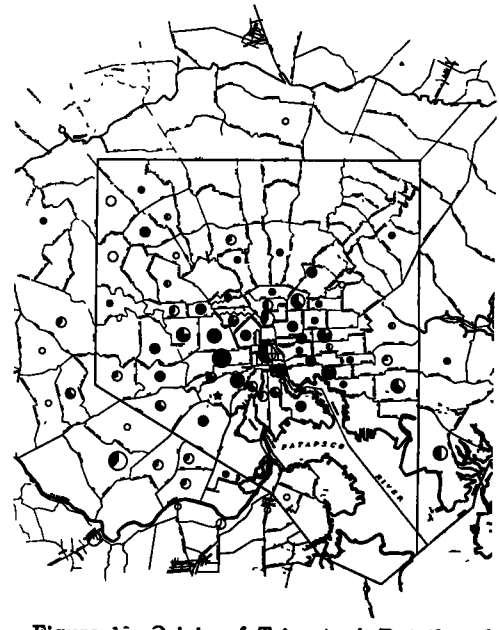

Figure 10. Origin of Trips to A Retail and Mail Order Store

daily. Figure 9 discloses the fact that although the number of employees was nearly equal to the number of shoppers, their modes of travel and times of trip varied greatly. Over half of the shoppers traveled as drivers or passengers in private automobiles and spread their trips throughout the day, whereas 82.4 percent of the employees traveled by mass transit and almost 89 percent of these arrived at the store before 9 A.M. The percentage of private vehicle travel far exceeded that of either of the downtown department stores, probably due to the greater availability of parking spaces. From Figure 10 it is seen that the origins of the trips, though reasonably

the downtown district yet well within the City. It is about a dozen city blocks in area and contains a miscellany of retail businesses, mosstly small, such as bank branches, restaurants, dime stores, drug stores, barber, tailor, florist, gift and repair shops, self-service food markets, bowling alleys, taverns, and motion picture theaters. These number about 120 in all with an average floor space of 5,000 sq. ft. The daily traffic generated was about 4880 trips. Figure 11 shows the predominance of automobile travel, especially for shopping, business, and social-cultural or recreational purposes and the heavy peak of social-cultural and recreational traffic after four o'clock in the

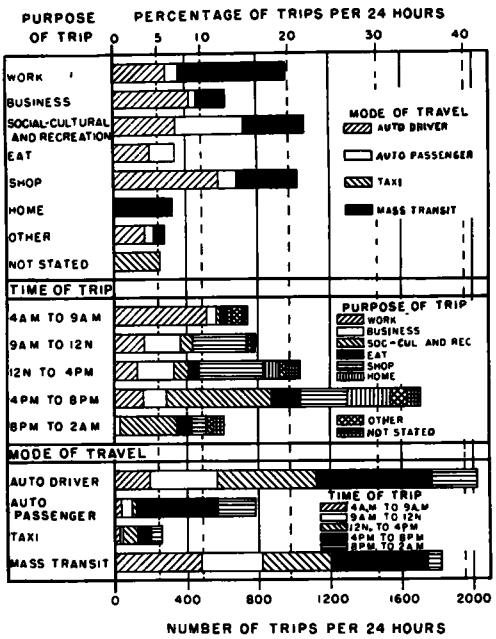

Figure 11. Analysis of Trips to A Neighborhood Shopping Community by Purpose, Time and Mode of Travel

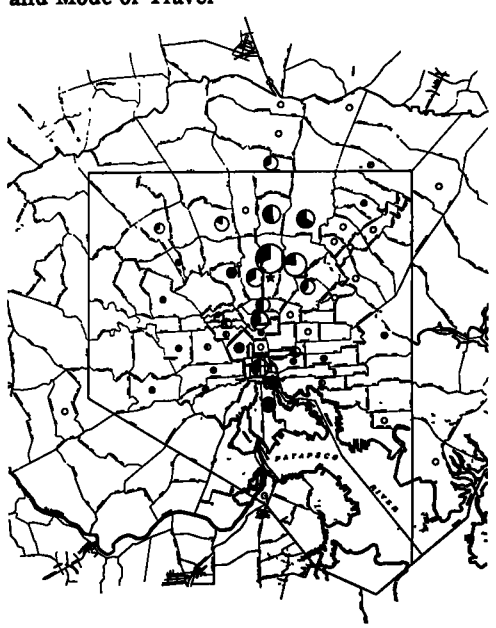

Figure 12. Origin of Trips to A Neighborhood Shopping Community

afternoon. Figure 12 shows that a large majority of trips originated within a two to three mile radius of the community.

General Market

This is perhaps the most popular market in the downtown area, handling substantially every type of perishable foodstuff. The daily number of trips exceeded 4200, a large majority of which are seen from Figure 13 to have been for the purpose of shopping. While all the workers arrived between three o'clock and ten o'clock in the morning, half of the trips during this period were by shoppers. Particularly apparent is the heavy burden imposed upon mass transportation facilities from 10

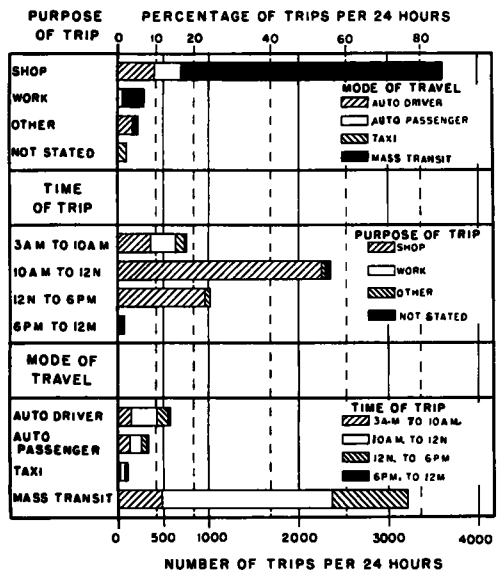

Figure 13. Analysis of Trips to A General Market by Purpose, Time and Mode of Travel

A.M. until noon. These shoppers amounted to 44.5 percent of the total number of persons who visited the market daily. Figure 14 reveals that the traffic was drawn largely from the west-central section of the city.

Department Store "C"

This is a comparatively new and large department store located in the northeast quadrant outside of the downtown area yet well within the built-up section of the City. From Figure 15 one sees that the pattern of its daily 3660 trips differed greatly from that of either the downtown department stores or the retail and mail order store. The percentage of shoppers, though much smaller in numbers, approximated that of Store "A" and "B", but

the proportion of automobile trips surpassed even that of the retail and mail order store.

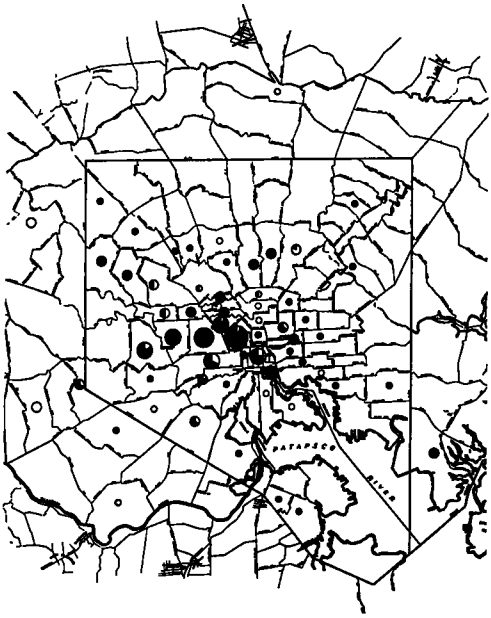

Figure 14. Origin of Trips to A General Market

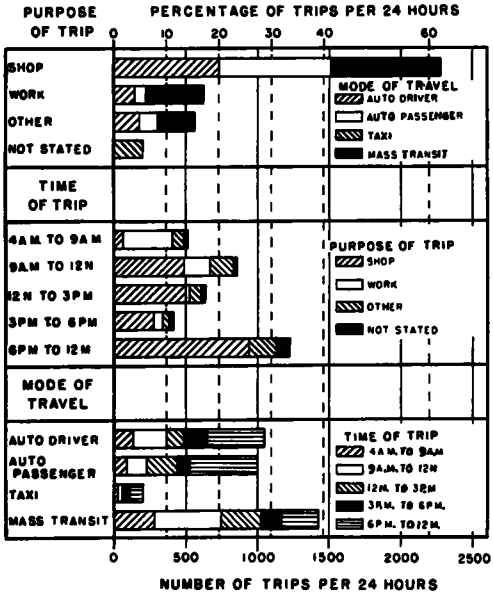

Figure 15. Analysis of Trips to Department Store "C" by Purpose, Time and Mode of Travel

However, it is interesting to note that most of these automobile shoppers arrived in the evening after 6 P.M. This characteristic was no doubt due in part to its being open on two nights each week as well as to the existence of a retail grocery department and the availability of automobile parking facilities. Figure 16 illustrates the fact that, although the trips originated largely with a 2- to 3-mile radius, there was an appreciable concentration of origins in the more distant eastern and northeastern sections.

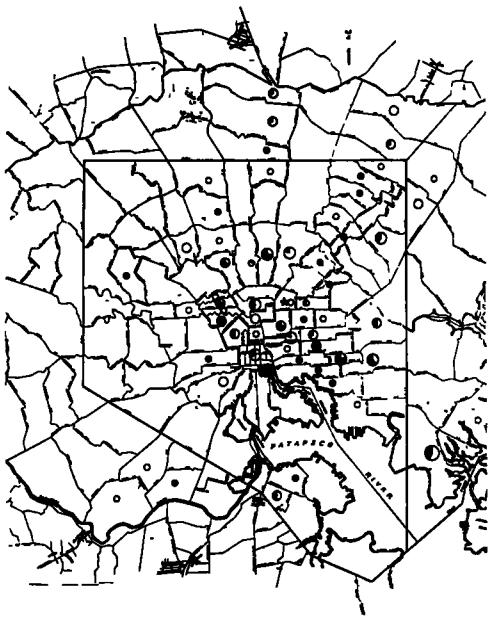

Figure 16. Origin of Trips to Department Store "C"

Industrial Plant

This is an entire industrial site controlled by a single organization and includes factory buildings, warehouses and shops. As seen from Figure 17, over 96 percent of the 2750 daily trips were made by employees of the company, and the bulk of these were split between those who reached the plant before 7 A.M. and those who arrived between 7 and 9 A.M. This latter class comprises a majority of the automobile travelers. However, 67 percent of all the trips were by mass transit. Figure 18 shows that a vast proportion of trip origins were in the vicinity of the plant, over 27 percent having originated in but two neighboring zones. This factor probably indicates a sizable amount of pedestrian traffic.

Office Building "A"

This office building in the central business district, though housing some individual

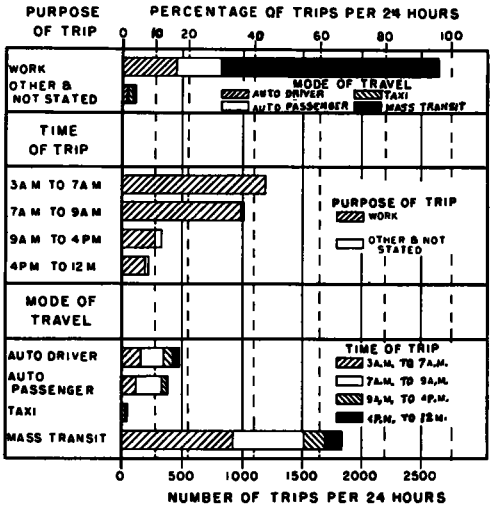

Figure 17. Analysis of Trips to An Industrial Plant by Purpose, Time and Mode of Travel

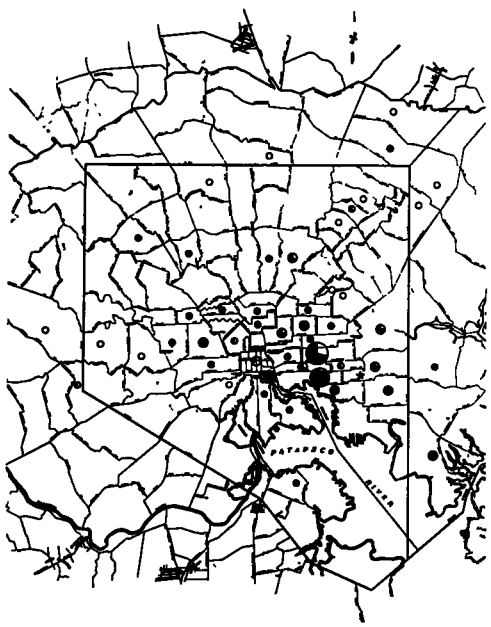

Figure 18. Origin of Trips to An Industrial Plant

lessees, was used primarily by the Accounting Operation Division of the U. S. Government Social Security Administration. The facts brought out by Figure 19 are obvious, in that a large portion (over 48 percent) of the approximately 3450 daily trips were made by employees who traveled on mass transit facilities between the hours of 6 and 9 A.M. An afternoon shift of workers generated the 3 to 4 P.M. traffic. Although one can observe from Figure 20 that the origins of the trips were well scattered throughout the City, the majority were located relatively close to the downtown area. For this reason, as in the case of the industrial plant, it seems probable that walking trips were numerous.

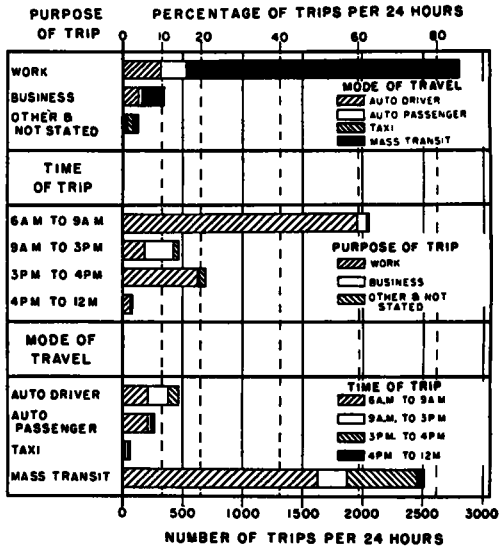

Figure 19. Analysis of Trips to Office Building "A" by Purpose, Time and Mode of Travel

Office Building "B"

This building, located in the downtown area, is used entirely by the company which owns it for the conduct of its business operations. It generated, daily, a little less than 1800 trips. Since its use differs somewhat from the previous type of office building, one would assume that the traffic which it generated was of a different character. However, Figure 21 reveals a marked similarity between it and Office Building "A". There are two exceptions. First, since there was no afternoon shift of employees, better than 82 percent of the trips were made between 6 and 9 A.M. Secondly, there was an increase of 5 percent in the amount of automobile travel

over that of Office Building "A". This is possibly explained by Figure 22 where the

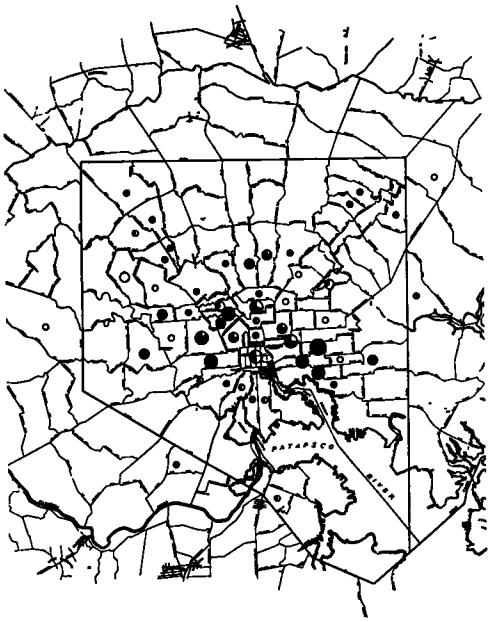

Figure 20. Origin of Trips to Office Building "A"

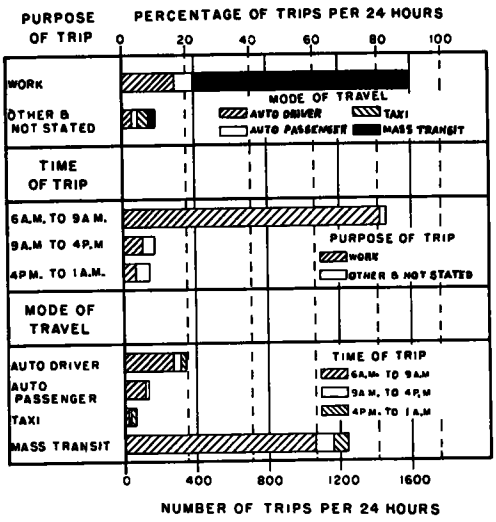

Figure 21. Analysis of Trips to Office Building "B" by Purpose, Time and Mode of Travel

trip origins appear to be more scattered than in the previous case and travel distances were therefore considerably greater. There is also the supposition that residence in the outlying regions of the area might indicate higher incomes accompanied by a larger ownership of private automobiles. Indeed there is other evidence to support the belief that the economic status of employees in this office building is higher than that of those in the one previously cited.

Theater

This theater is representative of the larger downtown places of amusement featuring first-run motion pictures. Though the daily

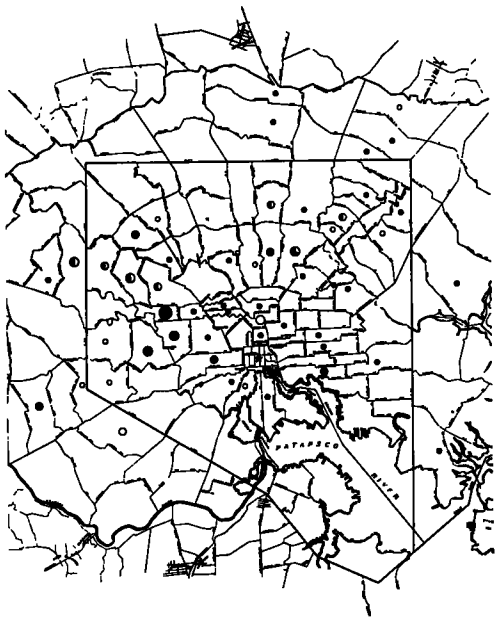

Figure 22. Origin of Trips to Office Building "B"

vehicular trips amounted to only 1670, this figure by no means represents the total number of persons attracted to the theater on an average day. A great many walking trips were undoubtedly made by persons who had already entered the downtown area for purposes of working or shopping. As would be expected, Figure 23 shows that upwards of 87 percent traveled to it for social-cultural or recreational purposes. Mass transit accounted for 67 percent of its trips and taxicabs 6.3 percent, while the remainder was evenly split between automobile drivers and passengers, thus indicating the attendance of couples. Of special interest is the fact that over 53 percent came between 7 and 9 P.M.,

nearly 30 percent of whom traveled by automobile. This period therefore constituted the peak period of parking demand, and any presumption that a high vehicle turnover might be applied when determining parking space requirements, is thereby invalidated. The only noticeable feature displayed by Figure 24 is, perhaps, the concentration of trip origins just beyond the central business district.

Public High School

The school which was selected is the second largest public male high school in the area.

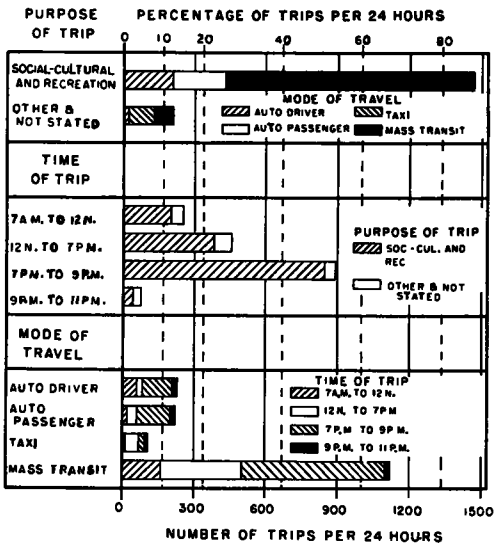

Figure 23. Analysis of Trips to A Theater by Purpose, Time and Mode of Travel

In addition, its classrooms provide facilities for adult instruction four nights a week. It daily generated 1535 persons, who traveled by some kind of vehicle. As seen from Figure 25, a majority of the workers, largely instructors, traveled in automobiles, while better than five-sixths of the students used mass transit facilities. Slightly more than 70 percent of each of these groups arrived before 9 A.M. Also, due to the evening courses, almost 16 percent of the students traveled to the school after 6 P.M. Although some of these were automobile drivers, none were automobile or taxicab passengers. Figure 26 discloses that the trips originated fairly equally throughout the area, with the automobile and taxicab travel predominantly from the northern and western sections.

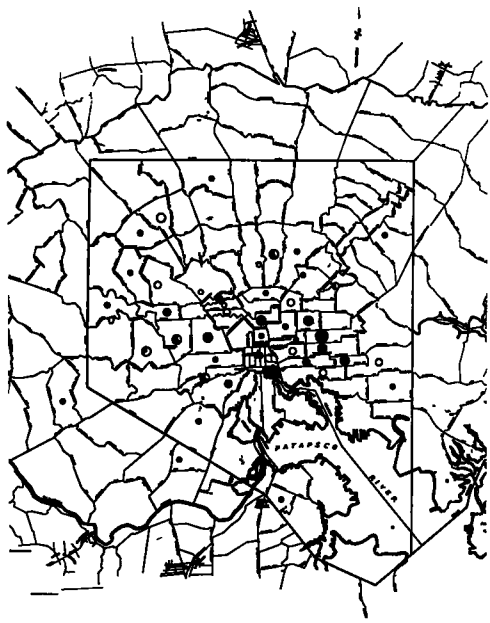

Figure 24. Origin of Trips to A Theater

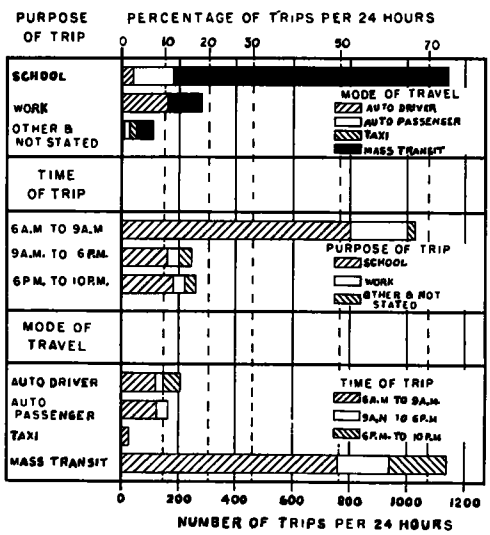

Figure 25. Analysis of Trips to A Public High School by Purpose, Time and Mode of Travel

University Campus

This university, located in the outlying area toward the northern part of the city, generated nearly 1500 trips on the average

weekday. The pattern of this traffic was much dissimilar to that of the public high

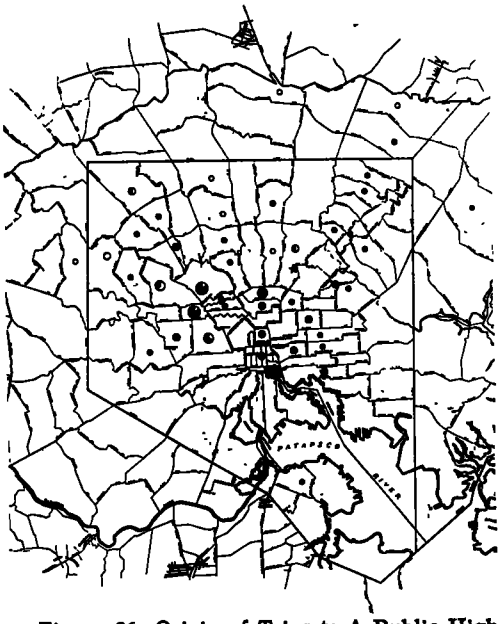

Figure 26. Origin of Trips to A Public High School

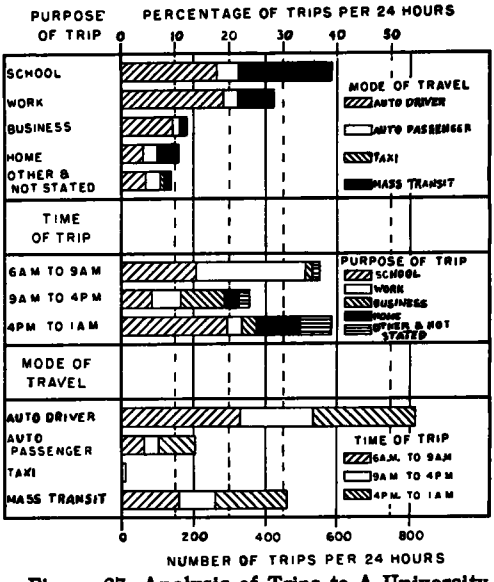

Figure 27. Analysis of Trips to A University Campus by Purpose, Time and Mode of Travel

school. Automobile driving is shown by Figure 27 as the predominant mode of travel for each purpose, while only about 30 percent of the trips were by mass transit. The excess of purposes to school over those to work was relatively slight. No doubt this is due largely to the unusually high faculty-student ratio and the number of non-student assistants working in research laboratories at that time. There were also trips "to home", usually after 4 P.M., which were presumably made by dormitory students. This fact, in addition to the large registration for afternoon and evening courses (78 percent of the total number of

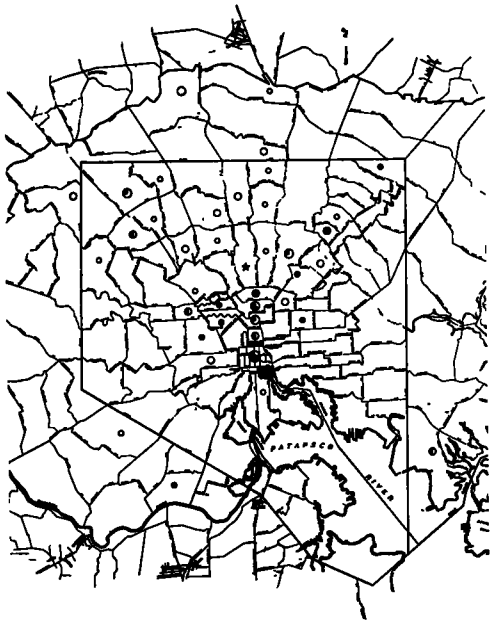

Figure 28. Origin of Trips to A University Campus

students) promoted more trips after 4 P.M. than occurred in the morning prior to nine o'clock. Most of the business trips were by automobile drivers between 9 A.M. and 4 P.M. According to Figure 28, automobile trip origins were distributed mainly among the northern zones, while the mass transportation travel originated chiefly in the central section.

Hotel

One of the largest in Baltimore's downtown business area, this hotel daily attracted over 1350 persons by some means of vehicular travel. Due to the lack of purpose informa-

tion with regard to taxicab trips, the first two charts in Figure 29 are somewhat incomplete. Although the preponderance of taxicab trips is quite apparent, a majority of the employees appears to have traveled by mass transit, while those persons with a business purpose used automobiles. Most people in search of entertainment arrived later than 6 P.M. and practically all trips after 10 P.M. were by taxicab. A review of Figure 30 discloses no definite pattern of trip origins, but it does tend to point out the large percentage of mass transit trips which originated in the east-

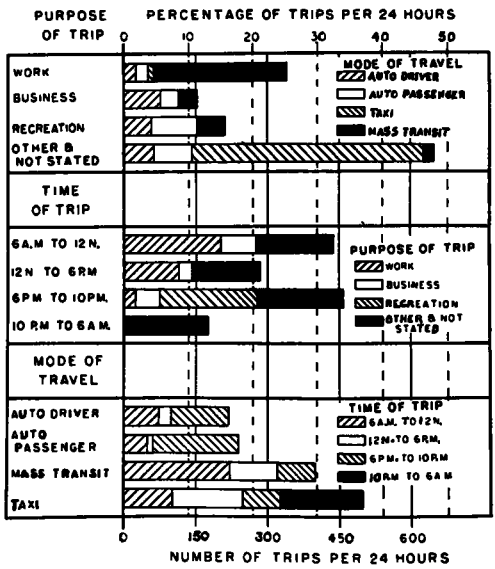

Figure 29. Analysis of Trips to A Hotel by Purpose, Time and Mode of Travel

central and west-central sections. More important, however, is the large number of taxicab trips which had their origin in those zones in which train and bus terminals are located. These are the downtown area and a fringing zone to the north.

It seems appropriate here to reiterate the consistent concurrence of this generator data with the surmised character and pattern of vehicular traffic.

Bus Terminal

This is the principal bus terminal in the city. It is situated on the northern fringe of the central business district and generated about 1050 trips daily. As in the case of the railroad station, a breakdown by purpose would be meaningless and is therefore not included. Nevertheless, Figure 31 does reveal an increase

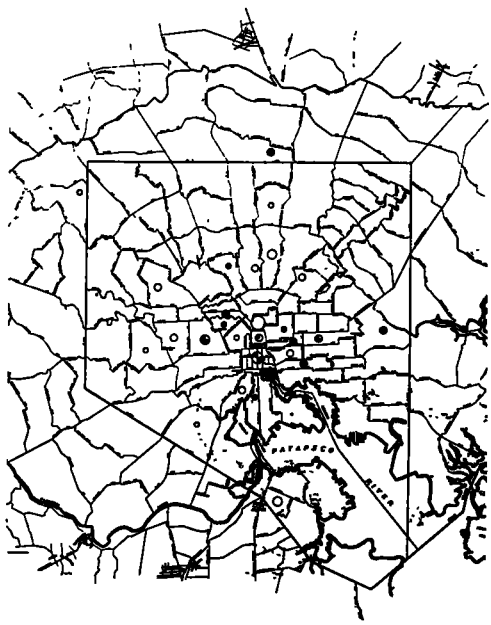

Figure 30. Origin of Trips to A Hotel

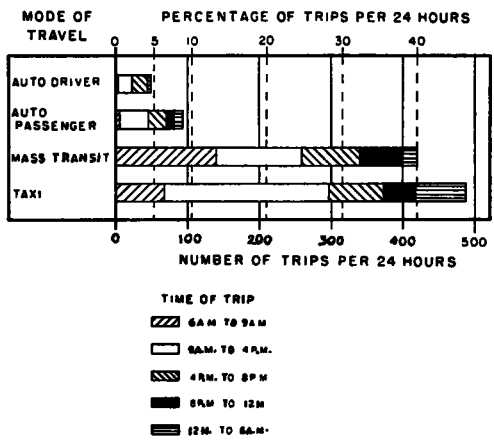

Figure 31. Analysis of Trips to A Bus Terminal by Mode and Time of Travel

in the percentage of mass transit trips over that obtained for the railroad station. This increase, however, was at the expense of an approximately corresponding reduction in automobile trips, while the amount of taxicab travel approached 50 percent, in favorable

agreement with that of the railroad station. The proportions of trips during a given time interval, for each respective mode of travel, were practically identical for the two terminals. In addition to an otherwise well-dispersed pattern, Figure 32 shows some concentration of trip origins in the downtown and north-central zones.

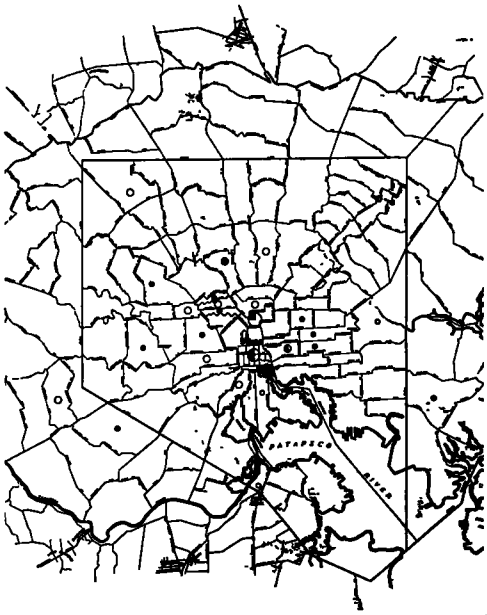

Figure 32. Origin of Trips to A Bus Terminal

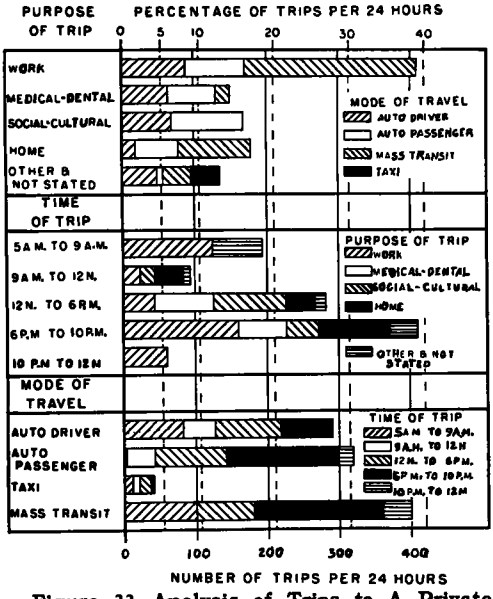

Figure 33. Analysis of Trips to A Private Hospital by Purpose, Time and Mode of Travel

Private Hospital

This is a relatively large hospital situated in an outlying area near the southwestern city boundary. It generated slightly less than 1050 trips a day. Figure 33 indicates that nearly 40 percent of the trips were for work purposes, and that over half of these were made by mass transportation. Medical-dental, social-cultural, "to home", and the combination of "other" and "not stated" purposes almost equally divide the remaining trips. All those with a social-cultural purpose made the trip by automobile. The large number of trips between 6 and 10 P.M. was swelled by nurses who came on duty in the evening and by those who returned "home" (i.e., nurses' home) from elsewhere, mostly by mass transit. The data indicate that all patients arrived in the afternoon and evening, while most of the visitors made their calls between noon and 6 P.M. Some 58 percent of all persons making trips traveled by automobile, nearly half of whom were drivers. It is readily seen that, as the number of trips decreases to around a thousand, presentations like Figure 34 rapidly lose their significance.

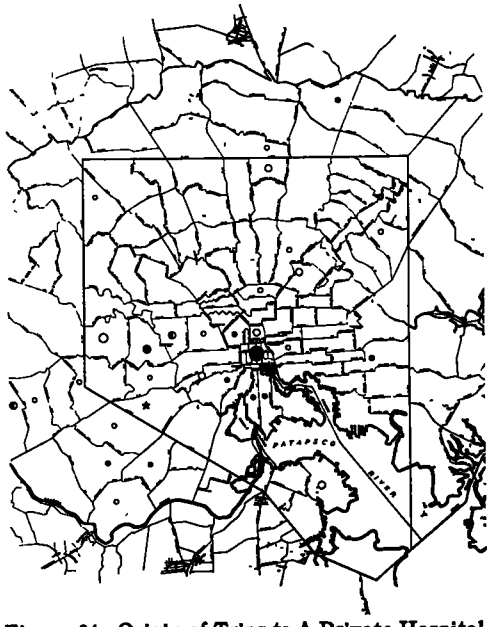

Figure 34. Origin of Trips to A Private Hospital

Nevertheless, this map immediately reveals the large proportion of trips which originated in the downtown area.

GENERATION OF VEHICLES

In the foregoing analysis, each trip represents the travel of a person. However, for application of the results of such a study to street traffic volumes the traffic engineer and city planner are interested in the number of vehicles originating from generators, as well as the attraction of vehicles to them. For the former information the method used in this investigation may be applied, considering the buildings as origins of trips rather than as destinations.

TABLE 1
VEHICLES GENERATED PER 24 HOUR WEEKDAY BY VARIOUS GENERATORS

Generator	Automobiles	Taxicabs	Total
Department Store "A"	1302	95	1397
Department Store "B"	571	90	661
Railroad Passenger Station	1607	2282	3889
Retail and Mail Order Store	1172	50	1222
Neighborhood Shopping Community	2016	172	2188
General Market	568	60	628
Department Store "C"	1053	125	1178
Industrial Plant	486	21	507
Office Building "A"	463	35	498
Office Building "B"	341	35	376
Theater	225	50	275
Public High School	208	20	228
University Campus	817	10	827
Hotel	217	257	474
Bus Terminal	49	279	328
Private Hospital	290	21	311

Although it is based only on destinations, Table 1 is presented to indicate the number of automobiles and taxicabs attracted by the several generators. It was derived by considering that each automobile driver trip represented one passenger car, while each taxicab trip (not each passenger) signified an additional vehicle. For reasons stated previously trucks are omitted.

PARKING DEMAND

The information accumulated in the Parking Study of 127 blocks of Downtown Baltimore[3] was also coded by sectors which, it will be recalled from the description of the O and D study, were equivalent to city blocks in this part of the City.

The procedure adopted in the study of traffic generation could not be applied directly to the parking demand created by the selected generators. This was mainly because most of the generators lay outside the 127 blocks of the Parking Survey and because it was impracticable to identify, and draw from files for detailed examination, the original questionnaires corresponding to the punch cards containing the parking information. The punch card information showed where the car was parked, at what hour and for how long, and the purpose of the trip. But it did not show where the parker went except to give the sector or block; that is, the punch card did not reveal the *building* to which he walked. This could only be gotten from the questionnaire. It should be stated that coding and punching to permit sorting by sectors, as in the case of the O and D Survey, was completely adequate for the original purposes of the Parking Survey. Had the use of the data for individual generator parking demand been visualized, it would have been possible to facilitate the identification of the questionnaire against the punch card by giving each individual parking operation a serial number by which it could have been so identified.

However, for the purpose of locating curb parking facilities, the sector or block numbers had been assigned an additional digit which pin-pointed the side of the block. This made it possible to sort the cards for parking operations which were followed by trips to buildings which fronted on the entire face of at least one side of a block. There were three such generators.

Only one of these will be reported here as an example of what this sort of investigation may produce. The case reported is that of a combination of department stores "A" and "B", occupying the same block. The traffic generation of both of these has been discussed previously.

PRESENTATION OF RESULTS—PARKING DEMAND

Proceeding in a manner similar to that followed in the traffic generation phase of this study, the Parking Survey punch cards which pertained to trips to the two contiguously located department stores were sorted and

[3] Report of the Transportation Study,—Baltimore Metropolitan Area, "*Parking Survey of the Downtown Area—Baltimore City*," Vol. IV, ed. Maryland State Roads Commission in cooperation with the City of Baltimore and the Public Roads Administration, Federal Works Agency. (Baltimore 1946).

listings made of all pertinent data. These are shown in Figures 35, 36, and 37.

Figure 35 shows that of the 1413 automobiles parked between 6 A.M. and 6 P.M. on the average weekday in 1946, about 81 percent of the trips were for shopping and about 13 percent for work. This varies by less than 3 percent from the weighted distribution of purposes for automobile driver trips destined to these two stores as determined from O and D Survey information. Over 73 percent of the shoppers parked between 10 A.M. and

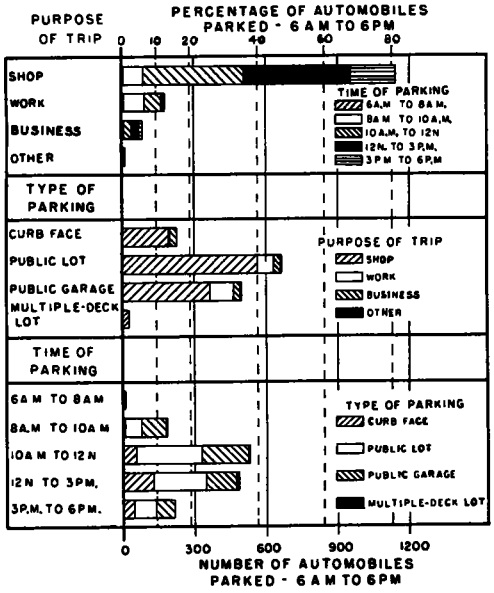

Figure 35. Analysis of Trips by Parkers Destined to Department Stores "A" and "B" by Purpose and Time and Type of Parking

3 P.M. at the average rate of 172 vehicles per hour. Public lots and garages accounted for about 84 percent of the parking, the remaining 16 percent occupying curb spaces. Nearly all employee drivers parked at off-street facilities. Curbs were used but little prior to 10 A.M., probably due to parking restrictions, but from noon until 3 P.M. the curb was used as much as the public garage.

Figure 36 clearly indicates that drivers working at the stores park for a long time. One would expect this. But what is surprising is the revelation that the weighted average length of time parked by shoppers was 2.8 hours. Recalling that 73 percent of these shoppers arrived within a 5-hour period, it may be concluded that the shopper parking turnover hardly exceeds two vehicles per day. It should be stated in this connection that some of these trips, resulting in long parking and reported as shopping visits to these stores, probably included walking trips to other stores, luncheon, the beauty parlor, the theater, etc. A further interesting feature of Figure 36 is the distribution of distances walked from parked cars to the stores. Note that the suspected short shopper-walks and long worker-walks are not apparent. It is probable that a considerable number of workers reached the garage, which was close by,

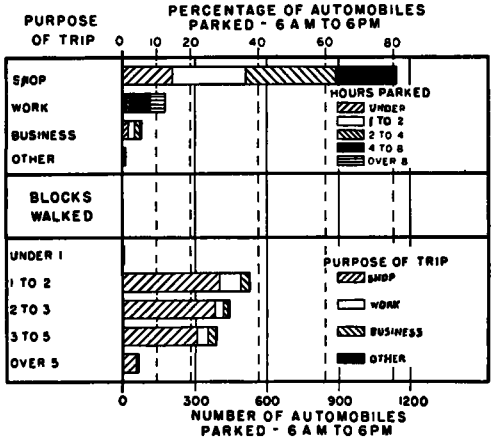

Figure 36. Analysis of Trips by Parkers Destined to Department Stores "A" and "B" by Purpose, Hours Parked and Blocks Walked

before the heavy influx of shoppers, thus preempting spaces which the latter desired.

Similarly, in Figure 37, it is seen that the short-time parker did not park any closer to his destination than the long-time parker; if anything the opposite was the case. Also, a very large proportion of those parking on public lots walked two to three blocks while a larger percentage of the public garage parkers walked only one to two blocks. These facts were no doubt due to the existence of a lot and a garage within these distances which particularly provide parking space for shoppers visiting these stores. Owing to the curb parking restrictions which exist in the adjacent blocks, the distances walked from curb spaces were relatively large. Nevertheless, the short-time character of this on-street parking is noteworthy.

PARKING SPACE DEMANDS AND REQUIREMENTS RELATED TO GENERATOR UNITS

Although the preceding analysis of parking survey data demonstrates the possibility of determining the parking demand created by certain types of buildings, it entails many obvious shortcomings not the least of which is the fact that relatively few municipalities have conducted or will conduct such exhaustive parking surveys. But O and D surveys of the type made in Baltimore are likely to be made in other places and those that have been made elsewhere will soon stand in need of being repeated or brought up to date. From these it is possible to ascertain the average 24-hour weekday parking demand for all large generators throughout the survey area.

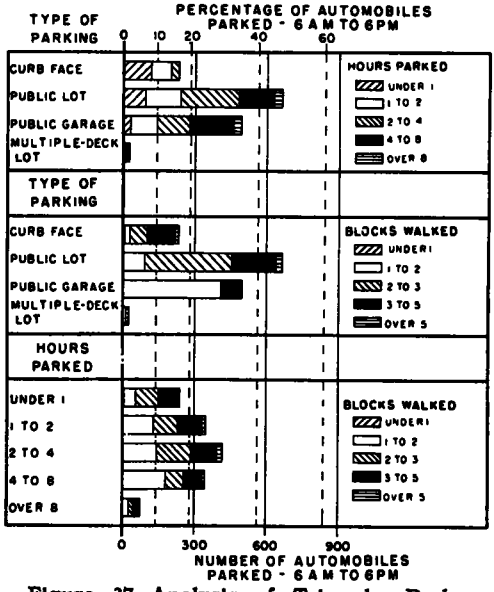

Figure 37. Analysis of Trips by Parkers Destined to Department Stores "A" and "B" by Type of Parking, Hours Parked and Blocks Walked

It was assumed reasonable that each automobile driver destined to one of the generators constituted a demand for one parking space. This, of course, does not mean that one parking space is required and must or should be provided. Peak hour demand and vehicle turnover per parking space must also be considered and these will vary with the type and location of generator and purpose of trip. Although peak hours were apparent, turnover factors could not be determined directly from O and D data since they contained insufficient parking information. However, by taking into consideration all of the elements involved in each case the turnover factors were estimated to range from one vehicle per space for a "work" purpose to four vehicles per space for purposes other than to shop or work.

In Table 2 these turnover factors have been applied to the automobile driver trips for each generator in order to compute the parking spaces required. In the same table there are also shown such obviously useful factors as the square feet of total floor or selling space, seats in schools and theaters, employees in industrial plants, beds in hospitals, etc., per parking space required.

The following comments on Table 2 may be helpful: The discrepancy between the floor areas per parking space required for the very similar Department Stores "A" and "B" may appear to be large, but it can be reliably stated that this variation is due to the different character of the traffic generated by the two stores. This is borne out by the relatively close agreement of the relationships between total floor area and the total number of persons making trips by all modes of transportation, which were 34.1 and 39.1 square feet per person for Department Stores "A" and "B" respectively.

The parking space requirement of the neighborhood shopping community is also worthy of further mention. It is noted that when many small retail businesses congregate in a central location, parking needs multiply greatly in the localized area. The shops in this community, numbering 120 with an average floor space of 5000 sq. ft., require 738 parking spaces or about six per shop, a requirement far beyond any reasonable average estimate for such small units, were they isolated. The significance of this finding is already having an influence on the shaping of a proposed Baltimore ordinance which, in all likelihood, will be revised to take cognizance of this effect.

From city to city across the country, standards like those suggested in the last column of Table 2 are being used in estimating the size and capacity of parking facilities, yet, when they are compared with each other or with actual on-the-ground observations or

TABLE 2

SUMMARY OF PARKING SPACE DEMAND CREATED ON 24-HOUR WEEKDAY BY VARIOUS GENERATORS AND RELATIONSHIPS WITH FLOOR AREA OR OTHER BASIC UNITS

Generator	Purpose of Trip	Auto Driver Trips[a]	Estimated Turnover	Parking Spaces Required	Gross Floor Area or Other Basic Unit	Gross Floor Area or Other Basic Unit per Parking Space Required
Department Store "A"	Work	104	1	104	182,145 sq ft (selling area)	283 sq ft (selling area)
	Shop	1036	[b]2	518	305,145 sq ft. (total area)	475 sq ft. (total area)
	Other	62	3	21		
	Total			643		
Department Store "B"	Work	146	1	146	185,000 sq. ft (selling area)	518 sq ft (selling area)
	Shop	415	[b]2	208	245,000 sq ft (total area)	686 sq. ft (total area)
	Other	10	3	3		
	Total			357		
RR Passenger Station	Total	1187	[c]1 2	989	93,583 sq. ft	95 sq. ft.
Retail and Mail Order Store	Work	286	1	286	1,300,000 sq. ft.	1816 sq ft
	Shop	808	[b]2	404		
	Other	78	3	26		
	Total			716		
Neighborhood Shopping Community	Work	294	1	294	120 shops at 5,000 sq. ft each equals 600,000 sq. ft	813 sq. ft
	Shop	582	[d]3	194		
	Other	[c]1000	4	250		
	Total			738		
General Market	Work	[f]5	1	5	45,000 sq ft 650 stalls	199 sq. ft. 2.9 stalls
	Shop	399	[b]2	200		
	Other	64	3	21		
	Total			226		
Department Store "C"	Work	144	1	144	100,000 sq ft	180 sq. ft
	Shop	735	[b]2	368		
	Other	134	3	45		
	Total			557		
Industrial Plant	Work	447	1	447	1,913,000 sq. ft. 3138 employees	4223 sq. ft 6.9 employees
	Other	19	3	6		
	Total			453		
Office Building "A"	Work	313	1	313	591,000 sq. ft (net rentable area)	1628 sq ft (net rentable area)
	Other	150	3	50		
	Total			363		
Office Building "B"	Work	292	1	292	252,000 sq. ft.	818 sq. ft.
	Other	49	3	16		
	Total			308		
Theater	Soc-Cul & Recreation	205	[g]1 5	137	50,000 sq. ft. 3000 seats	318 sq ft 19.1 seats
	Work	20	1	20		
	Total			157		
Public High School	Work & School	201	1	201	256,400 sq ft. 1527 students	1263 sq. ft. 7.5 students
	Other	7	3	2		
	Total			203		
University Campus	School	266	[h]2	133	398,500 sq ft (net academic area)	910 sq. ft (net academic area)
	Work	283	[h]1.2	236	613,500 sq. ft. (total area)	1401 sq. ft. (total area)
	Home	60	1	60	3335 students	7.6 students
	Other	26	3	9	4346 seats	9.9 seats
	Total			438		
Hotel	Work & Business	100	[k]1	100	162,000 sq ft. 425 guest rooms 700 capacity	1013 sq. ft. 2.7 guest rooms 4 4 capacity
	Recreation	56	[m]1.4	40		
	Other	61	3	20		
	Total			160		
Bus Terminal	Total	29	[c]1 2	24	25,000 sq. ft. (net terminal area) 46,000 sq. ft. (incl. garage area)	1042 sq. ft. (net terminal area) 1917 sq. ft. (incl. garage area)
Private Hospital	Work, Home & Medical	172	1	172	197,000 sq. ft. 400 beds	934 sq. ft. 1.9 beds
	Other	78	[n]2	39		
	Total			211		

[a] Except those to serve passengers.
[b] Low due to peak-hour traffic.
[c] Greater than unity due to 24-hour period.
[d] Higher due to shorter time parked at specialty shops.
[e] Also excepts trips "to home."
[f] But many workers drive trucks.
[g] Low due to evening peak hour. Figure 23.
[h] Higher due to evening and night classes.
[k] Business not at hotel—actually "to room" purpose.
[m] Low due to evening peak hour. Figure 29
[n] Low due to visiting-hour peaks.

counts, there is a ghastly lack of conformity. This is not surprising since so much of it is pure guesswork and so little of it based upon valid measurements or counts of any kind. Even when such investigations are made, as in the present instance, the results need to be verified and supported by similar findings in other places before generalizations may be attempted.

CONCLUSIONS

1. This study demonstrates and establishes the practicability of a method for obtaining qualitative and quantitative information about the traffic generated by various types of buildings. It also establishes a practical method of securing mass information on the parking demand created by various generators.

2. The data presented here as examples of the kind of information which the analysis may produce are not to be construed as finally representative for each type of generator. They must be used with caution until substantiated or modified by further application of the method in other areas.

3. In order to have assurance of the stability of samples, generators must attract a relatively large number of trips. From experience gained in this investigation the minimum number of trips appears to be at least one thousand.

4. The heterogeneous buildings of neighborhood shopping communities, while not generating appreciable traffic individually, may attract a sizable number of vehicles when considered collectively. This is due to their mutual proximity and consequent added power of attraction.

5. Buildings of approximately the same size, which house activities that are of similar character, may attract traffic and create parking demands which are quite dissimilar. The danger of generalizations that are too sweeping, is obvious.

RECOMMENDATIONS

1. The procedures demonstrated in this study are recommended for use in connection with and as a by-product of urban origin and destination surveys wherever comprehensive information is sought pertaining to a considerable number of large generators. It is evident that if the number of generators is limited or if they are small, it will probably be less expensive and more accurate to conduct a spot-check survey by interviewing a large sample at the site.

2. In order to facilitate the application of these methods it is recommended that present O and D and Parking Survey techniques be revised to include the following:

a) Whenever more than one generator occupies the smallest subdivision of the O and D Survey area, the individual buildings which are selected for special study should be coded specifically at the outset. This would prevent laborious scanning of the original questionnaires.

b) If this is not practicable, the names or addresses of the buildings should be reported as destinations. In this case, all of the original interview forms should be carefully listed and filed by serial number in such a way as to facilitate their matching with punch cards.

c) Include a serial number on the parking survey questionnaires and on the punch cards, so that for each trip they may be readily associated.