CPAS

Center Of Planning And Architecture Studies

Lecture Number five

PRACTICAL METHODS FOR SURVEYS AND ANALYSIS

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Traffic Surveys and Analysis

The scope and nature of traffic engineering has changed in recent years. Information is required not only for the planning of road systems but on the social and environmental consequences to the community of such plans. Nor can road planning be considered in isolation; the scope of the work has widened and travel requirements must be seen in a context of the interaction between all modes. Policy decisions affect the facilities available, changing and creating new opportunities in urban life, which lead to new habits. Adequate monitoring of these changes is essential if greater flexibility is to be maintained in planning and new trends incorporated in the previous long-term forecasts on which a plan has been based.

Surveys are needed for many purposes and if these are to be efficiently conducted it is essential that their objectives are clearly defined. The types of survey range from the determination and characteristics of a large-scale movement pattern, for use in a structure plan, to small surveys to ascertain the local plan needs, or the response of a small group of citizens. These may vary from the study of a potential pedestrian precinct to the special problems of access to a public road from industrial or commercial premises, involving the movements of a work force and visitors, or the location of passenger traffic and freight terminals. There are also the problems of preservation and conservation of areas, the growth of urban and rural traffic and the development of tourism.

TRANSPORTATION SURVEYS

The fundamental interaction between land use planning and the nature of the travel pattern has been brought together in a unified process which includes public policy decisions and the evaluation of alternative strategies.

The first phase of a study is the formulation of goals for the defined area and the setting of objectives based on available resources, time spans and public aims. The next stage is the planning of relevant surveys, determining the level of detail required to obtain a specified accuracy, based on current information, and completing surveys, analysis and model building. Finally, forecasts are made for predetermined periods; usually, long-term alternatives are tested at an interim stage, each being evaluated against sets of economic, operational and social criteria laid down in the goal formulation phase. The transportation planning process is shown diagrammatically in Fig. 3.1.

Land Use

A distribution of residential, educational, commercial, manufacturing and service industry is tabulated by intensity of use and by age and condition of property. Similarly information is collected on recreational land and vacant space and on the potential of underdeveloped or derelict land. The environmental state and quality of both the natural and built environment is assessed.

Socio-economic Activity

Population characteristics are reviewed for the major activities of work, education, shopping and recreation. The associated economic base information is also collected and budgetary constraints examined.

Transportation Facilities

An inventory of all existing travel facilities is prepared by mode and examined in relation to current use. Where considerable base material is available within the area, or available from a similar place, it is possible to synthesise travel movements and reduce the need for full-scale travel surveys. The size and scope of the studies is influenced by the objectives, degree of likely change, particularly of land use in the forecast period,

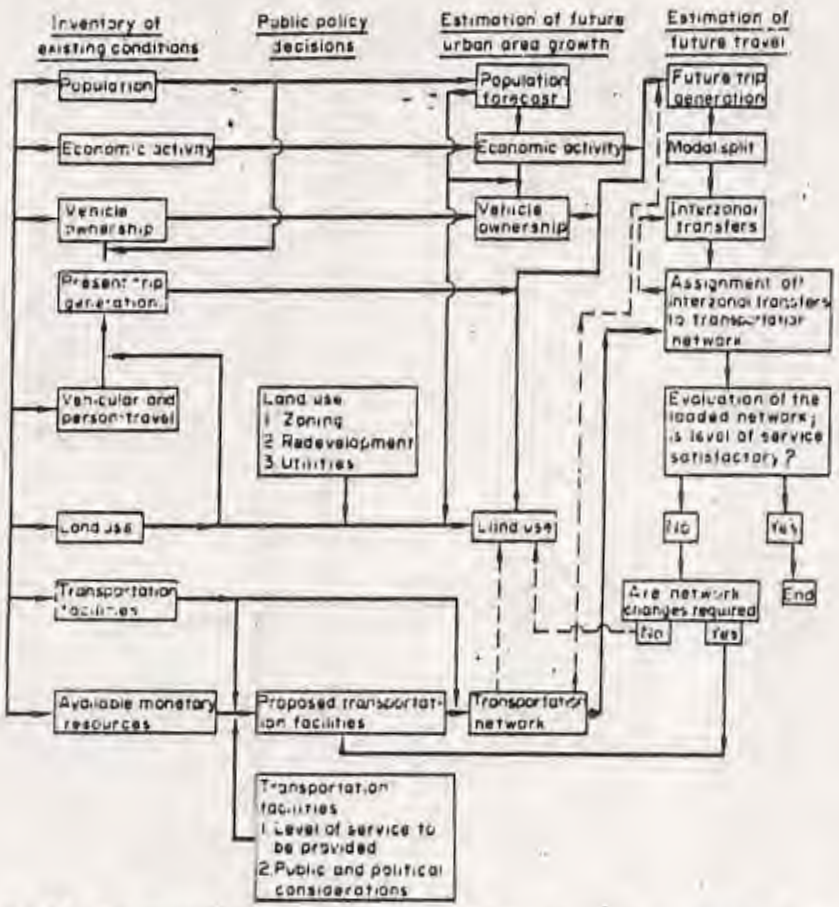


FIG. 3.1. The transportation planning process. (Source: Memmott, Martin and Bone, Predicting future demand for urban area transportation, *H.R.B. Bull.* 326.)

diversification of the population and complexity of the detailed projections required in the plan testing and evaluation stage.

Definition of Study Area

Surveys can range from the national level through regional, county, district or local levels down to a single land-use generator. In ascending size order each level overlaps and includes the preceding group, and it is often necessary to use outputs from one survey level as inputs to another, although the nature and type of detail will vary with each survey purpose.

The outer edges of the study area are bounded by an external cordon whose delineation may create difficulties but in all cases would include land capable of development in the project period. Criteria used to distinguish areas include population density. Usually a minimum of 400 persons/km² is taken to define the limit of an urban area, but would, in any case, include all settlements within 2·5 km of the main urban area boundary. The proportion of the working population who commute from outlying areas to the main centre is often important and where the proportion exceeds 15% of the active residents of an outlying area it is generally included in the study. Information on these commuting proportions is obtained from the Registrar-General's Work Place Tables. Shopping and recreational movements may also be considered in defining the total area under review, but the finally selected cordon should be compatible with other survey boundaries.

TRAVEL SURVEYS

The activities, resulting from land use and economic characteristics of an area, generate travel, and the type and extent of these movements are studied by travel surveys. Survey techniques include the external observation of journeys or the direct interview of travellers. Interviews can be undertaken either during the course of the journey or at terminals (homes, offices, factories, schools, etc.) and interchanges (stations, bus stops, airports, depots, etc.). Travellers entering an area from external zones are intercepted by cordons placed around the survey area or, where comparisons are required of the use of alternative routes, by screen lines drawn across the axis of movement. Within cities, screen lines and cordons are often used to compare and check travel between areas with the information derived from home interviews and counts of vehicles at each point. Screen lines should be sited to avoid central areas and localities where vehicles are cruising around to find parking or points where the line may be crossed several times on the same journey. Natural and

man-made barriers, like rivers and railways, where crossing points are limited, make good boundaries.

It is necessary to know the basic volumetric characteristics of the system being studied in order to plan the proposed survey; later extensions may be both difficult and expensive to carry out. Sampling techniques are widely used to reduce the overall field-work and subsequent analysis. The choice of an adequate sample is important in establishing an accuracy for the expanded results.

SURVEY METHODS

There are five basic methods which can be used singly or in combination, depending on the nature of the problem and the information required.

Registration Number Surveys

This is a simple method not needing police or elaborate site equipment, but it has the major disadvantage that neither primary origins nor final destinations are obtained. Observers need good vantage points and, for large flows, the registration numbers and passing times of vehicles may be tape recorded. Recording stations must be simultaneously manned with starting and finishing times offset by the time required to travel between stations. Sampling methods are difficult to apply, but one method is to record only registrations ending in selected digits. If the journey time between two stations is of the order of a few minutes, little error is introduced by recording only the digits of a registration. The probability of any one number appearing on x vehicles in a group of v vehicles passing in the selected time period can be determined from the Poisson distribution.

The method can be readily applied to a variety of routes without causing delay or influencing the habits of road users and is not badly affected by weather conditions as observers can be stationed under cover, although night conditions cause obvious difficulties. Bias will result from the false recording of a registration number as a vehicle will have been noted as entering the area and not leaving it and another as leaving the area only. Mistakes are difficult to avoid under intensive recording conditions and legibility also suffers, making transcription difficult. A large number of observers are required, as all the stations of a cordon must be manned at the same time, but different hours of the day can be sampled on different days. Two observers must be used, one calling and the other recording (unless tape recordings are made), for unidirectional flows in excess of about 250 veh/h. A skilled observer can call out up to 1000 registration numbers for periods less than an hour.

For manual analysis, the station lists are called out in turn and matches of registration numbers appearing at other stations, in the correct time order, are booked separately from those that enter and terminate in the area or are generated and sighted leaving the cordon. In a second method, a card index system is used and the information for the IN direction is worked through for all posts and placed on a card from a series, which is numbered 1 to 999, representing the three digits of a vehicle's registration. The OUT direction sheets are then recorded on the cards in a similar manner and vehicles are matched, times abstracted and movements through posts summarised. Similar listing and matching can be carried out using punched card machinery or by computer program but transcription costs are relatively high and manual methods can directly eliminate the more obvious recording and transcription errors. Evans has given a method to reduce the probable errors due to inaccurate recording—The estimation of road traffic flow by registration number observation, A.W. Evans, *Jn. Royal Stats. Soc.*, 22, 1, 1973.

Tag and Disc Surveys

In this method, survey stations are set up and precoded tags or discs, showing such items as vehicle classification, post number and the time of entry, can be stamped with a time clock before they are fixed to the vehicle or given to the driver for collection at exit points from the system. The tags are again time stamped and the exit post number is also recorded. Vehicle delay is kept to a minimum, but a similar disadvantage to that of registration number surveys applies so that full origin and destination

information is not available. While there is also less likelihood of bias, some drivers may lose the tags or object to their being fixed to their vehicles. Coloured tags or separate stickers, according to station of issue, may also be used in conjunction with additional observers sited at intermediate points, noting the numbers of the various colours present on their sections of route. Analysis work is similar to the techniques employed for registration number surveys, although simpler, and can be carried out manually or by machine methods. Mark-sense cards are particularly suitable as no subsequent office coding is needed.

Postcard Surveys

This method is useful for preplanning purposes in a major transportation survey to obtain general information on the movement pattern. It is also used where interview methods may cause extensive queuing and delay and is also often used in surveys of public transport passengers. Survey stations can be sited on cordons or screen lines, with police control to stop vehicles, or they may be located at traffic signals, bus stops, stations, parking sites or on board a vehicle in transit. Cards are usually prepaid for subsequent posting but, alternatively, they can be collected at another cordon point or left in a collection box at a station or car park.

Detailed information on passengers, journeys and purposes, vehicle types and garaging and routes used can be obtained with little delay. While few enumerators and minimum site organisation is required, it is important that ample prepublicity is given in the local press and on radio if worthwhile results are to be obtained. Bias is almost certain to be present due to the vagaries of human nature and response rates are usually low, ranging from 25 to 50%. It has been found that lower returns are recorded for truck drivers, visiting traffic and night drivers and that the response rate is likely to fall off through the day. Drivers who make a number of journeys across a cordon in the course of a day are often reluctant to complete more than one of the several cards they receive. Numbered cards have been used in a lottery to encourage a higher response rate, but cards may be collected and falsely completed.

Route Interviews

This method is generally adopted for rural and external city cordon surveys. The traveller is stopped by a police officer and an interviewer records journey details from a predetermined set of questions. Information collected on journeys includes starting and finishing points, last purpose and next purpose stops (i.e. excluding casual stops for petrol and refreshment), journey purpose, vehicle classification, numbers of passengers, goods carried, reasons for routeing or mode choice, income and travel costs. Sampling methods employ time and volume clusters or random sampling techniques.

(1) *Time cluster sampling.* During each hour of the survey a period of time t is selected when all vehicle drivers are interviewed and a further time period T when no interviews are carried out. The size of the sample, expressed as a percentage, is then $100t/(t+T)$. A convenient time interval for a 50% sample is 15 min for both t and T and the interviewers can then alternate interview directions to cover both IN and OUT flows. It is important that accurate time intervals are maintained and that all vehicles arriving within the selected periods are interviewed. If both directions are being covered, this will normally require centre of the road stations and the switching of half the interviewers to the other direction on or about 2 min before the end of the selected period. The remaining interviewers will switch direction on completion of their 15-min interviews. The main disadvantage is that small queues may begin to form during each period, and without the aid of the station supervisor for the additional interviewing, the back-log may not be readily overcome. Alternatively, if the change over of direction is difficult to arrange, a 33⅓% sample can be taken using a 10-min interview period and a 5-min break to change interview direction.

(2) *Volume cluster sampling.* A predetermined number of vehicles x to be interviewed is selected, the number adopted per cluster is generally dependent on the availability of interviewers. To avoid confusion, interviewers should ideally carry out only one interview in each cluster.

Also, depending on the sample size, a cluster of vehicles X is allowed to pass without interviewing. The size of the sample expressed as a percentage is then $100x/(x+X)$. While interviews in both directions can be conducted at the same time, more interviewers than method 1 will be required.

(3) *Variable rate sampling*. In this method of random sampling developed by the Road Research Laboratory, interviewers are employed at a constant rate, the sampling size fluctuating according to the volume flow. Depending on the characteristics of the stream, sample rates are calculated for either ½ h or 1 h periods, and usually, to reduce the possibility of bias, for individual classes of vehicle. This is likely to occur where vehicles are bunched and groups are led by slow vehicles. The operation is controlled by the supervisor who is in a position to see both the interviewers and the police controller responsible for drawing the required vehicles from the stream. Vehicles not being interviewed are allowed to pass the station continuously at reduced speed. When all interviews in one group have been completed at the station, the supervisor signals the police controller to let in a further group, by drawing out the NEXT vehicles in the stream, equal in number to the interviewers. Combinations of methods 1, 2 and 3 can be used and examples of station layout are shown in Fig. 3.2.

Organisation

Route interview surveys require the most elaborate organisation and are susceptible to interference from the weather. Careful framing of questions is needed to avoid bias and ambiguity together with a strict site organisation for interview procedure and handling the recorded data. Duties of interviewers must be clearly outlined and some previous training at a low volume survey station is desirable. It is particularly important that interviewers rigidly adhere to the standard questions and that care is taken to avoid recording false answers, either deliberate or unintentional, on the part of the drivers, e.g. giving next major town as destination, omitting intermediate stops or including a casual stop.

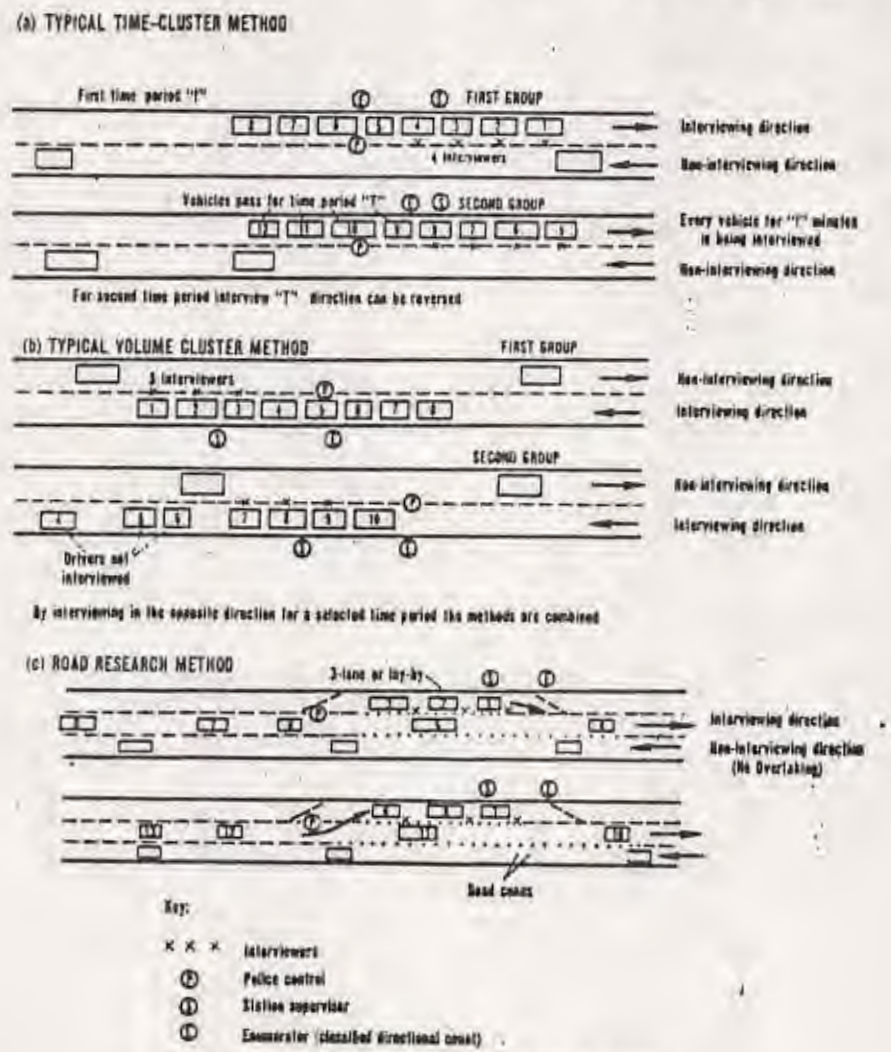


FIG. 3.2. Route interview methods and station layouts.

However, the method when properly conducted is most satisfactory, and gives little delay to the motorist (30 s interviews for simple by-pass studies to 90 s for full interviews including journey purpose, but this does

not include the total time spent from leaving the traffic stream to rejoining it). Where travel characteristics are fairly uniform, the interviews may be carried out over a period of days or weeks on different routes. Typical examples of forms, and questions, are shown in Fig. 3.3.

Careful siting of the interview stations is necessary to safeguard the site crew and the travelling public. In choosing a site, account will be taken of sight distances on the approaches, vehicle speeds and overtaking and these will help determine the positition of signs and letter sizes for warnings and instructions. Interview points must be carefully laid out so that drivers move quickly to their interviewer and safely out into the main stream. A station supervisor allocates shifts and duties, issues forms and checks and collates recorded information. Normally not more than about four interviewers are used at a station because of the variable length of interview time, causing one driver to hold up another's departure. Each site also requires a continuous census to be undertaken. Survey periods range from 12 to 16 h (typically 0700 to 1900 h and 0600 to 2200 h), but 24-h surveys may be warranted (e.g. 500 vehicles between 2200 and 0600 h). While stations are normally sited away from intersections it is possible to conduct surveys at traffic lights during the red phase, but it is advisable to only complete one interview in each period. For safety reasons it is best, particularly on multi-lane approaches, for the signal controller to be operated manually and the red phase can be extended if all interviewers have not vacated the carriageway.

The increasing difficulties of organisation and traffic congestion arising on high volume urban routes have led to a number of methods being tried to reduce the interview time and/or analysis time. One system uses the mark-sense card specially prepared for making a graphite mark in an appropriate coding area usually on an upper surface. Another method uses preperforated cards with up to a dozen commonly occurring origins and destinations precoded. Interviewers memorise the coding for these areas and push out the appropriate perforated hole with a stylus by holding the card in a set position against a perforated plastic holder. Destinations or origins, other than those which have been precoded, must be written in by hand for subsequent office coding.

With all types of survey it is helpful to have self-coding items recorded at the time of interview for such items as station number, time period, vehicle type, direction, journey purpose, number of passengers, type of

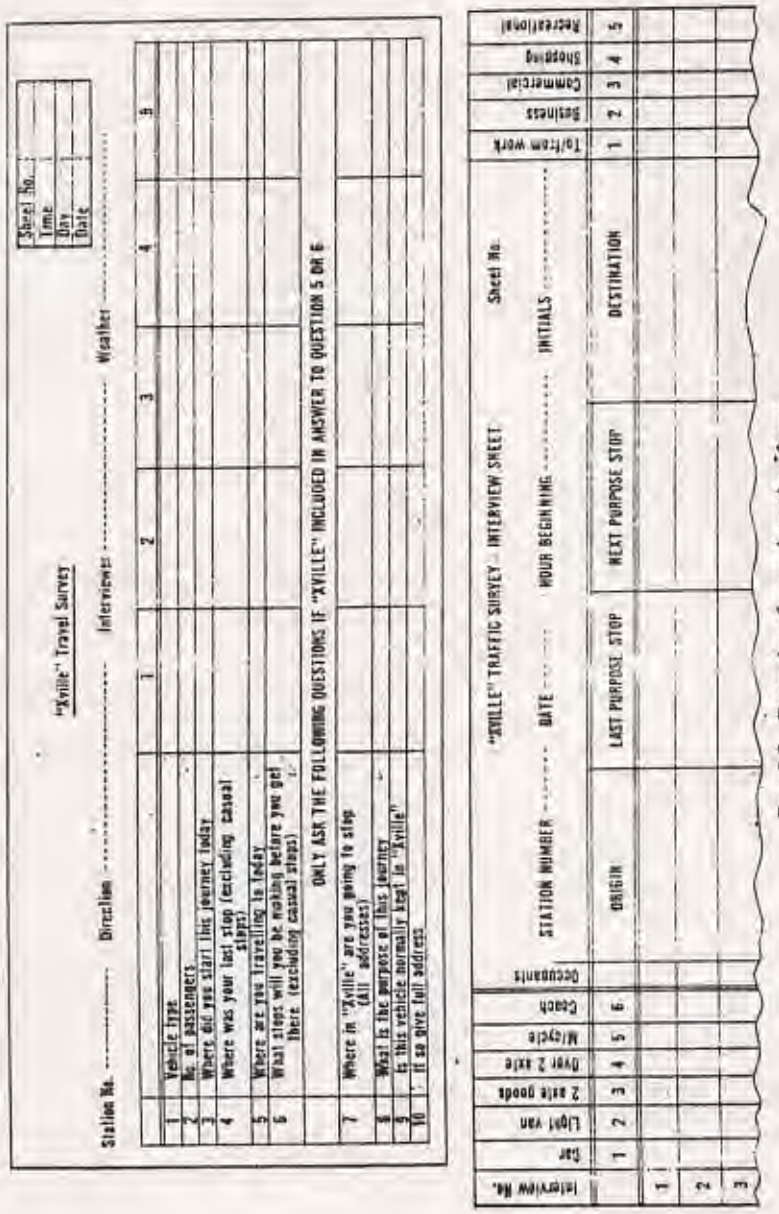


FIG. 3.3. Examples of route interview forms.

goods carried, etc. Direct gang punching of the general station information is a further aid and interview cards with coloured time strips marked on them for each hourly period, or individually coloured cards according to direction or vehicle type, improve site control and subsequent office procedures. Weather protection is necessary for the interview forms in the event of rain. This can be provided by using plastic overlays to the recorder's clipboard.

Updating and Monitoring Surveys

Trends in the movement pattern and changes due to road improvements are essential factors in traffic planning. The New York Port Authority has used a continuous survey procedure which enables full-time trained interviewers to be employed. This overcomes, to some extent, the possibility of error due to haste and inexperience which may occur on the more usual route interviews. It dispenses with the need to employ a large labour force during the survey period, both for interviews and subsequent coding, and eliminates the errors associated with data expansion to suit seasonal influences. The effects of route improvements and the monitoring of traffic trends can be made within the survey area. Each stage of the sample is selected randomly for a time period, site direction and lane and the required sample size is precalculated. Rotation from lane to lane and by direction is prearranged after the first position has been selected at random. In this way little inconvenience is experienced and the majority of lanes and ramps are free from interview congestion. The interview team also code the work which allows a change in task and avoids monotony. This familiarity with the whole procedure both improves speed and the accuracy of the work.

Sample Size

The selection of a sample size consistent with the required accuracy of the estimate and causing minimum delay to the motorist is most important. If all journeys on a road are the same, obviously one interview and a volume count could supply all the information needed. Conversely the greater the variation in journeys the larger is the required sample size.

Wide variation will occur where there are small flows in a traffic stream for a variety of origins and destinations but, in general, it can be stated that there are diminishing returns for increasingly large samples of highly consistent high volume flows.

It is important in a sample to be able to estimate within a range of values where the true value is likely to lie. Such a range is called a confidence interval, u, and can be measured in units of standard deviation, e.g. $0{\cdot}95u = 1{\cdot}96$, $0{\cdot}90u = 1{\cdot}65$, i.e. 90% confidence that the population mean lies within 1·65 s.d.'s either side. The sample can be tested for statistical adequacy by considering a sample n, out of total flow T, to have a number of trips n' with a required journey attribute and for which a confidence interval $I_{N'}$ can be determined from

$$I_{N'} = \frac{n'}{n} \pm u \sqrt{K\left[\left(\frac{n'}{n}\right)\left(\frac{n-n'}{n}\right)\right] \Big/ n}$$

where $K = (1 - n/T)$ and approaches 1 as T becomes increasingly larger than n.

A 10% sample of households yielded 1010 trips in zone i of which 90 went to zone j. The estimate of total flow for a 10% sample of T is 10100, trips of attribute $N' = 900$, as n' was 90. Then for $u = 1{\cdot}65$, $I_{N'} = 0{\cdot}0891 \pm 0{\cdot}014$, i.e. $10100\ (0{\cdot}0891 \pm 0{\cdot}014) = 758 < N' < 1041$ trips, defining the upper and lower limits of the confidence interval and the suitability of the sample size for that particular attribute.

Table 3.1 shows the relationship between sample size and the probable accuracy for a given volume of trips for a confidence interval of 0·95.

TABLE 3.1. ESTIMATED VARIATIONS DUE TO SAMPLE RATE

Estimated number of journeys	Percentage variation ± for given sample rates of							
	1	2	3	4	5	10	20	30
100	200	145	115	100	90	65	44	36
500	90	65	52	44	40	28	20	16
1000	65	44	36	32	28	20	14	12
10000	20	14	12	10	9	6·5	4·4	3·6

HOME SURVEYS

In many places, particularly urban areas, route interviews and similar surveys are difficult to carry out due to the multiplicity of routes and the high flows at peak hours. Furthermore, they do not adequately sample the distribution of travel in time nor yield suitable and sufficient socio-economic information for use in model building.

The home survey methods, usually by direct interview or questionnaire, enable the maximum amount of information to be collected on travel habits which are subsequently used for predicting traffic flows and travel choices. The increasing use of mathematical models, based on land use, make it necessary to distinguish journeys between all types of terminals and activities for instance commercial, industrial, shopping, educational and recreational purposes.

SAMPLING

The normal method of conducting the survey is for a random sample to be drawn from the whole population using, as a sample frame, either the Register of Electors or the Valuation List. The former lists addresses of qualified electors (i.e. those over 18 years) and is compiled annually, whereas Valuation Lists are only up-dated by the Inland Revenue every five years, although they include commercial and industrial premises, besides residential property and the data is often held on punched cards. Careful checks must be made to ensure that the sampling list, usually households, is up to date and representative. Other sampling methods may be appropriate for different types of survey, including random sampling of land uses from grid coordinates on maps and stratified quota sampling of sectors of the population with the required attributes.

Sample size is affected by the type, density and distribution of land uses, population characteristics and travel facilities but primarily by the required accuracy of the estimates and the likelihood of their variability. Table 3.2 indicates typical sample sizes for home interview surveys in general transportation studies, but where local information is only required to calibrate established base data, much smaller samples are needed. Samples of residences will omit a number of essential travellers who are temporarily or permanently residing away from a home and living in

institutions, hotels, educational establishments and military camps. It is often necessary for data completeness to obtain information on these institutional residents by sampling from room lists.

TABLE 3.2. HOME INTERVIEW SAMPLE RATES

Total population (1000's)	Sample size (%)
<20	>25
20–100	25–10
100–250	10–5
250–1000	5–1½
>1000	1½–½

COMMERCIAL VEHICLE AND TAXI CAB SURVEYS

The travel movements of commercial vehicles and taxis is usually obtained directly from vehicle operators selected from rating lists or a land-use survey. Local authority vehicle registers will exclude firms with vehicles registered elsewhere and may include vehicles operated in other areas.

Log sheets are designed for a record to be kept for each vehicle of journey purpose (picking-up or delivering goods and service calls) for all destinations stratified by land use, time of day and vehicle type. Because of the variety of commercial vehicle trips, and a tendency to under report, it is necessary to adopt intensive survey methods and correspondingly larger samples. These range from 10–20% in large cities, 20–30% in medium-sized towns, to 50% in smaller urban areas. Similar problems arise in taxi surveys where these form a significant proportion of travel within an area. The usual procedure is for a substantial proportion of drivers to be requested to complete trip record cards. Because of journey variability, surveys of commercial vehicles and taxis are usually based on a week's trip pattern.

HOME INTERVIEW AND QUESTIONNAIRE SURVEY PROCEDURES

Usually, after an explanatory letter about the objectives of the survey has been sent to the selected address, an interviewer calls and collects pretabulated information about the household and the trip making of the occupants for a selected time period. A cheaper alternative to interviewing is to distribute a questionnaire for self-completion by the occupants. Forms are delivered with a covering letter explaining the purpose of the survey, the date the forms will be collected when any assistance can also be given. In either method the required information is similar. Items are collected on the distribution of household ages, sexes, occupations, incomes, type and age of vehicles owned or used, as well as a detailed record in time of the purpose and mode of all journeys made by the household. Minor journeys may be forgotten if more than a day old and trip record cards should be issued for completion as a diary where information is needed over an extended time period. The intensive interview method overcomes the disadvantage of one person answering for others by requiring all members of a household (usually those over the age of 16) to be contacted directly.

Misleading information may result if interviewers prompt respondents or the questions are not clearly stated without ambiguity. The preferred method is to undertake a presurvey to check procedures and the validity of questions to extract the required information. Both weekday and weekend travel characteristics are generally investigated, and account taken of seasonal influences in sample design. If interviews are confined to a short period, then bias may result due to weather conditions, school holidays or unusual events.

Because questions and answers can be presented and recorded unhurriedly by these methods, good travel estimates are possible provided that the sample frame is both up-dated and accurate and that correct sampling procedures are employed. The questionnaire method poses the questions in a standard form and it may also be easier for a family to collectively recall journeys. Simplicity of coding and checking procedures is essential for minimising the data edit costs. Call backs (usually two or three) are needed to complete the sample, but alternatively with questionnaire methods a stamped envelope can be left for the return of the forms. Typical survey forms are shown in Figs. 3.4a, b.

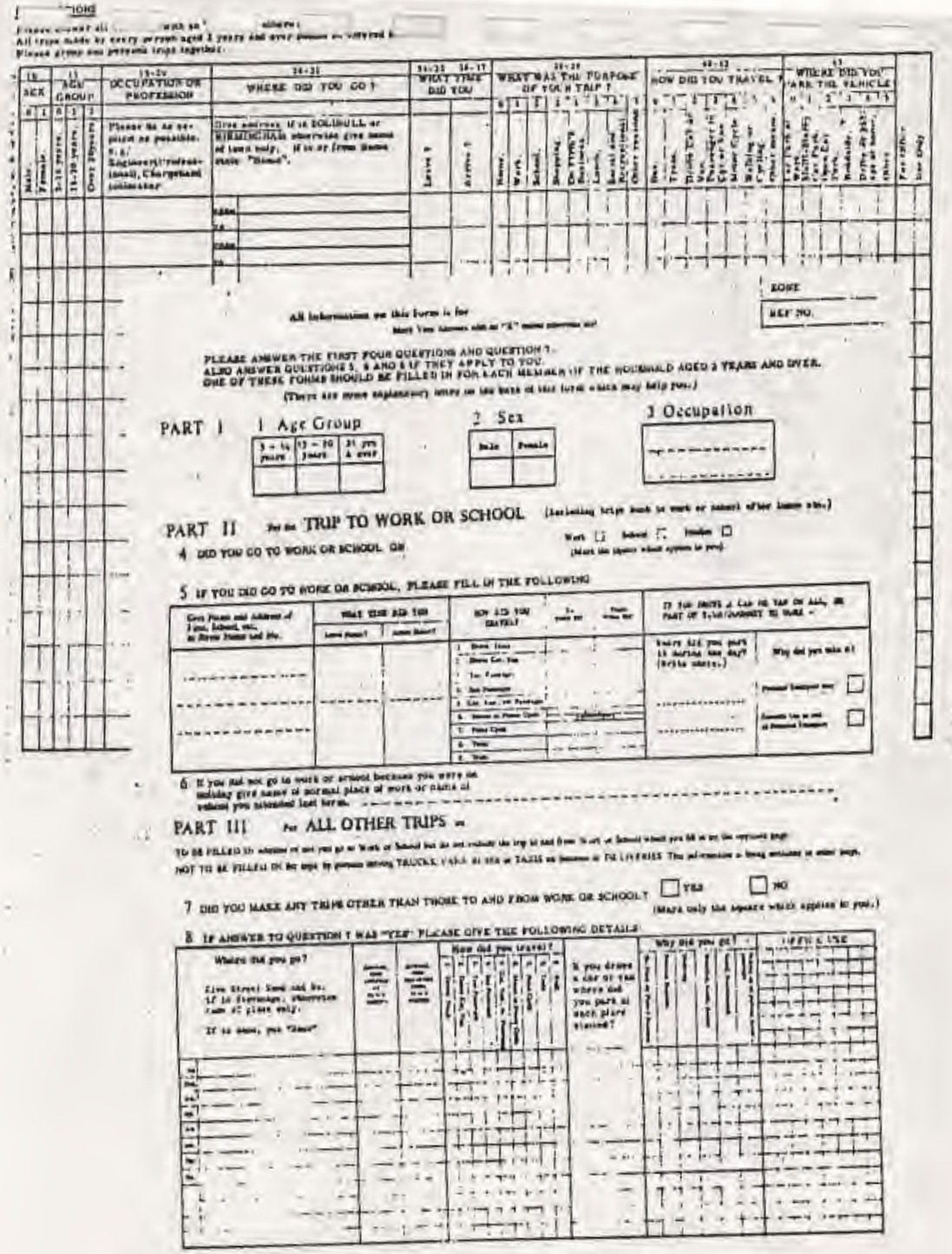


Fig. 3.4a. Home questionnaire form.

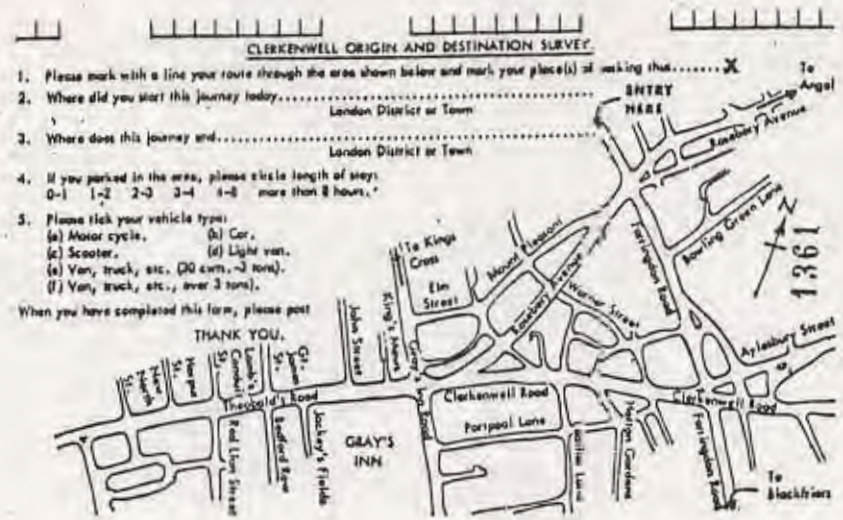


FIG. 3.4b. Pre-paid postcard.

Survey errors are those associated with sampling from the frequency distribution of daily trips from a dwelling, at one point in time, and the non-response bias caused by some householders not being contacted even after call backs, and refusals.

When calls are made, the small sized and low income group households are least likely to have anyone at home and those households containing the most prolific travellers are also most likely to be vacant. Supervisory sample checks should also be made at the interview stage to detect the rate and type of reporting and recording errors of interviews.

Alternative methods to the above have been tried and these include telephone interviews, where a large proportion of the intended respondents are telephone subscribers, interview forms set out in newspapers and in special radio or television programmes. In the latter case the questionnaires have been delivered to households prior to the programme, or are cut out from weekly programme guides, and are completed during the course of the programme after explanatory films and talks.

CHECKING TRAVEL DATA

Besides providing the basic data on external to internal traffic, the cordon and screen counts and surveys are used to adjust the home interview surveys. Where discrepancies occur between the origin and destination trip pattern, deduced from the route interview surveys and vehicle counts, and an assignment of the expanded home interview data to the existing network (i.e. the reproduction of the current flow map on the base year network), it is customary to adjust the trip rates from the home interviews accordingly. If the total number of movements is correct, but distortions have arisen between particular areas or sectors, then screenline data may be used to adjust the trip attraction or generation equations or the distribution functions.

It is important that a large proportion of the total traffic crossing a cordon or line must be at risk for sampling, and only minor roads, carrying less than 5% of the total crossing traffic, are excluded. Normally, volume counting programmes are instituted at key locations to monitor weekly and seasonal patterns and identify special cases for additional interview surveys.

Generally, the decision to adjust data depends on a number of factors, particularly the degree of disparity between the observed and expanded totals and other population and social data comparisons. If these are too great then non-response or additional surveys may be required.

ZONING

The collected data will consist of a multitude of journeys with different specific origins, destinations, purposes and modes which must be related to other traffic, sociological and economic factors. Without aggregation the amount of data will only serve to confuse and obscure underlying relationships, but the degree of aggregation varies with the particular requirements, and it is useful to have methods which permit this to be varied at different stages for different purposes. With external traffic the whole country or state is zoned and as areas further away from the centre tend to have decreasing influence, this is represented by the scale of zoning. In these outer areas, population centres, ports, intercommunication centres, topographical features, particularly mountain regions and rivers, must all be taken into account and influence the drawing up of the zonal boundaries.

For internal traffic within the city, the aim is to obtain zones of a similar generating size and also of a uniform traffic nature. Topographical features often form the main boundaries, with a further breakdown by land use, e.g. residential, shopping, recreational, industrial and communications centres, determining the size of individual zones. A compromise has often to be made on zonal homogeneity by selecting a predominant land-use activity. One criterion which determines a zone's size is the capacity of its road network. At a saturation level of 0·5 veh/person this limits the zonal population to about 5000 persons and for industrial zones to about 2500 persons. It should also be small enough to reduce any major errors in assuming that the zonal centroid is the centre of the road network which limits the area to about 1 km^2. The centroid is determined from either the trip generation or population density. However, the smaller the zones the more extensive will be the survey work to obtain statistically reliable data and correspondingly greater computing requirements in the subsequent model building phase. Study costs are also usually proportional to the square of the number of zones.

Zonal boundaries are determined by the transport network and act as a "watershed" of traffic generation enclosing the main public transport stops and corridor movements with the principal roads bisecting the zone. For some general planning purposes zones may require clustering into sectors and districts and conversely for detailed traffic analysis a breakdown of zones into a number of sub-zones which can include groups of shops, factories, hospitals, schools and stations. A further boundary consideration is the need for compatibility with the Registrar-General's census districts and other local authority areas. External areas often have a three-stage breakdown into regions, compatible with economic planning or standard regions, areas which include single or groups of counties and also zones to match the smaller local authority and district boundaries. The use of a grid system, based on the standard Ordnance Survey, permits the later reformulation of zones into any size and boundary configuration (8 figure references allow 100 m squares) and give complete interchangeability of data between different surveys and areas. An example of zoning and a numbering system are shown in Fig. 3.5.

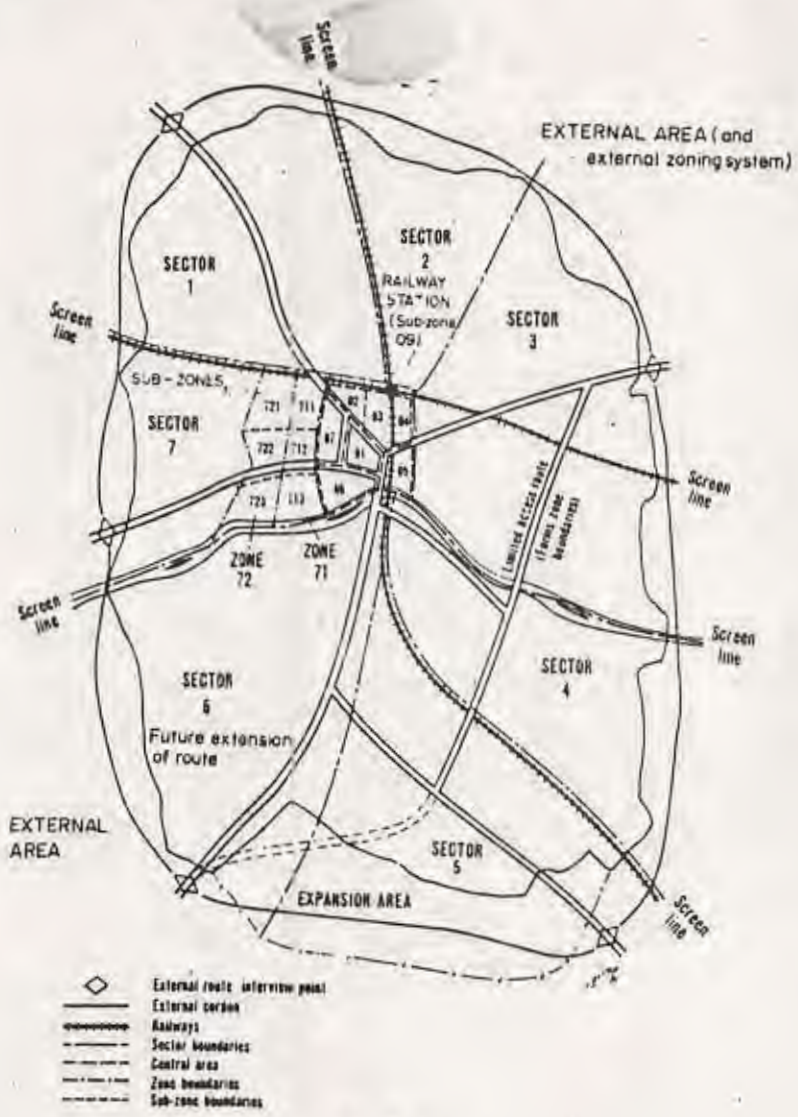


FIG. 3.5. Zoning.

TRAVEL CHARACTERISTICS

The first stage of the analysis is to form a matrix of the zone-to-zone flows, for the principal journey purposes and time periods as shown in Fig. 3.6. An aid to understanding the information is the diagrammatic

TABULATION CHART: MATRIX OF ZONE TO ZONE FLOWS

TIME PERIOD ---------- MODE ---------- PURPOSE ----------

To Zone / From Zone	INTERNAL ZONES	Sub total	EXTERNAL CORDON POINTS	Sub total	Grand total
INTERNAL ZONES	TABULATION PROCEDURE 1. Sum sub zones - sub total of zone 2. Sum zones - sub total of sectors 3. Sum external cordon - sub total External - External, External - Internal, Internal - External, 4. Sum sectors and External cordon - Grand total of exchanges. 5. Sum totals across screen line and compare to count.				
Sub total					
EXTERNAL CORDON POINTS					
Sub total					
Grand total					

FIG. 3.6. Tabulation of zone-to-zone flows by time period, mode and purpose.

representation of the movement pattern, for comparison with the base planning data, as shown in Fig. 3.7. Desire line charts, which show to scale by line thickness the numbers of journeys between zones, indicate by selected time periods the area's movement pattern. Other distinctive divisions can be made between major and minor flows, between zones and sub-zones and between central and other sectors. Traffic is assumed to be generated at zone centroids and sometimes cordon points, and movements are traced between origin and destination pairs. Other methods

FIG. 3.7. Traffic desire lines are shown by time (e.g. peak hour, 24 h by mode and purpose). (Source: Coventry Transportation Study, Phase 1, 1968, City of Coventry.)

of illustrating traffic statistics and base social and economic information is by the use of single and multiple dimensional pie and bar charts. If the individual journeys between zones are summed as they cross each side of a grid square, values of equal magnitude throughout the survey area can be traced out by a contour line of equal desire line intensity. Various measures including modes and journey time waitings can be similarly traced out. Automatic methods of plotting trip data can be used with computer graphical plotting equipment or oscilloscopes directly from the

input cards or tapes. On an oscilloscope a light trace is programmed to move between coordinates of the grid at a speed inversely proportional to the number of journeys between each pair of points and thus expose a photographic film to a greater or lesser extent. The result is a map plate of varying light intensities proportional to the traffic desire lines and flows.

From the build-up of information from many surveys certain general characteristics emerge, particularly for towns and cities of similar nature and size, which are of particular use to planning authorities and for the conducting of other local surveys. The principal factors which influence city travel are (i) population size, (ii) land use, (iii) type of city development, employment and growth, (iv) available transport systems, (v) population/vehicle ownership ratios and incomes, (vi) climate, (vii) journey length and (viii) purpose of journey. Some typical relationships are shown in Tables 3.3 and 3.4 and Figs. 3.8 to 3.10a, b.

TABLE 3.3. DISTRIBUTION OF TRIPS BY PURPOSE (%)
(*London Traffic Survey*, Vol. 1, 1964, L.C.C.)

Purpose	Car-owning households	Non-car households
Work	38·7	60·6
Employer's business	2·6	1·1
Personal business	15·9	6·6
Entertainment	5·3	5·4
Sport	0·9	0·9
Social	7·3	7·0
Shopping (convenience)	5·4	6·5
Shopping (hard goods)	2·2	2·8
School	5·9	3·3
Miscellaneous (non-home based)	15·8	5·8

FIG. 3.8. Inventory of planning data.

Total internal city traffic is proportional to the urban population with work journeys forming the largest category and usually linearly related to total population. The proportion of work journeys by car mainly depends on car ownership levels, type of employment, availability of mass transit, parking policy and relative accessibility for different trans-

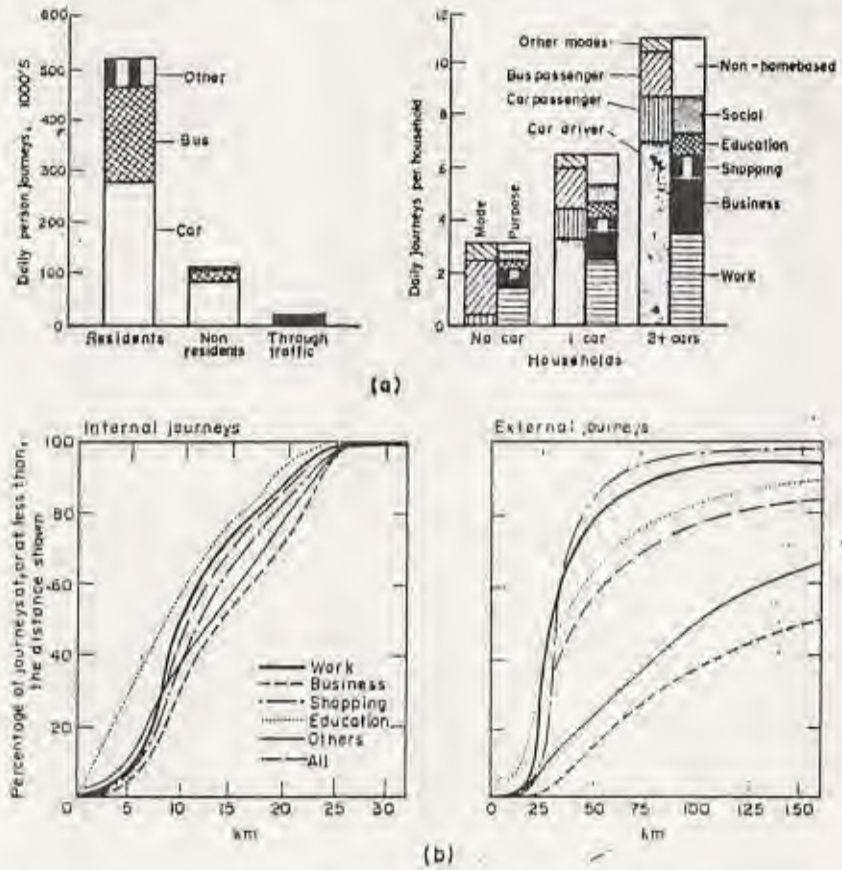


FIG. 3.9. (a) Daily trip characteristics of Coventry (Source: Coventry Transportation Study, Phase 1, 1968, City of Coventry).
(b) Journey lengths for internal and external journeys, West Midlands (West Midlands Transportation Study, Vol. 1. Freeman Fox Wilburn Smith and Associates, 1968).

TABLE 3.4. DISTRIBUTION BY PURPOSE OF ALL TRIPS FROM HIGH INCOME ZONES TO THE DESTINATIONS SHOWN WITH ORIGIN IN SOLIHULL (%)

Destination/Purpose	Year	Work	Shopping	Social	Home & other	Proportion of total trips
Solihull	1963	3·8	6·3	6·0	83·8	56·6
	1968	6·1	10·6	12·2	71·1	78·5
Birmingham	1963	60·0	5·9	6·8	27·4	20·6
	1968	55·4	7·6	7·6	29·4	16·1
Other areas	1963	14·1	14·3	20·0	51·6	22·8
	1968	28·1	3·1	15·6	53·2	5·5

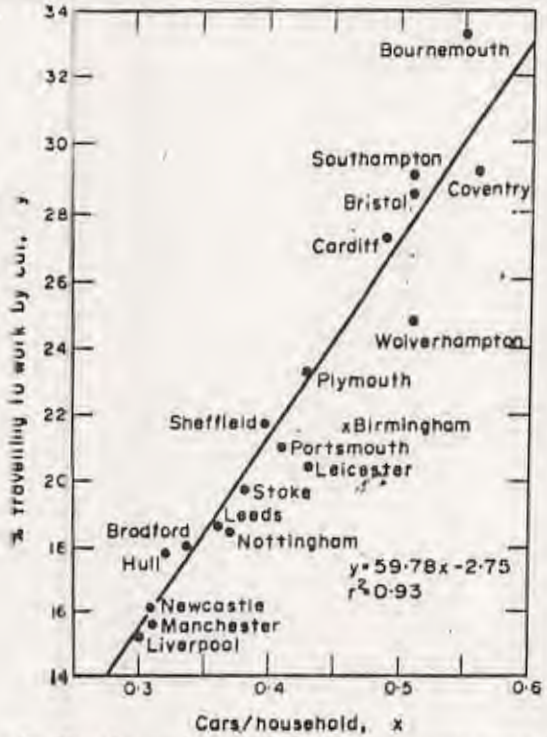


FIG. 3.10a. Travel to work by car, 1966. National sample census, 1966.

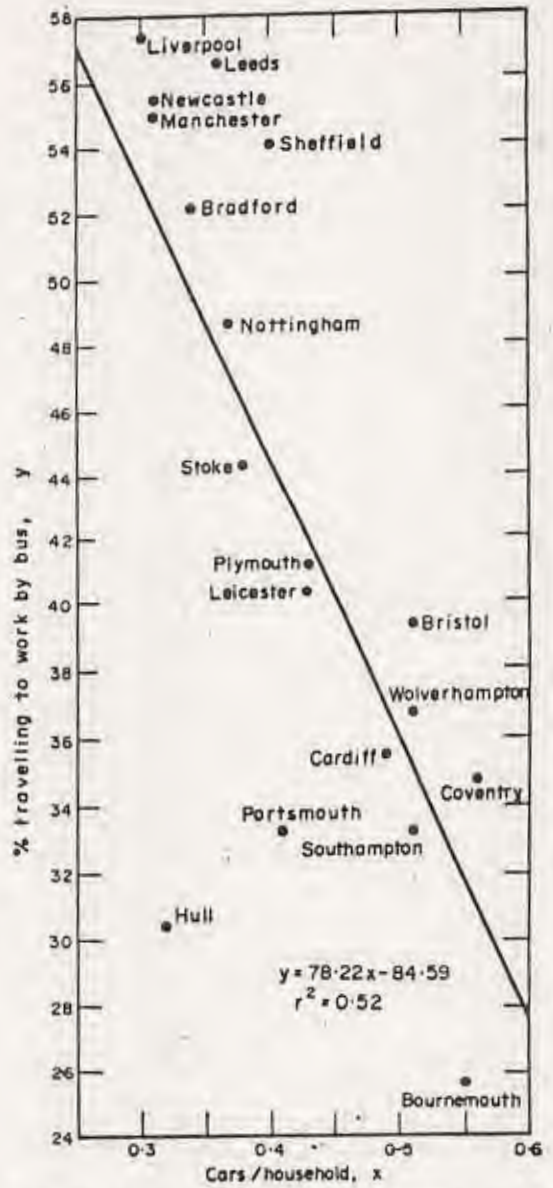


FIG. 3.10b. Travel to work by bus, 1966. National sample census, 1966.

port modes. There is usually an increasing percentage of walking and car trips with decreasing population size due to less well-developed public transport, smaller journey distances, shorter peak periods and less overall congestion. Tables 3.5 and 3.6 and Figs. 3.11 to 3.14 illustrate characteristics of travel modes and distance relationships by mode.

TABLE 3.5. TRAVEL MODE FOR WORK TRIPS (%). SURVEYS 1962–66

All work trips in	Walk	Cycle	Bus	M/cycle	Car	Train	Others	Town characteristics
Doncaster	16·7	19·9	38·6	6·4	18·4	–	–	Popn. 86,402. Yorkshire manufacturing town.
West Bromwich	22·9	13·4	42·2	5·6	15·9	–	–	Popn. 95,909. Town within W. Midland conurbation.
Solihull (high income zones only)	4·97		6·26	0·55	81·57	3·83	2·8	Popn. 96,010. Town on southern fringe of W. Midland conurbation.
Stevenage	11·34	16·43	19·78	8·88	41·75	–	–	Popn. 42,964 (100,000 future). Hertfordshire new town.
Northampton	23·00	19·00	28·00	30·00		–	–	Popn. 123,530. Manufacturing and market town. (R.R.L. Report LR 141.)
West Midlands	17·1	5·7	38·7	3·0	27·9	1·2	6·4	Popn. 2,400,000. Conurbation. West Midlands. (*Transportation Study*, Vol. 1, 1966.)

The proportion of centrally oriented trips is not only determined by size but by function and historical development. Some conurbations, which in the past existed as free standing towns have coalesced, retaining competitive centres with their own surrounding catchment areas. Generally the proportion of central area journeys to the total internal journeys decreases slowly with increasing city size. Travel to the centre is greatest from the innermost residential zones but diminishes with distance. Whereas bus travellers predominate near the centre, the proportion travelling by car for each distance band outwards increases as the level of public transport falls. This pattern is changed where high capacity rail systems serve outlying "dormitory" towns often developed around stations which serve as a focal point for local bus services. Car ownership reflects this pattern with fewer owners in the older and poorer inner areas where even garaging costs may be prohibitive. The high income

TABLE 3.6. MODES OF TRAVEL TO WORK AND JOURNEY TIME

	Work journey catchment areas					
	Dagenham (Essex)			Bilston (Staffordshire)		
Travel mode to work	Numbers (%)	Total time (minutes)	Mean time (minutes)	Numbers (%)	Total time (minutes)	Mean time (minutes)
Walk	1322 (3·8%)	27,070	20·5	2554 (20·8%)	42,660	16·7
Ferry	506 (1·5%)	26,780	52·9	—	—	—
Cycle	2802 (7·9%)	77,650	27·7	1940 (15·8%)	33,760	17·4
Public transport	11,057 (31·3%)	469,375	42·5	3838 (31·3%)	128,200	33·4
Private motorised	19,579 (55·5%)	715,576	36·6	3940 (32·1%)	81·960	20·8
Totals and overall means	35,266	1,316,720	37·3	12,272	286,580	23·4

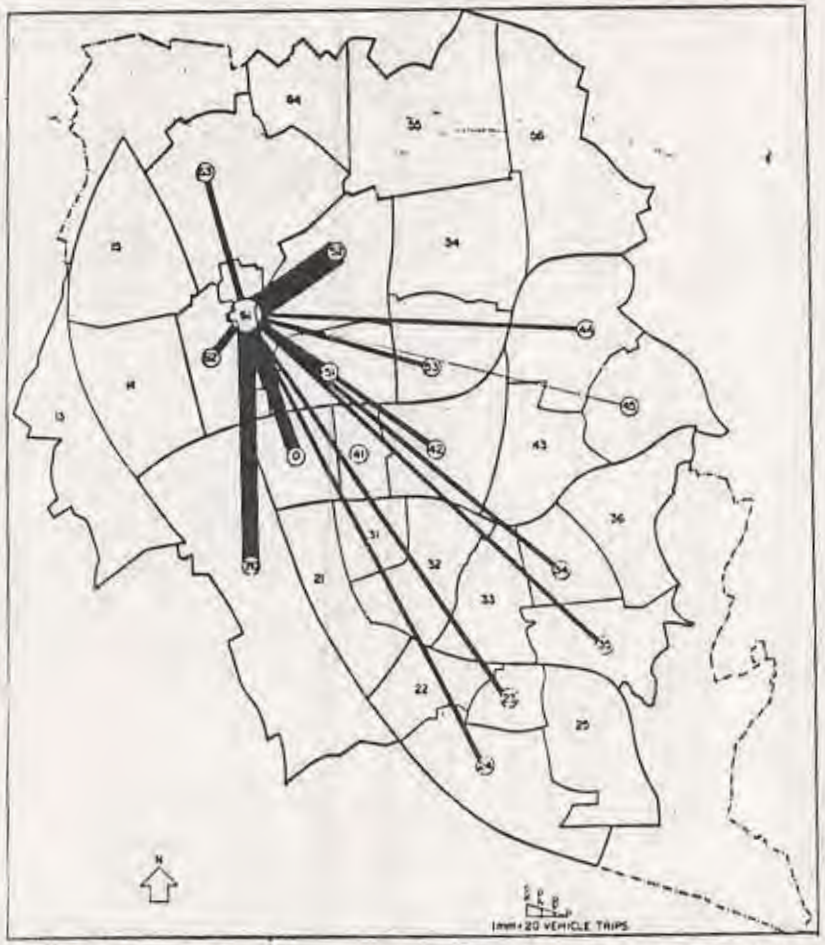


FIG. 3.11. Stevenage: internal commercial vehicle trips from High Street, 24-hr period.

populations may use taxis for internal journeys retaining their own cars for out-of-town journeys. Journeys by rail usually show an increase with distance from the centre.

By-passes serve the function of removing extraneous traffic from a town or a part of it, e.g. a central area. The percentage of rural to rural traffic which is by-passable falls as a proportion of the total internal journeys from

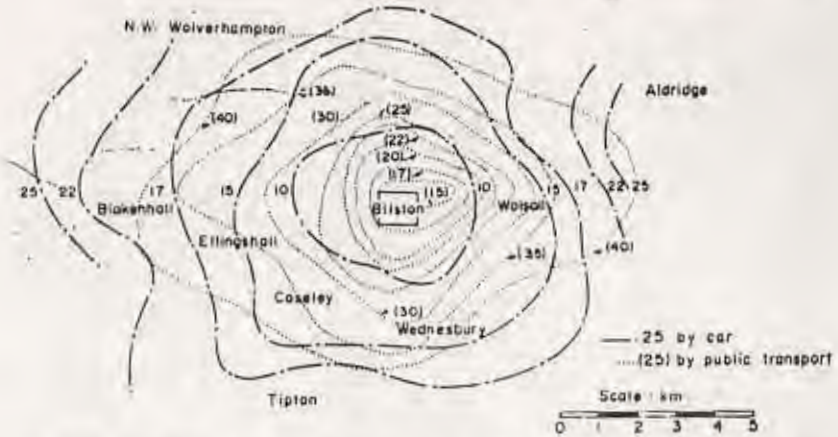


FIG. 3.12. Journey time isochrones to factory area Bilston, West Midlands conurbation (minutes).

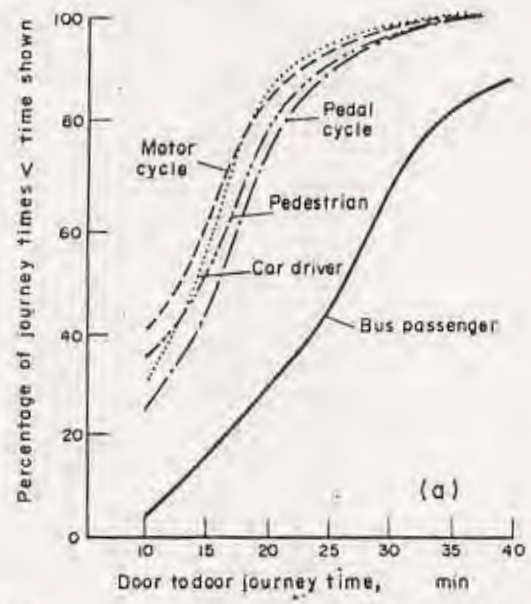


FIG. 3.13. (a) Journey time to work by different modes. (Source: F. R. Wilson, *Journey to Work*.)

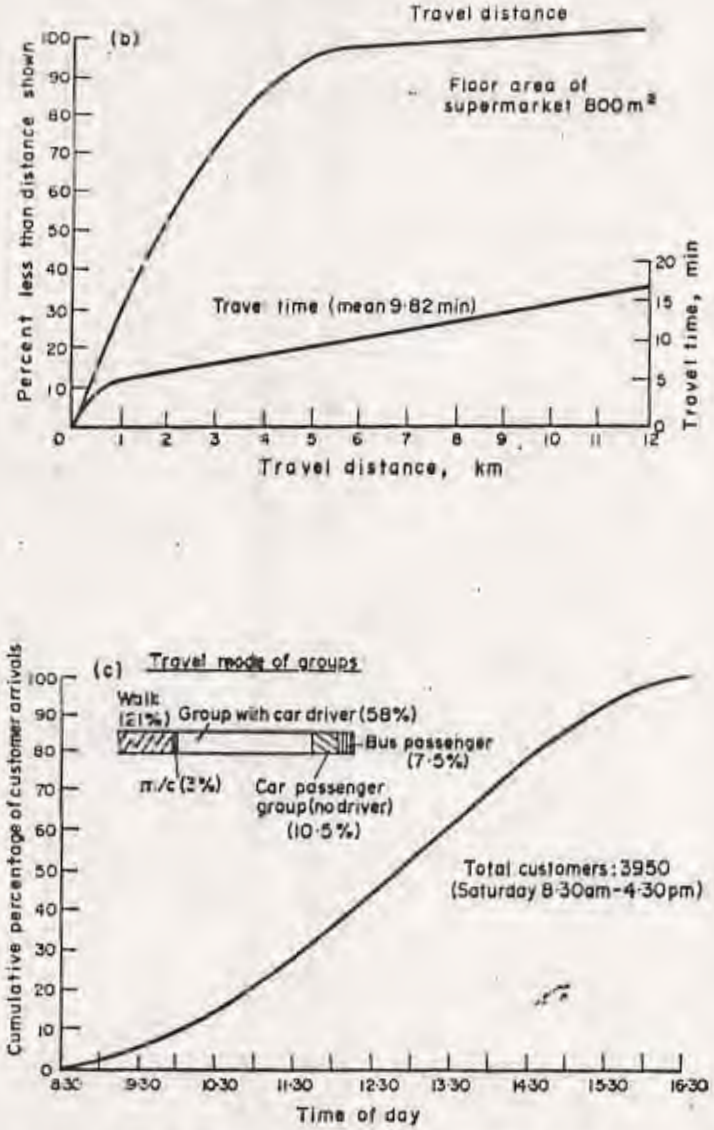


Fig. 3.13. (b) Journey distance and time distribution by shoppers to supermarket. (c) Cumulative frequency curve of customer arrivals at supermarket.

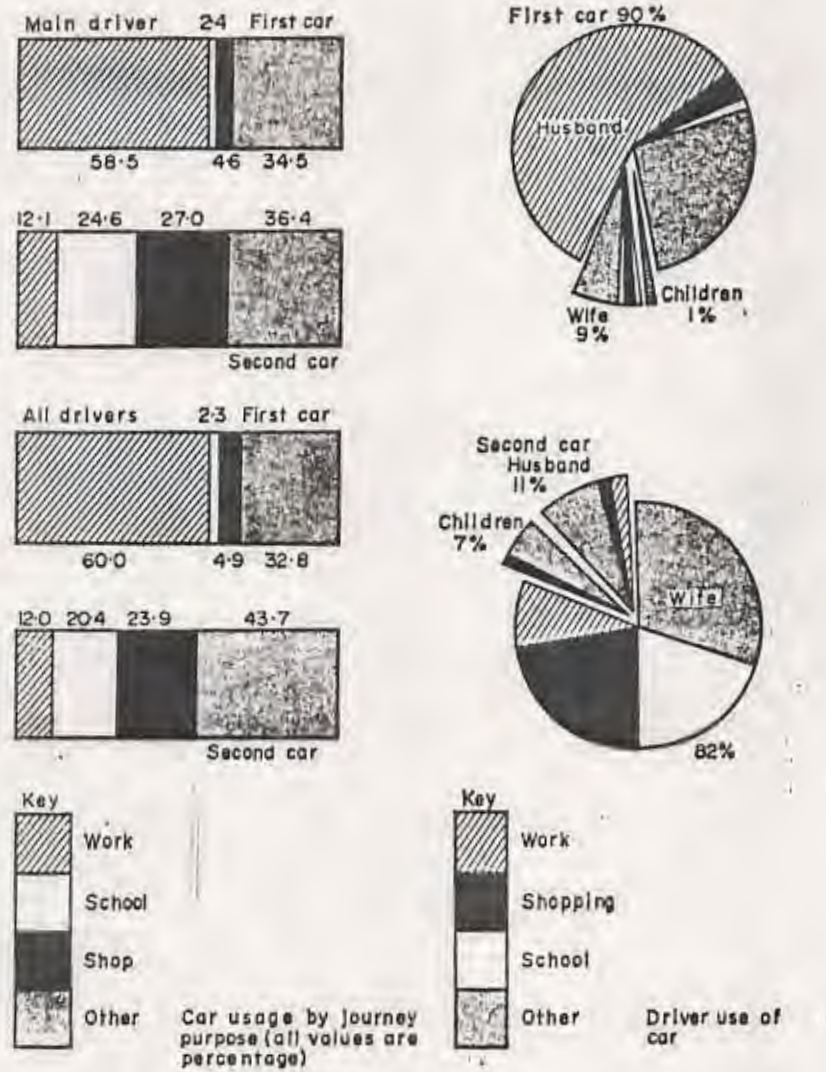


Fig. 3.14. First and second car use. (Source: L. W. Ackroyd and S. J. W. Druitt, A comparison of first and second car usage patterns, *Traffic Engineering and Control*, 9, 1969.)

about 50% with a town population of 5000 to a few per cent in the largest cities. Similar principles apply to parts of towns in the creation of environmental and pedestrian areas and leads to the creation of a hierarchical road network serving definitive traffic functions.

ANALYSIS OF TRAVEL SURVEYS

Surveys are carried out for a variety of purposes and it is essential, if pertinent and useful results are to ensue, to avoid unnecessary and costly field work by setting down clear aims for the study with assumptions explicitly stated. Thereafter the process is one of identifying problems, evaluating constraints and setting down the principles of plan selection. The more important types of survey work include studies for traffic management, public transport, route selection, development and structure plans, regional and conurbation transportation, land-use surveys and research. Forecasting and strategic planning nearly always forms an essential feature of the work. The required accuracies and form of modelling used varies with the type of work and forecast period. As the forecast period lengthens so the band of uncertainty widens. Tomorrow's forecast is likely to be correct because the underlying causes and effects will not have changed measurably, whereas those for 20 years will certainly contain different socio-economic factors and attitudes may be very different. It is advisable for long forecast periods to provide interim reviews so that plans can be monitored and modified to accommodate change. The principal elements of a transportation survey are shown in Fig. 3.1.

TRAFFIC MODELS

The analyst seeks to develop, usually in a mathematical form, a model of the real world, i.e. in the case of travel models by identifying wherever possible causal relationships describing population behaviour, albeit by the aggregation of individuals into groups. Travel determinants are principally land use and the propensity of the individual to expend "effort" and resources to overcome spatial separation. Early nineteenth-century developments in social science first studied human interaction and

location in a form analogous to Newton's law of gravitational attraction which equates the force (F) between masses m_1 and m_2 inversely to their distance apart (d) squared: $F = m_1 m_2 / d^2$. Early models took the form $M_{ij} = P_i P_j (d_{ij})^{-2}$ where M_{ij} is the market attraction of two towns with populations P_i and P_j sited at distances d_{ij} apart. Markets and trips are part of the same phenomenon and as a general proposition they can be studied in terms of their interactance, i.e. the product of attributes describing population, vehicle numbers, floor areas or retail trade, etc., and their separation in distance, time, effort or cost, etc.:

Thus $t_{ij} = K a_j g_i f(d_{ij})$

where t_{ij} = the number of trips attracted between centroids of an attracting zone a_j and a generating zone g_i,

$f(d_{ij})$ = is a function of the zonal separation and can be of a number of forms, e.g. $(d_{ij})^{-\alpha}$ where α ranges from 1 to 3 or as an exponential function $e^{-\alpha d_{ij}}$,

K is a constant for dimensional adjustment of the measures used in a_j and g_i; α is an empirically derived exponent.

TRIP GENERATION

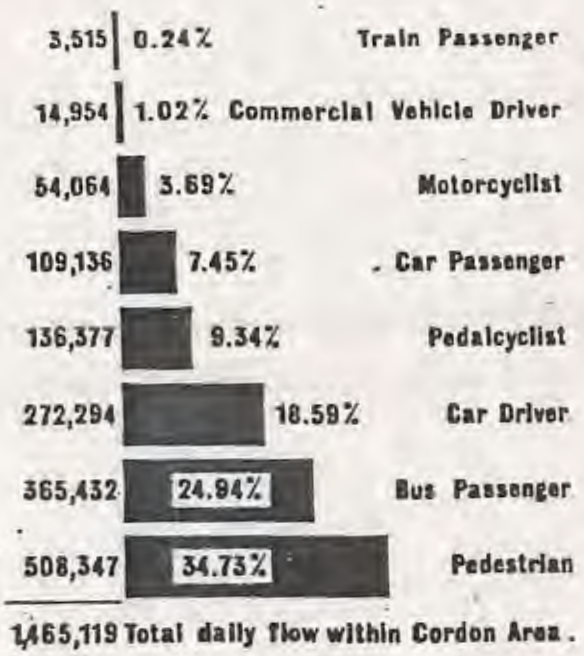
A trip is defined as a single journey made by an individual between two points by a specified mode of travel and for a defined purpose. Differences in definition and the disaggregation of complex trip types creates difficulties of comparison of trip attributes between surveys. Usually multi-mode and purpose journeys are simplified into trips identified by a principal mode and purpose, ignoring intermediate stages and stops for secondary purposes. Trips are often considered as generated by a particular land use and attracted to other specific land uses. About three-quarters of all trips are home based, i.e. they arise or terminate at a residence. Non-home-based trips are mainly those between attracting land uses, e.g. from work to a restaurant.

The number of trips arising in unit time, usually for a specified zonal land use, is called the trip generation rate. It can also be estimated for a zone by aggregating the trip production rate of individual cars or households for the total numbers in each selected category. Both methods make use of the correlation between trips made and particular characteristics

Fig. 66 shows the completed analysis for route A.50. The flow band along the line of A.50 is proportional to the peak hour flow in vehicles per hour and is the "working" capacity. The "clearway" capacity assumes that the route is free from stationary vehicles, that pedestrians are segregated, and that the capacity of intersections is equivalent to that of the intervening sections of the route. All principal routes were analysed in this manner.

Journey Times

Fig. 67 indicates the journey times along the main radial routes from the City centre during the evening peak. All journeys started at the boundary of the Inner Leicester area. The times are represented by time contours, the spacing of which gives an indication of the measure of congestion on a particular route.



68 Leicester Cordon Area – total daily trips by mode.

11 Result of Survey

Home Interview Survey

The r[illegible]t of the Survey is presented in the form of tables and diagrams, followed by comments and where necessary conclusions.

It would be useful to compare the Leicester figures with those for other cities and the national average, but unfortunately no information is available for the United Kingdom.

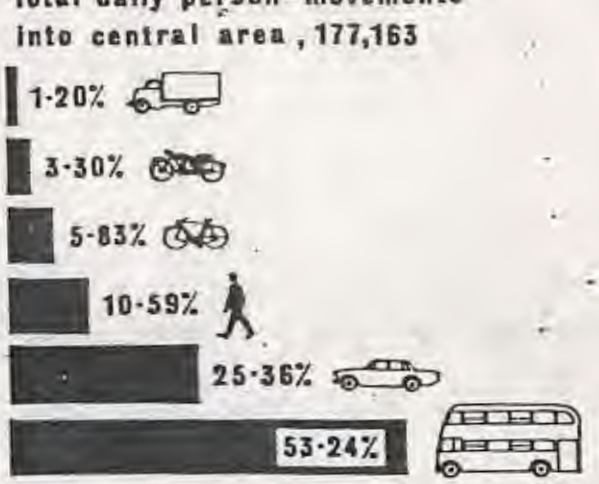
(1) Total Trips, Leicester Cordon Area, for 24-hour day, 8-9 a.m. peak and 5-6 p.m. peak, by Mode

Table 7

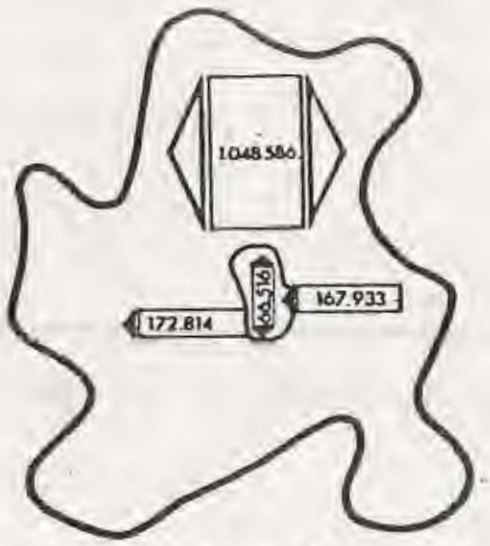
Mode	Total Trips — All Areas		
	24 hours	8–9 a.m.	5–6 p.m.
Car Driver Trips	272,294	27,018	30,541
Car P[illegible]enger Trips	107,352	13,501	12,642
Taxi Passenger Trips	1,794	94	37
Commercial Vehicle Driver Trips	3,062	208	328
Commercial Vehicle Passenger Trips	11,892	1,289	1,575
Bus Passenger Trips	365,432	51,262	46,458
Motor Cycle Driver Trips	45,025	2,796	6,866
Motor Cycle Passenger Trips	9,039	612	1,519
Pedal Cycle Trips	136,877	14,769	18,371
Train Passenger Trips	3,515	881	677
Walking Trips	508,847	76,228	39,599
TOTAL	1,465,129	188,658	158,713

This Table shows the pattern of all movements in the Leicester Cordon area from which important basic conclusions can be drawn.

A total of 1,465,129 trips were made on a typical weekday, equivalent to 3·53 specified trips per person (aged three or over) per day. Diagram 68 shows the distribution of these journeys by mode.

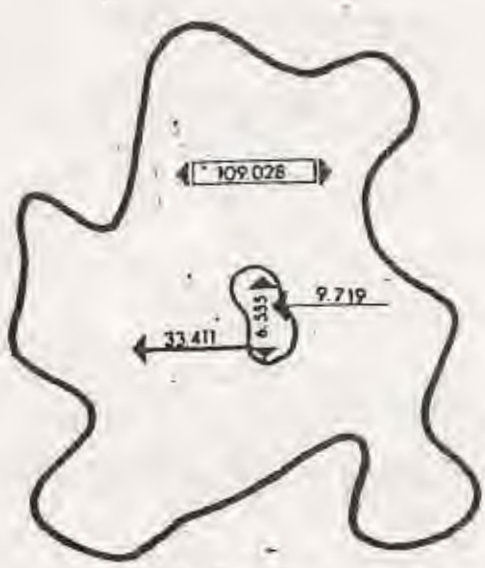


70 Inner Leicester – total person movement by mode.



24 hour day

8–9 p.m.



5–6 p.m.

80 Total trips into and out of Inner Leicester and inter-zonal trips.

Fig. 77 indicates the total inter- and intra-sector trips throughout the 24-hour day. Again the consistency of pattern is observed, all movements associated with a traffic sector being proportional to the population of that sector.

Fig. 78 indicates the total trips between fringe zones around Inner Leicester in the morning peak. What is particularly revealing is the triangular pattern of movement developed between adjacent zones. This illustrates a marked characteristic of Leicester where industrial land uses are associated with residential uses. There is a strikingly low proportion of movement across Inner Leicester.

Fig. 79 indicates the total trips into and out of fringe zones around Inner Leicester and to and from internal zones outside the fringe zones in the morning peak. Again there is a significantly low proportion of trips across Inner Leicester.

Fig. 80 indicates the distribution of trips into and out of Inner Leicester and inter-zonal trips, for 24-hour day, 8–9 a.m. peak and 5–6 p.m. peak.

(5) Total Trips, Leicester Cordon Area, by Purpose

So far the analysis has dealt with the distribution of journeys by mode. The analysis now considers journeys in terms of purpose. The journey purposes investigated were:– *(a)* Work; *(b)* Firm's Business; *(c)* Personal Business and Shopping; *(d)* "Others" (including Social and Recreational, School, Pick up or set down passenger, Catch 'bus or train, Eat a meal).

(A) *Total Trips, Leicester Cordon Area, for 24-hour day, by Purpose*

Table 11

Purpose	Total Trips: 24-hour day							
	Car Driver	Car Passenger	Bus Passenger	Motor Cycle Driver	Pedal Cycle	Walking	Other Modes	Total (All Modes)
Work	104,907	27,959	138,380	26,745	77,362	111,913	14,264	501,530
Firm's Business	38,554	2,241	3,287	2,702	2,552	6,738	2,462	57,536
Personal Business & Shopping	58,271	27,113	93,001	7,908	19,061	128,795	4,560	338,709
Others	70,261	49,980	130,690	7,669	37,903	262,044	7,944	566,491
TOTAL	271,993	107,293	365,358	45,024	136,878	508,490	29,230	1,464,266

Car driver work trips account for 38·75% of all car driver trips, whilst car driver personal business and shopping trips account for 21·42%. 26·06% of car passenger trips are associated with work, and 46·5% are associated with "other purposes".

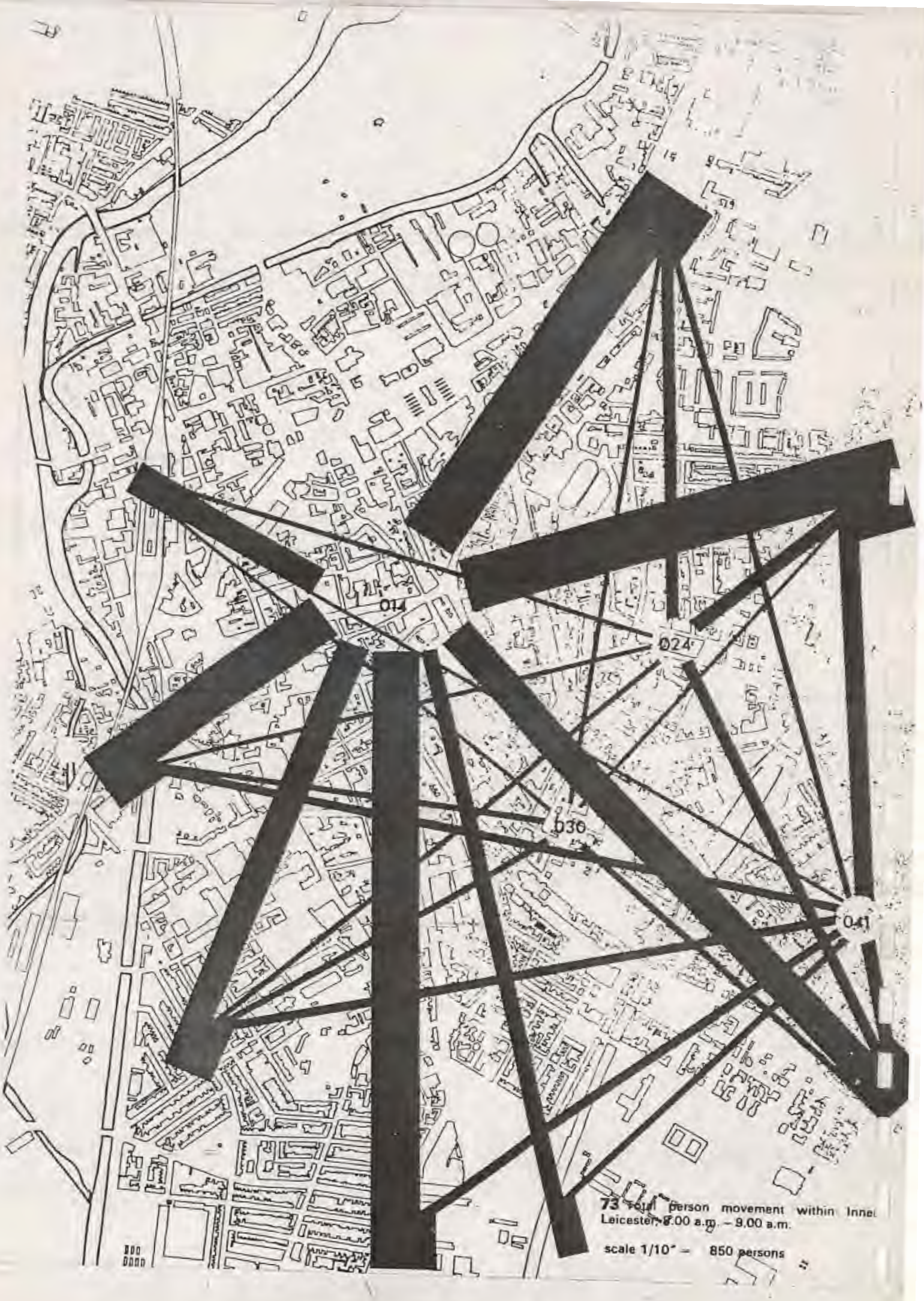
Bus passenger trips are distributed, according to purpose, as between Work trips – 37·86%; Firm's Business Trips – 0·90% and Personal Business and Shopping Trips – 25·45%.

The distribution, by journey purpose (all modes combined), is shown in Fig. 81.

(B) *Total Trips, Leicester Cordon Area, for 8–9 a.m. peak and 5–6 p.m. peak, by Purpose*

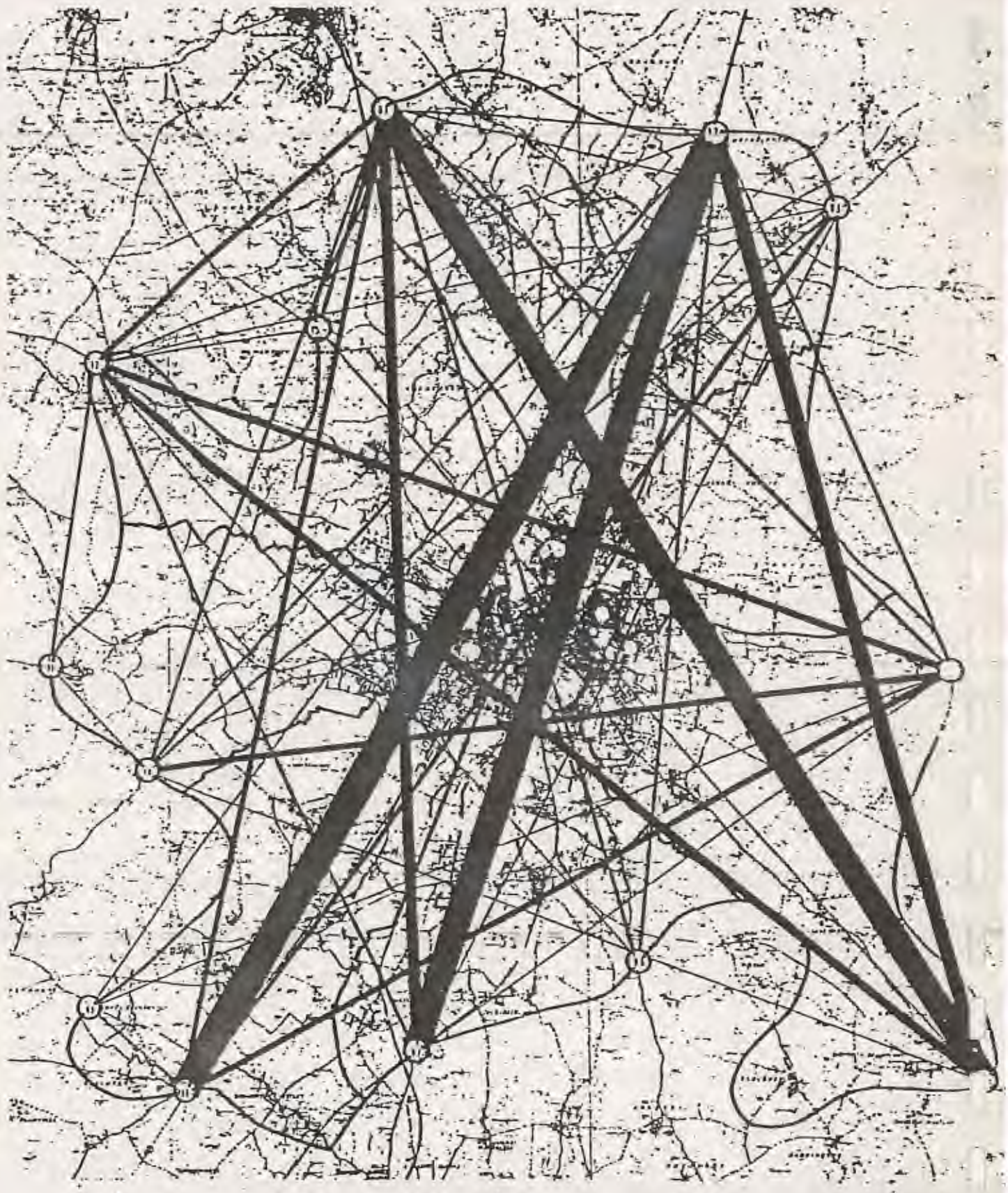
Table 12

Purpose	Total Trips: 8–9 a.m. peak							
	Car Driver	Car Passenger	Bus Passenger	Motor Cycle Driver	Pedal Cycle	Walking	Other Modes	Total (All Modes)
Work	16,257	6,138	26,034	2,190	8,800	14,717	1,648	72,2[illegible]
Firm's Business	2,423	147	464	232	114	293	198	3,87[illegible]
Personal Business & Shopping	2,123	1,165	2,454	141	455	4,451	106	10,8[illegible]
Others	6,214	7,050	22,310	234	7,399	66,731	1,132	101,0[illegible]
TOTAL	27,017	13,500	51,262	2,797	14,768	76,192	3,084	8,6[illegible]



73 Total person movement within Inner Leicester, 8.00 a.m. – 9.00 a.m.

scale 1/10" = 850 persons



96 Pattern of through trips entering the Leicester Cordon Area.
scale 1/10" = 500 p.c.v's.

dictated by their traffic function, the availability of land and the minimum severance of the urban use structure. In this solution the entire length of the Inner Motorway would have to be elevated.

Traffic Volumes and Assignment

The future traffic volumes to be assigned to the road network comprise all car driver trips, all commercial vehicle trips and all external traffic. The volumes of the morning and evening peaks were compared and whichever was higher was chosen for the purposes of design. The actual predicted volumes are set out in the section "Future Traffic Growth and Distribution" in Chapter I. The more important figures are summarized below:—

(a) 160,000 car driver trips would be made, during the evening peak, within Greater Leicester.

(b) 36,700 car driver trips would be made, during the morning peak, into Inner Leicester.

(c) 52,000 "passenger car unit" commercial vehicle trips would be made, during the morning peak, within Greater Leicester.

(d) 5,250 "passenger car unit" commercial vehicle trips would be made, during the morning peak, into Inner Leicester.

(e) 730 "passenger car unit" through trips (external traffic) would be made, during the evening peak, through Greater Leicester.

(f) 26,500 "passenger car unit" local trips (external traffic) would be made, during the evening peak, into Greater Leicester.

Fig. 122 shows the assignment of future commercial vehicle trips and external traffic for the evening peak. It was decided to combine these two types of traffic as they are the life-blood of the city and cannot be the subject of a modal split. These flows are the *essential minimum* requirement which must be accommodated by the road network in any solution.

Fig. 123 indicates the assignment of future car driver trips for the evening peak.

In considering each separate link of the network of primary distributors the assignment consisted of the sum of the car driver trips and the above mentioned *essential minimum* (commercial vehicle trips plus external traffic) for either the morning or the evening peak, whichever was the greater.

Fig. 128 shows the total lane requirements for the Inner Motorway based upon the above assignment assuming 2,000 p.c.u's. per hour per lane.

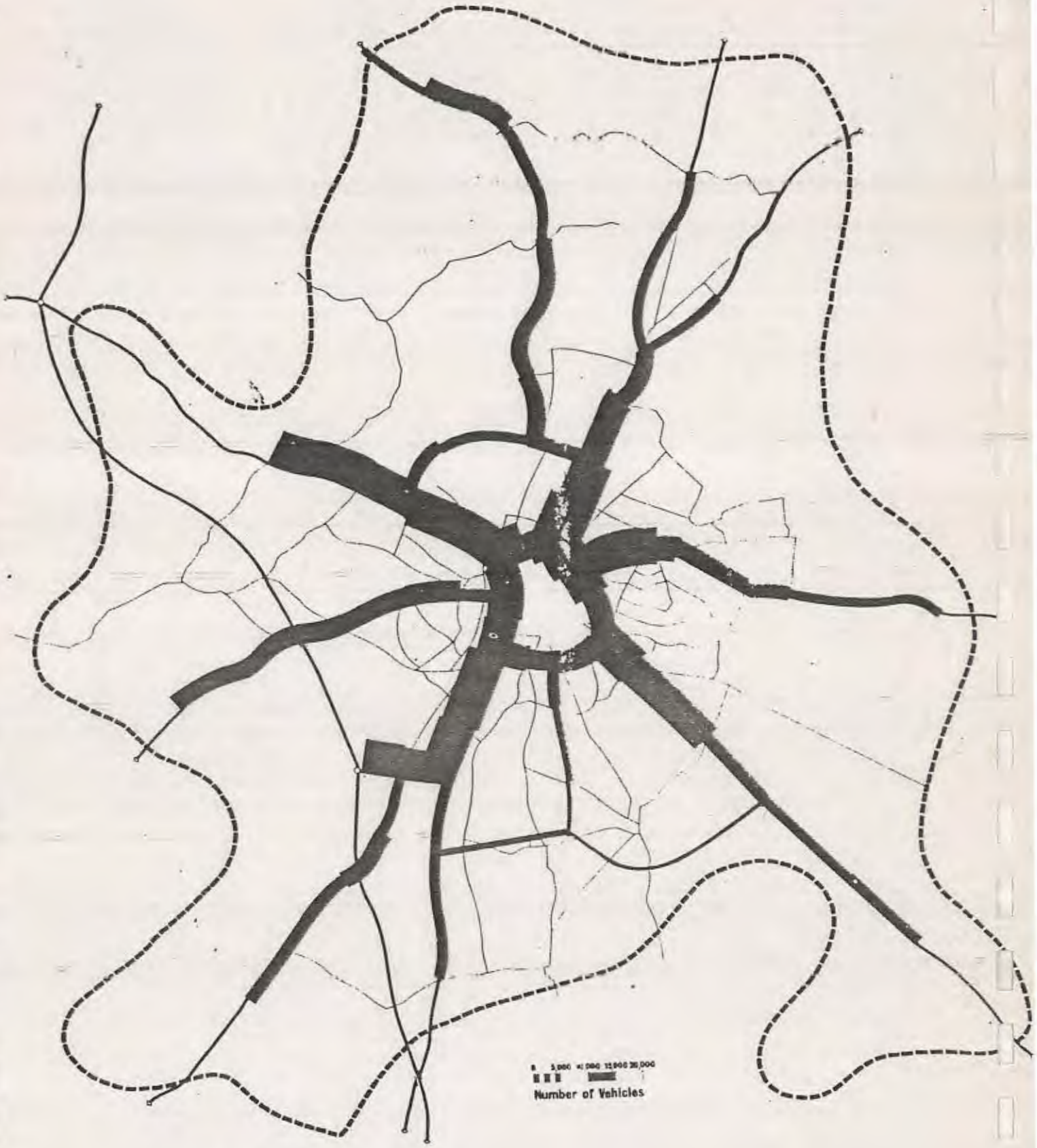
Fifteen lanes would be required on radial A46 north running parallel with Belgrave Road and sixteen lanes (the heaviest demand) on the south-western link. These are the largest requirements but it will be observed that the number of lanes on the remaining links would be only slightly smaller.

Design

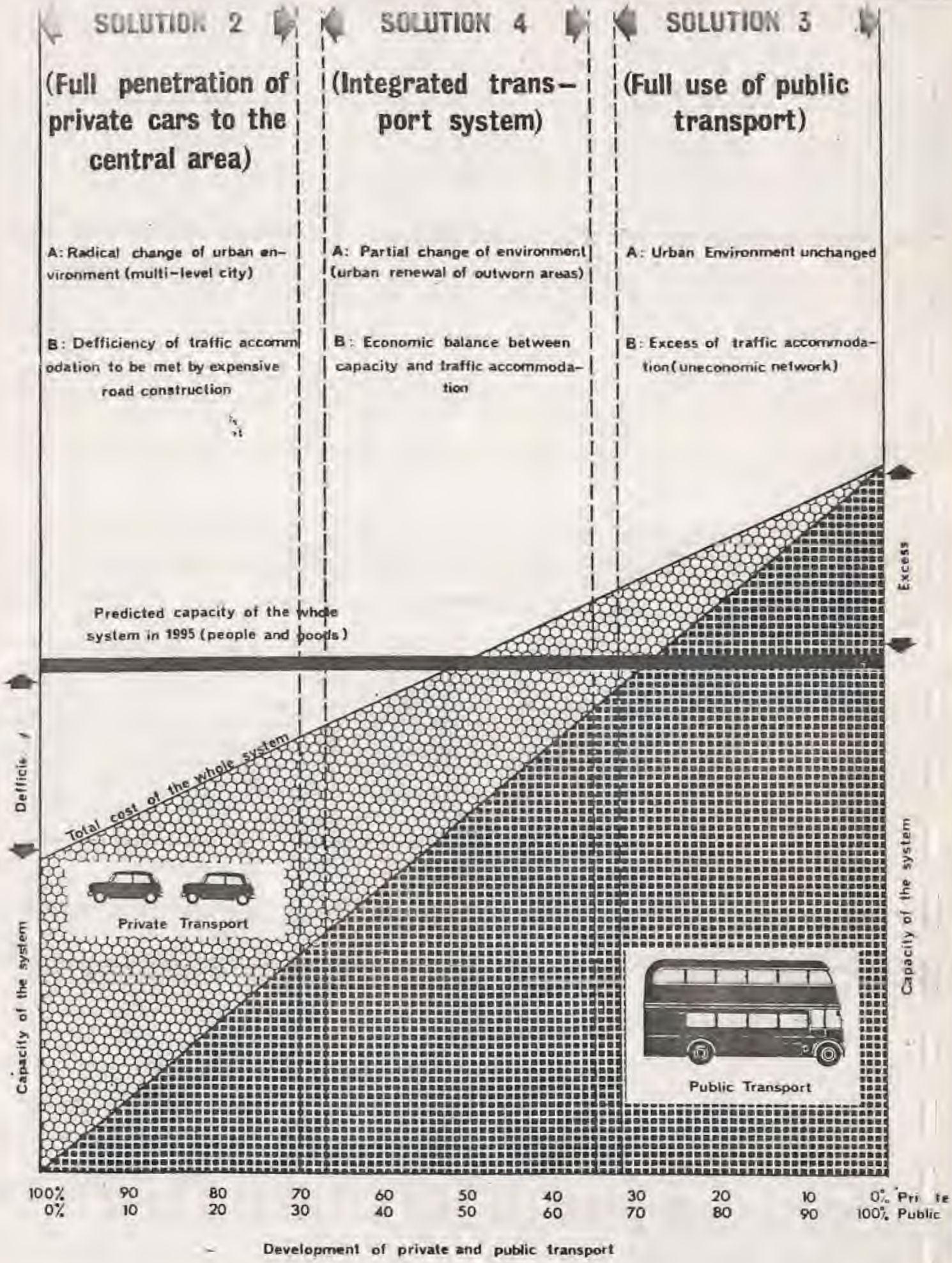
(a) Road links and intersections

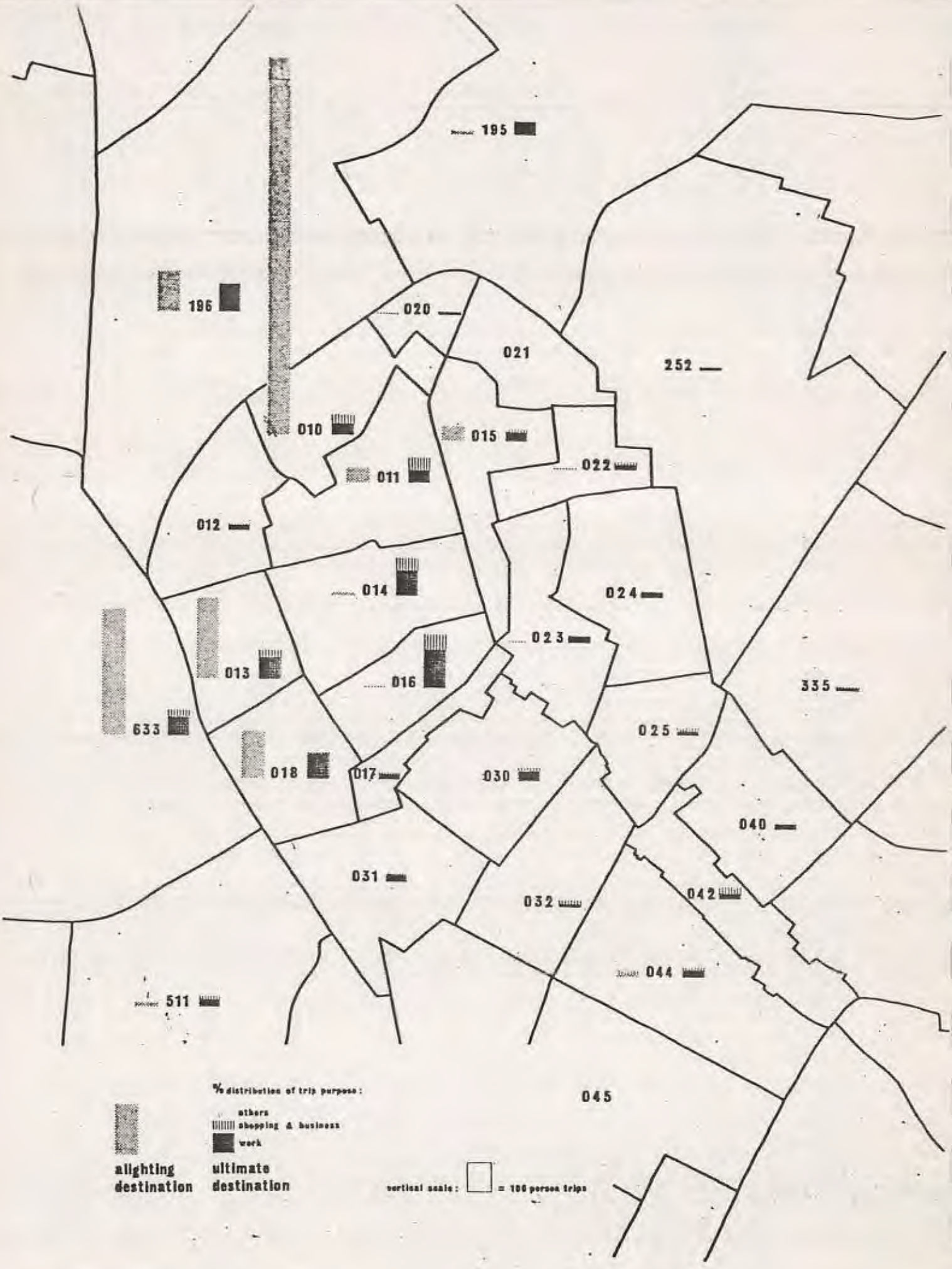
To accommodate the gigantic flows of traffic requiring up to sixteen lanes the orthodox solution of a dual carriageway road would not be acceptable, but it would be possible to construct the road links in tandem horizontally or vertically.

The adoption of a system of reversible tidal flows (change of direction) on certain lanes in order to accommodate the peak hour movement would bring only marginal benefit. In any event, investigation has shown that it would be possible to provide only one or two reversible lanes on each link as opposing flows are themselves relatively high.



122 Assignment of Commercial Vehicle trips and external traffic, evening peak, 1995.


SOLUTION 2
(Full penetration of private cars to the central area)
A: Radical change of urban environment (multi-level city)
B: Defficiency of traffic accommodation to be met by expensive road construction
SOLUTION 4
(Integrated transport system)
A: Partial change of environment (urban renewal of outworn areas)
B: Economic balance between capacity and traffic accommodation
SOLUTION 3
(Full use of public transport)
A: Urban Environment unchanged
B: Excess of traffic accommodation (uneconomic network)
Predicted capacity of the whole system in 1995 (people and goods)
Excess
Defficie
Capacity of the system
Total cost of the whole system
Private Transport
Public Transport
Capacity of the system
100% 0%
90 10
80 20
70 30
60 40
50 50
40 60
30 70
20 80
10 90
0% Pri te
100% Public
Development of private and public transport



101 Alighting and ultimate zones of 'bus passengers during 12-hour day.

Fig. 99 shows the distribution of 'bus passengers from external sources entering and leaving the Leicester Cordon area between 7 a.m. and 7 p.m. The proportion entering between 7.30 and 8.30 a.m. is 29% of the total, falling to insignificant levels throughout the day with a small peak at lunch-time and a pronounced flow of traffic between 4 and 4.30 p.m. attributed to shoppers and school children. Almost the entire reverse flow takes place between 3.30 and 7 p.m.

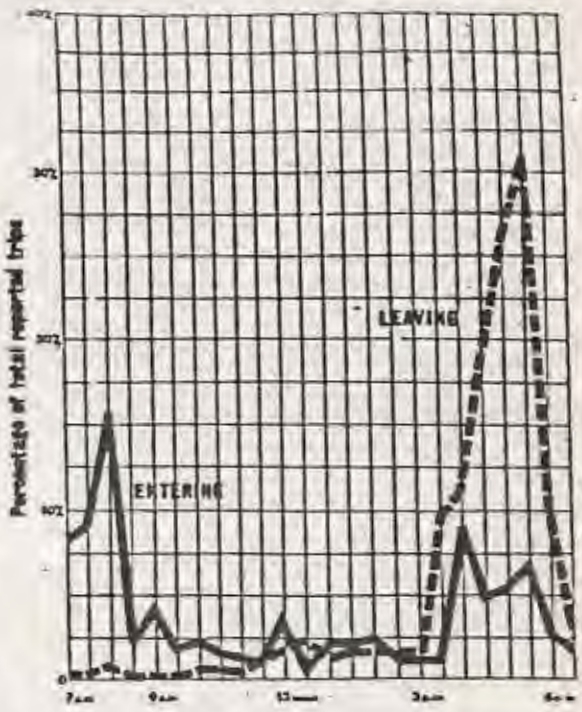
The total number of 'bus passengers entering the Leicester Cordon area between 7 a.m. and 7 p.m. is 4,600. Fig. 100 shows the distribution of 'bus passengers entering the Leicester Cordon area between 7 a.m. and 7 p.m. The width of the flow bands are proportional to the number of persons making trips. The "thick-hatched" line indicates the number of 'bus passengers with a destination in Inner Leicester and the "thin-hatched" line the number of passengers with a destination in other internal zones. The greatest concentration of flow is from Loughborough to traffic sector 1 and from Nuneaton and Hinckley to traffic sector 6. The predominant flows into Inner Leicester are from Loughborough and the Coalville area.

Fig. 101 shows the alighting zone and the ultimate zone of 'bus passengers with an origin outside the Leicester Cordon area, during the 12-hour day. About 850 'bus passengers travel into Inner Le ster during the morning peak. The predominant trip purposes are work and shopping.

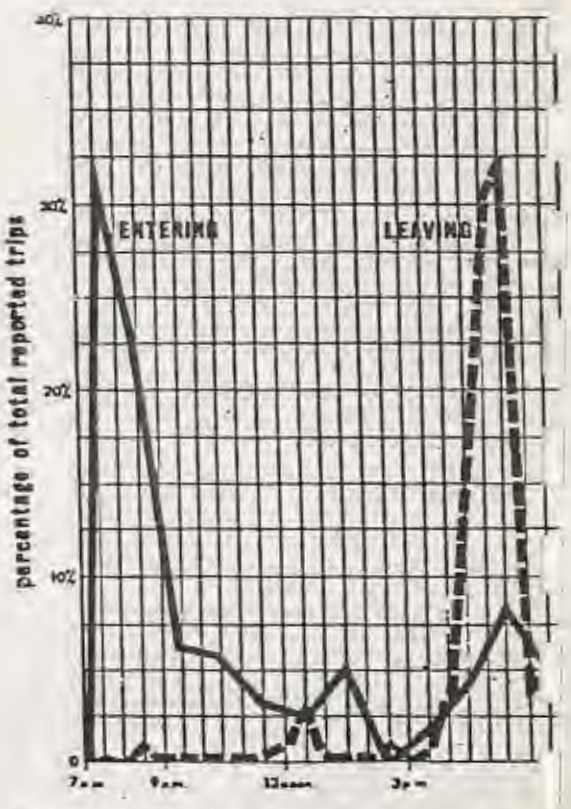
Fig. 102 shows the distribution of train passengers from external sources (the 18 railway stations considered in the survey) entering and leaving the Leicester Cordon area between 7 a.m. and 7 p.m. 1,100 passengers enter the Cordon area from the 18 stations. Fig. 102 shows that the predominant inward flow is in the morning peak from 7 to 9 a.m. and that the outward flow is almost entirely confined to the evening peak. 853 passengers enter the Leicester Cordon area by train between 8 and 9 a.m.

Fig. 103 shows the distribution of train passengers entering the Leicester Cordon area between 7 a.m. and 7 p.m. The flow bands are again proportional to the number of persons making trips. The majority of train passenger trips are to Inner Leicester. Predominant flows are from Melton Mowbray, Loughborough and Market Harborough, and to a less extent from Hinckley.

Fig. 104 shows the distribution by trip purpose of train passengers entering Inner Leicester between 7 a.m. and 7 p.m. The amount of sengers handled by the two stations, "London Road" and "The Central", is shown by the vertical columns. The ultimate destinations are spread uniformly throughout Inner Leicester. The predominant trip purposes are work and shopping.



99 Distribution of 'bus passengers entering and leaving the Leicester Cordon Area.



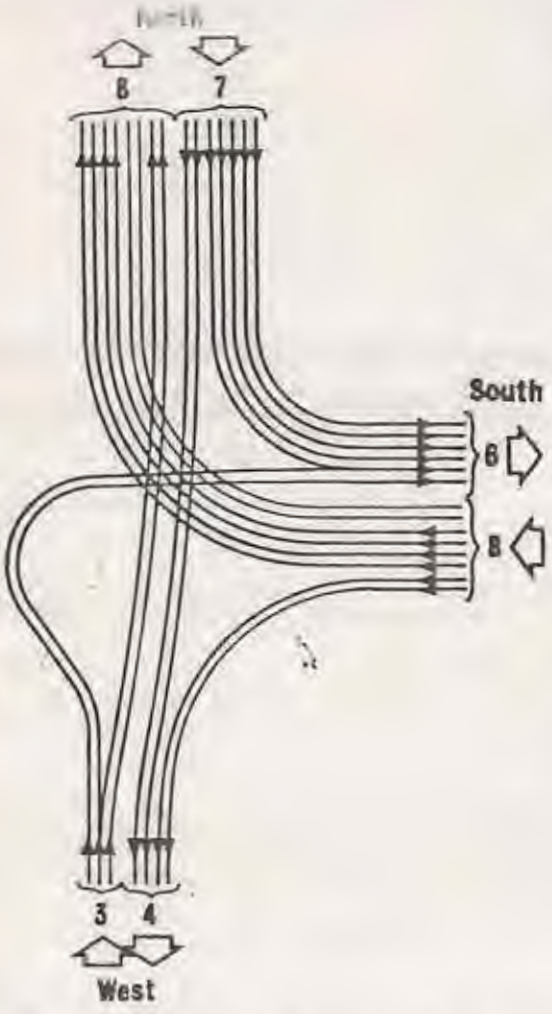
102 Distribution of train passengers entering and leaving the Leicester Cordon Area, 12-hour day.

12 Development Plan

The general planning policy and Development Plan proposals which are important in the preparation of the Traffic Plan, namely population, socio-economic structure and land use, are considered below. These predictions, together with vehicle ownership, enable trip generation estimates for 1995 to be made.

Population

Fig. 12 shows the population of the City and the Leicester Cordon area (Greater Leicester) from 1951 to 1963 and the projected populations for 1975, 1985 and 1995. It is estimated that the population of the Leicester Cordon area will increase to 640,000 in 1995. The estimates are based upon rates of growth for natural increase and



124 Full car penetration; requirement for turning lanes at the Belgrave Gate intersection. Reversible Lanes (red).

Volumes of traffic were [illegible] turning movements at intersections in the same manner as to the road links. With the considerable number of lanes required the intersections reached mammoth proportions.

Fig. 124 indicates the requirement for turning lanes at the Belgrave Gate intersection.

In order to demonstrate the implications of the First Solution a detailed design for a twin-intersection on the north-western corner of the Inner Motorway has been produced (Fig. 125). An area of 48½ acres of land, equivalent to that part of the central area comprising the Market Square and the Town Hall Square with environs (see Fig. 12), would be required to accommodate this intersection, one of many.

The Inner Motorway, in order to perform its function, would have to consist of a series of vast multi-level intersections connected by very short links.

This network of primary distributors would have to be supplemented by a network of secondary distributors of formidable dimensions, requiring in turn a considerable number of two-level intersections.

The cost of the Inner Motorway, including construction and acquisition of land, would be in the order of £115 million.

The cost of the Main Radials of urban motorway standard within the City alone, including construction and acquisition of land, would be in the order of £125 million.

The overall cost of the complete road network, including secondary distributors, for full penetration of the private car – which without producing a detailed design would be unrealistic to forecast – would require the expenditure of astronomical sums of money.

(b) Parking and circulation within the Central Area

The predicted peak accumulation of parking for 67,000 private cars is shown in Fig. 109.

It would be possible to produce several different design solutions for the accommodation of stationary vehicles in great numbers, ranging from complexes of multi-level garages to a solution whereby the parked vehicle is stacked on gigantic *"shelves"* in a ring around the business and commercial core of the city.

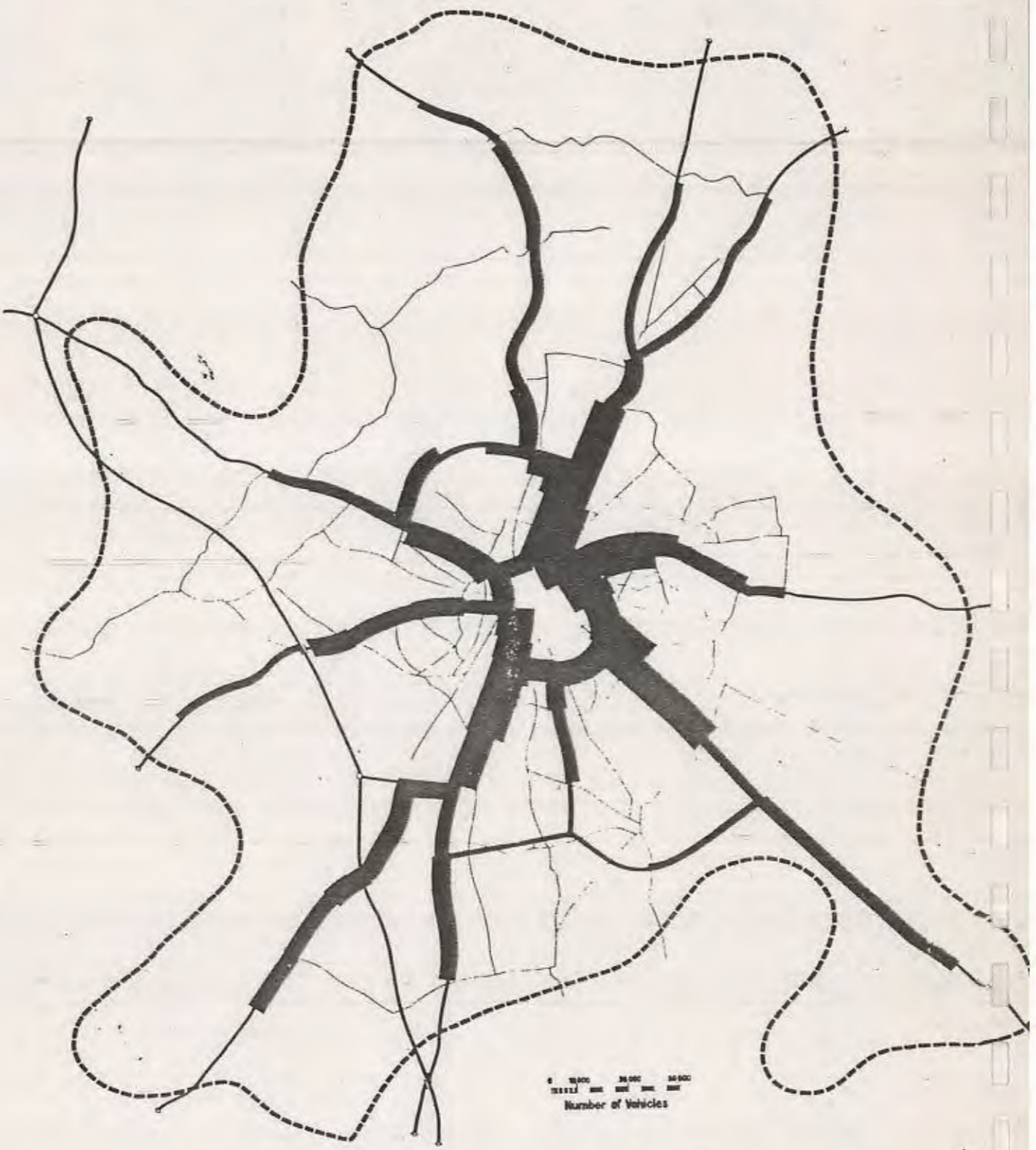
Fig. 121 shows in outline the elevated Inner Motorway embracing Inner Leicester with terminal parking complexes around the shopping core.

It is assumed that this core would be treated almost as a pedestrian precinct allowing only for the full penetration of commercial vehicles along specially designed service loop roads. The suggested parking complexes are composed of groups of interconnected multi-storey garages built over a podium of two-level development of central area uses.

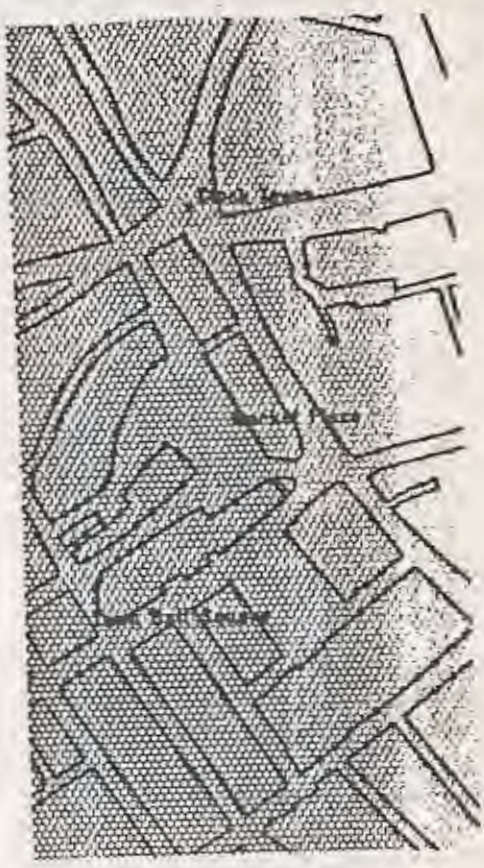
The circulation system serving these parking complexes would have to be designed at first or second floor level, as it should be completely divorced from the service network to the commercial and other central area uses at ground level. These elevated roads would link the garage complexes, by means of terminal tentacles or loops, directly with the primary network.

At least 52 lanes would have to be provided for these garage service roads to accommodate the flows of cars arriving during the morning peak and 68 lanes to accommodate the discharge during the evening peak.

The land required for the provision of the terminal parking complexes would be 133 acres and the total floor space devoted to parking in the order of 340 acres. The enterprise would demand comprehensive redevelopment of areas around the shopping core on an enormous scale and would result in a revolutionary transformation of the existing urban structure. The present planning and administrative machinery is not geared to cope with such a task.



123 Assignment of car driver trips, evening peak, full car penetration, 1995.



Equivalent Area of the City Centre

Full Car Penetration; Twin Intersection of the Primary Distributor

1000 Feet

The city centre would then consist of the shopping core surrounded by gigantic *"car stacks"* – monuments to the private car – and these in turn would be surrounded by an intricate pattern of access and discharge ramps.

Parking garages for the private car – a thing of personal convenience, which for most of the day would be lying idle on a fantastically expensive "shelf" – would be the dominant buildings, *the motor age cathedrals*, in this Leicester of the Private Car.

The cost, including construction and acquisition of land, of the parking complexes would be in the order of £50 million, and of the necessary circulation a further £110 million.

General Conclusion

This solution to the Leicester Traffic problem, whereby uninhibited penetration of the private car into the central area is allowed, although technically possible must, from the cost aspect alone, remain an academic exercise on paper.

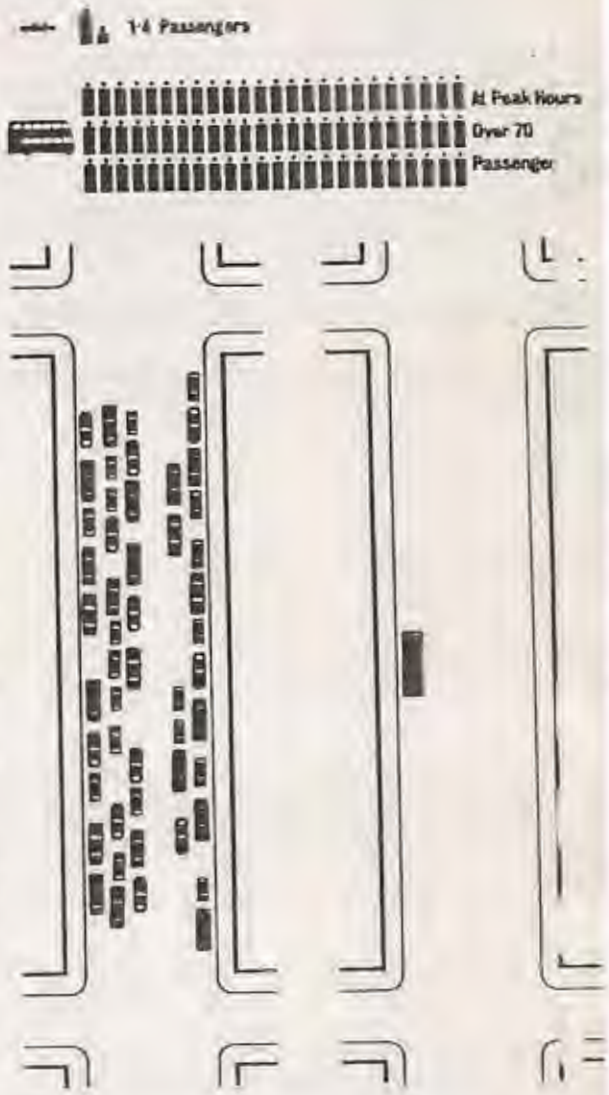
The total cost of the Primary Distributors (Inner Motorway and N , Radials of urban motorway standard within the City) and the Terminal Parking Complexes (including access roads and ramps) would be in the order of £400 million. To this would have to be added the cost of a system of Secondary Distributors only relatively less massive and expensive.

It is doubtful whether this solution would be acceptable on social as well as environmental grounds.

The private motorist in Leicester must realize that, in the light of an objective and unbiased analysis of the situation, the use of the car in the central area will become more and more difficult, the extension of administrative restrictions unavoidable and finally, in about the 30-year period, the almost complete prohibition of entry into the central area an economic and social necessity.

The motor car, occupying about 150 square feet of precious urban space and carrying an average of 1·4 occupants (but frequently only one with a big cigar), is the clumsiest and the most uneconomic form of urban transport (Fig. 124a). *This is the dilemma: the city centre or the motor car.*

Another solution must, therefore, be found.



124a Comparison of road space requirement for the private car and a 'bus.

4 The Second and Recommended Solution: Integrated Transport System

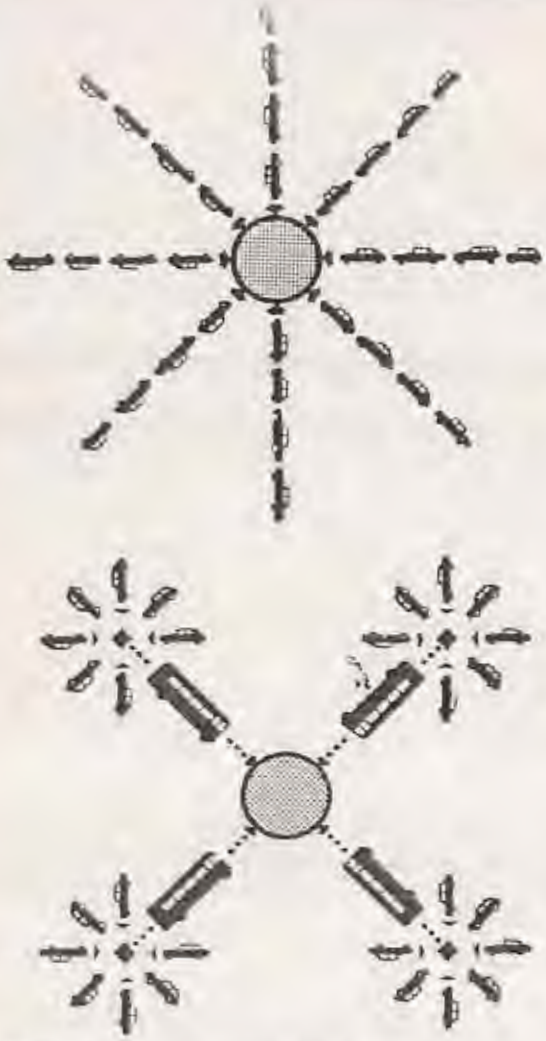
A practical solution to the Leicester Traffic Problem should fulfill the following conditions:—

1. The new Transport System must allow for the healthy growth of the city within the limits outlined at the beginning of Chapter I.
2. The historic values and local identity of the city must be preserved. The process of development should take the form of gradual evolution and replacement of outworn areas rather than revolutionary transformation of the urban structure.
3. The maximum level of circulation at the minimum cost should be aimed at.
4. The conditions of life created by the new system should make living easier, more comfortable and more attractive. The basic needs of the motorized society with the continuously growing standard of living must be fulfilled.
5. The cost of the new system must be within the financial possibility of the city aided by Government grants.
6. The scheme must be capable of realization under the present central and local government organization.

It would be wrong to expect a *simple solution* to a *complicated problem*. Equally it would be wrong to rely on *one* single factor when probably a *set* of factors combined in a consistent policy would provide an answer.

Opposite:

125 Full car penetration; design for a twin-intersection on the Inner Motorway at western approach.



127 Comparison between the system with uninhibited use of the private car (above) and the system with Interchange Car Parks.

The success of the proposed Transport System is dependent on a balanced interplay of several elements of which the basic ones are:—

(a) Interchange Car Parks.
(b) Public Transport.
(c) High capacity Road Network.

The same network of primary distributors as in the first solution has been accepted but an attempt made to reduce the traffic flows to a manageable size.

Interchange Car Parks

It is proposed to establish along the radial routes a series of interchange car parks of the type shown in Fig. 119.

The function of these car parks is to collect the cars travelling on the radials towards the city centre and from the surrounding district in order that the car drivers and passengers might be conveyed to the city centre by means of public transport.

The effect of these interchange car parks on traffic flows is shown in Fig. 126. The flows are reduced towards the city centre and would therefore require a considerably smaller number of lanes both on the radials and on the Inner Motorway.

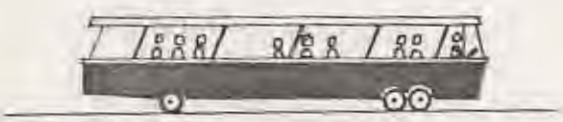
The diagrams in Fig. 127 explain the difference between this system and the system providing for uninhibited concentration of private cars upon the city centre.

Interchange car parks would create new magnets for traffic, thus relieving the pressure on the central area, and should be linked whenever possible with suburban shopping, entertainment and sports centres.

There is little doubt that these new urban nuclei provided with vast parking accommodation (cheap or even free of charge), would be attractive to the private motorist.

Primary Network

The primary network would carry the *essential minimum* (total commercial vehicle trips and total external traffic) and the total car driver trips, reduced by the number intercepted by the interchange car parks. The lane requirements for the Inner Motorway (see Fig. 128) vary from four to six lanes for the various links. They should be compared with the lane requirements for unlimited use of the private car. The road links and intersections of the Inner Motorway can be designed to the minimum dimensions and be compatible with the scale of the city.



EXPRESS SERVICE

INTER DISTRICT SERVICE

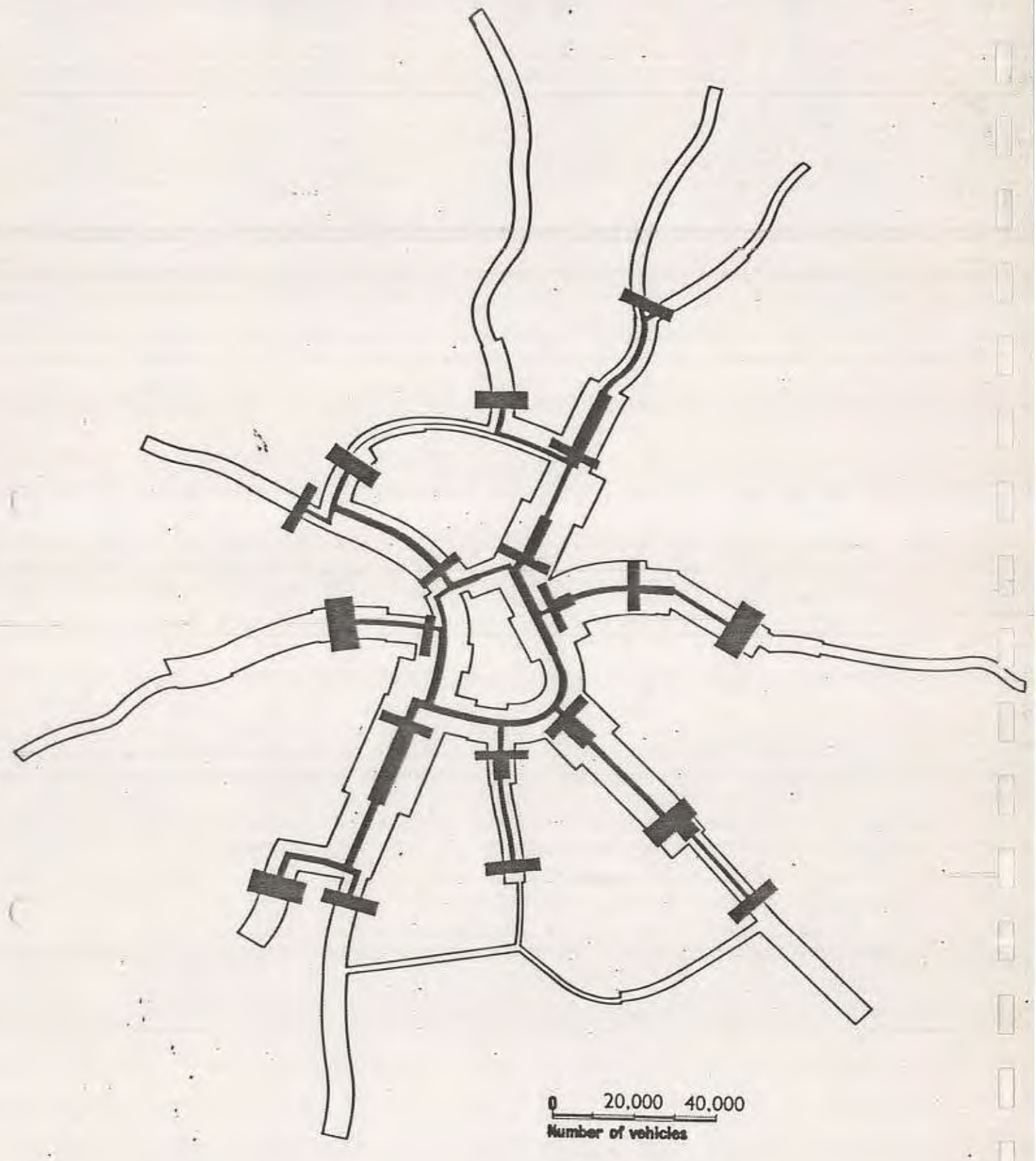
CITY CENTRE SERVICE

132 Suggested types of vehicles for 'bus services.

Public Transport

In the realization that the central area with its heritage from the historic past could not be planned for the private car a search had to be made for alternative forms of urban transport whereby great numbers of people could be conveyed quickly and comfortably to all parts of the central area. It was felt that for a city of the size of Leicester the following forms of public transport could be considered:—

(a) The traditional *'bus*, but in a new, revitalized form, as the chief means of public transport.
(b) The *Monorail*, an express service with limited numbers of stops, linking the concentrations of residential population with the city centre.
(c) *Taxis.*
(d) *Pedestrian conveyors*, along the routes of the greatest concentration of pedestrian movement, either in the form of pedestrian bridges or in the form of elevated, continuous walkways down the centre of main shopping streets.



126 Total predicted flows to Inner Leicester, 1995, and the effect of Interchange Car Parks

Code List 1(d)

CITY OF LEICESTER COMPREHENSIVE TRAFFIC SURVEY 1963
WELL KNOWN PLACES OR PUBLIC BUILDINGS

196	Abbey Park
017	Adult Education Centre, Belvoir Street
642	A.E.I. – Braunstone
177	A.E.I. – Melton Road
013	Alderman Newton's Boys' School
637	Alderman Newton's Girls' School
023	Automobile Association, Charles Street
015	Auto-Magic Car Wash
011	Bell Hotel
732	Beaumont Leys Sewage Farm

continued

Home Interview Questionnaire and Procedure

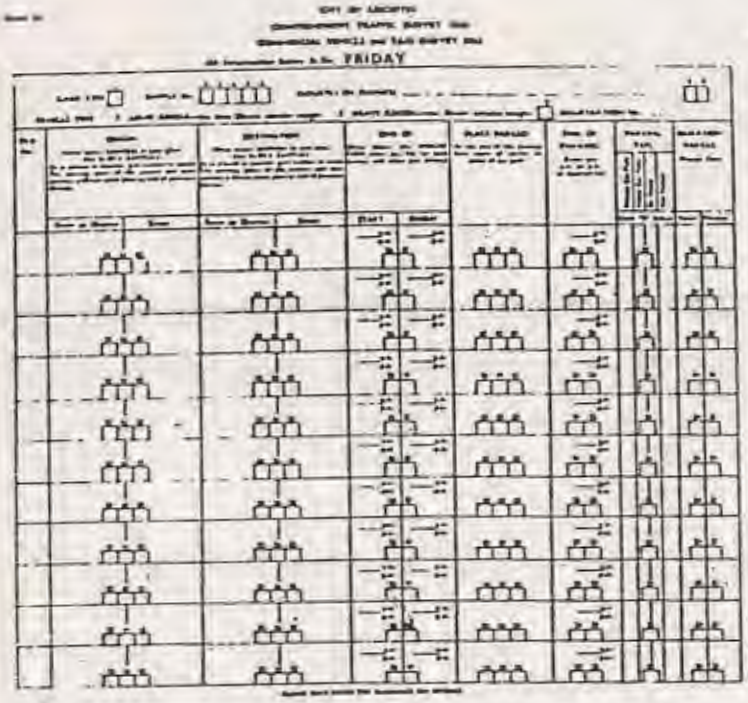
The two basic home questionnaire forms, Form 14 and Form 15, were identical insofar as travel information was concerned, but Form 14 was intended only for completion by the head of household and Form 15 by every other member of the household three years of age and over. Form 14 contained, in addition to travel information, information concerning the household as a whole.

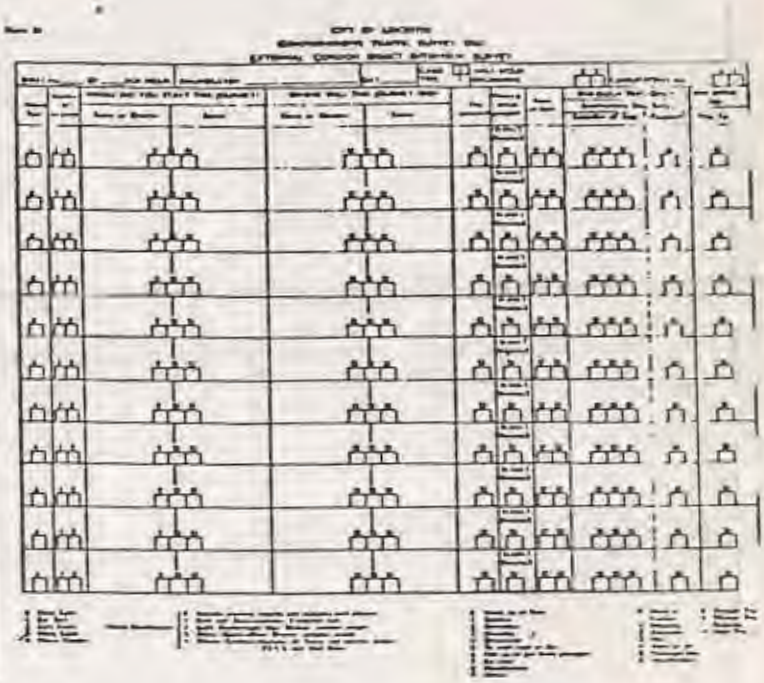
To avoid confusion, Form 14 was printed on dark yellow paper and Form 15 on light yellow paper. At this stage it is intended to give only a broad description of home interview procedure; information as to completion and coding of the information will be given later. There is a separate horizontal column for each journey made. In the first vertical column, headed "Where did this journey begin?" is entered the exact location of the commencement of the journey. The second column, headed "Where did this journey end?" contains details of the destination of the journey. In the third column, headed "When?", are given the times of the start and finish of each journey. In the fourth column, headed "How did you travel?", is entered the mode of each journey. In the fifth vertical column, headed "Purpose of journey", is entered the reason for each journey.

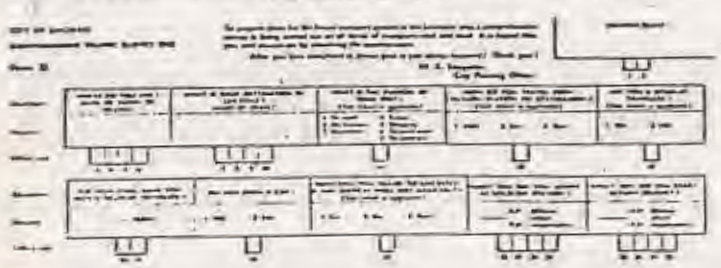
The last section is only completed if a person drove a vehicle on all or part of his journey. Here he must give details of where the vehicle was parked, the type of parking, the time of parking, the duration of parking and how many passengers. On the reverse side of the form, the questions to be answered are: "How many people at this house?" and "How many private cars were owned by people at this house one year ago and five years ago?".

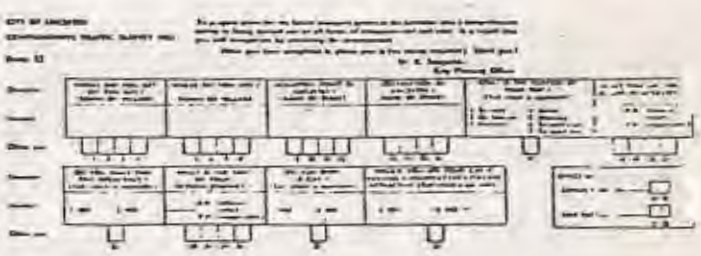
Procedure for distribution, completion and collection of questionnaire forms is described below. An introductory letter was sent to each selected sample warning them that they had been selected and that an interviewer would call upon them in the course of the next few days. No specific date was given, thus avoiding the risk of any possible intentional absence from the home by the householders concerned. The home interviewer called at each household selected and left one copy of Form 14 for the head of the household and a copy of Form 15 for each member of the household aged three years and over, explaining to the person interviewed how each form should be completed. The interviewer completed the "FOR OFFICIAL USE" column at the head of the form, with the zone number, sample number (from 1 to 14,334), person identification and industry and occupation; the number living at the house and cars owned were entered on the reverse side. The interviewer then arranged a date and time for collection of the completed forms after the day for which travel information was required.

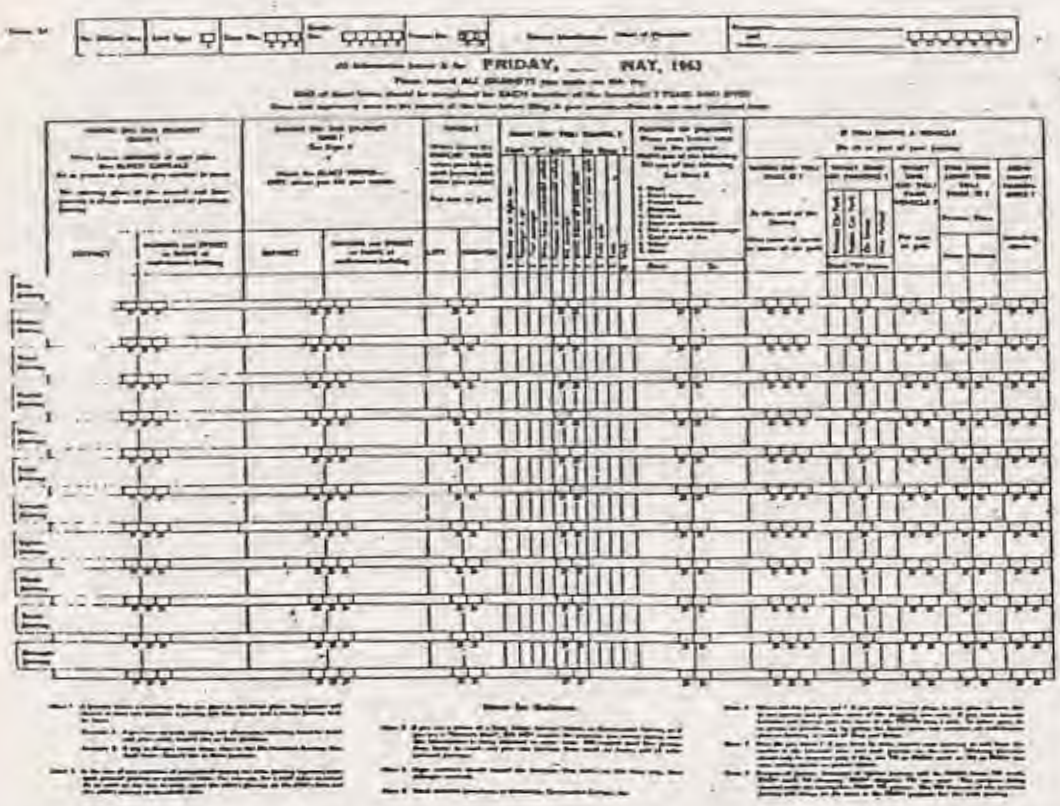
During the process of sampling, the number and address of each sample had been copied on to Form 1 and typed on to the introductory letter. From Form 1, Form 3 (field sheet to be used by household interviewer) was completed. Form 3 gave the sample number, the number of the house, the street or road name, the date upon which the questionnaire forms were issued to that particular sample, the

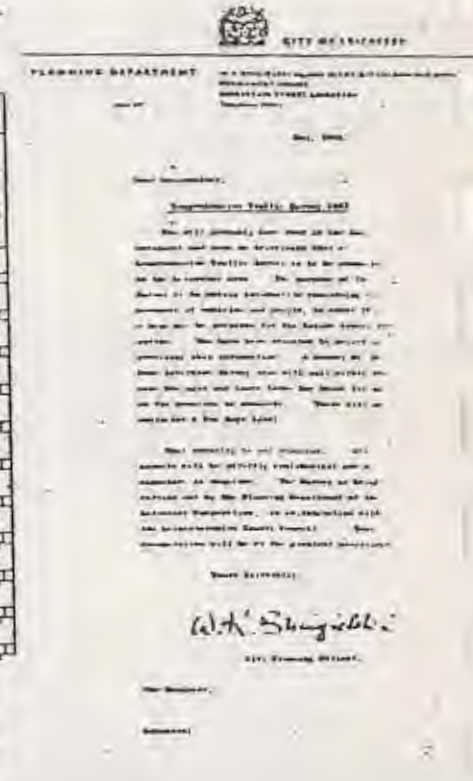












A.2 Forms 10, 11, 12, 13 and 14.

characteristics of car driver trips is t
high proportion of trips made from work to home before lunch a
from home to work after lunch. In fact, the pre-lunch peak is nearly
great as the morning peak. The number of car driver trips ass iat
with the purpose "pick up and set down passenger", parti ilar
during the morning and evening peaks, illustrates the increasi
tendency for one member of the family to drive another men er
work and then use the car for other purposes during the da Tl
greatest number of shopping car driver trips are made during t
mid-morning and mid-afternoon periods.

Table 7: Distribution of Trips, by Purpose

8–9 a.m.		5–6 p.m.		5–6 p.m.	
PURPOSE "TO"	%	PURPOSE "FROM"	%	PURPOSE "TO"	%
Work	61·7	Work	77·2	Home	78·6
School	22·9	School	1·2	Work	3·9
Firm's Business	2·8	Firm's Business	2·3	Firm's Business	1·2
Personal Business	2·8	Personal Business	4·4	Personal Business	1·2
Shopping	1·4	Shopping	8·3	Shopping	3·2
Social or Recreational	0·5	Social or Recreational	2·3	Have Meal	0·3
Pick up or Set down Passenger	2·2	Pick up or set down Passenger	1·2	Social or Recreational	·3
Catch Train or Bus	3·6	Catch Train or Bus	3·1	Pick up or set down Passenger	·0
Home	2·1			Catch Train or Bus	4·2
				School	·1
ALL PURPOSES	100%	ALL PURPOSES	100%	ALL PURPOSES	100%

Table 7 indicates the distribution of trips, by purpose "to an "from", morning and evening peaks. During the morning pea th trips from home to work account for 61·7% of all trips made and trip to school for 22·9%. During the evening peak the trips from /or account for 77·2% of all trips and trips to home for 78·6%.

Table 8: Distribution of Trips, by Purpose, Crossing and Non-cro sin Screenline

PURPOSE "TO", MORNING PEAK			
NON-CROSSING SCREENLINE		CROSSING SCREENLINE	
PURPOSE	%	PURPOSE	
Work	53·77	Work	73 0
Firm's Business	7·58	Firm's Business	8·67
Personal Business	5·74	Personal Business	4 ·0
Shopping	1·10	Shopping	0 7
Have Meal	0·00	Have Meal	0·00
Social or Recreational Pick up or set down Passenger	0·96	Social or Recreational Pick up or set down Passenger	0·23
	12·45		8 1
Catch Train or Bus	1·06	Catch Train or Bus	0·63
School	8·82	School	2·07
Home	8·52	Home	3 2
ALL PURPOSES	100%	ALL PURPOSES	10 %

PURPOSE "FROM", EVENING PEAK			
NON-CROSSING SCREENLINE		CROSSING SCREENLINE	
PURPOSE	%	PURPOSE	
Work	63·40	Work	78·02
Firm's Business	3·42	Firm's Business	6 1
Personal Business	10·23	Personal Business	5 2
Shopping	10·29	Shopping	2·45
Have Meal	0·16	Have Meal	0·00
Social or Recreational	3·41	Social or Recreational	2 0

continu

Opposite:

A.7 Above: Distribution of all "Person/Modes" crossing Screenline, 7.00 a.m. – 7.00 p.m.

Below: Distribution of 'Bus Passengers crossing Screenline, 7.00 a.m. – 7.00 p.m.

CURRICULUM VITA

Name : Samir El-Hosaini

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Nationality : Egyptian

Languages : Arabic, English

Professional Education :

1961 B.Sc. Hons. Civil Engineering Alexandria University .

1966 Ph.D. Traffic and Transportation ; Univ. of Liverpool, England .

Present Position :

Professor of Traffic, Transportation and Road Design, Department of Civil Engineering, Al-Azhar University Cairo.

Professional Experience:

1966 - 1967 Senior City Planning Officer of Traffic and Transportation, Traffic and Trans. Sections Liverpool City Planning Dept. Liverpool Corporation, England. Design One way system in Liverpool, Transportation of goods to the main Shopping Center, Design of Ring Roads .

1967 - 1968 Senior Engineer in Ministry of Transport Cairo .

1968 - 1971 Lecturer of Traffic, Transportation and Road Design Dept. of Civil Eng. Al-Azhar University, Cairo .

1969 Conducted and Directed "Automatic Traffic Control in Ramses Str. " , Cairo .

1971 Conducted and Directed " Study and Planning of Parking in Cairo City Center"

1971 - 1973 Visiting Lecturer of Traffic, Transportation and Road Design, Dept. of Civil Eng., The City University London .

1974 - 1979 Associate Professor of Traffic Transportation and Road Design, Dept. of Civil Engineering, Al-Azhar University, Cairo.

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1972 - 1973 - Evaluation and Study of Environment in Oxford Street Project , London .

1974 - Conducted and Directed " Planning and Design of Galaa Square in Cairo for Today ".

- Conducted and Directed "Planning and Design of Galaa Square in Cairo for 1990 ".

1975 - Planning and Design of Grade separated intersection on Cairo outer ring road a Ismailia Canal for Year 2000 .

1976 - Planning and Design of Traffic Guide signs for the entrances and main routes of Cairo, Automobile Club , Cairo .

-"Preliminary Report of Traffic Signs standards in Egypt", Conference of traffi signs, Ministry of Interior, Cairo .

1976 - 1978 - Head of Transportation and Roads Section with COPA-EGYPT , WEIDLEPLAN-GERMANY Consulting Group for the Planning and the Final Design of the First New Residential City of Helwan (15th of May City) to accommodate 200,000 inhabitants with all the necessary services, Ministry of Housing and Reconstruction Cairo, Egypt .

1977 - Consultant with SIR WILLIAM HALCROW & PARTNERS-ENGLAND and PROF. AZIZ YASSIN Consulting Group for the Ismailia Demonstration Project, Egypt .

- Parking Study of Cairo Hotel Tahrir Square, Governorate of Cairo .

1977 - 1978 - Head of Transportation and Roads Section with COPA-EGYPT and SWECO-SWEDEN Consulting Group for the Final Planning of th First Stage of the New Industrial City (TENTH OF RAMADAN CITY) to accomodate 500 000 inhabitants with all the necess r services, Ministry of Housing and Recor - truction, Cairo , Egypt .

../... 3

1977 - 1979 — Consultant with GACDAR Consulting Group for the Planning and Development of the Holy City of Medina, Ministry of Municipal and Rural Affairs, Kingdom of Saudi-Arabia .

1978

- Traffic Circulation on Nile Bridges and their surroundings outside the CBD of Cairo, Governorate of Cairo , Egypt .
- Parking Study of Cairo Plaza Multi-Purpose Complex, Boulaq, Cairo .
- Replanning of Ramses Square, Abdel-Monem Riad Square and Galaa-Ramsis Axis to accommodate traffic using 6th of October bridge and Galaa Overpass, Governorate of Cairo, Egypt .

Publications :

a- Books
- "Traffic Engineering", 1975
- "Transportation Planning", 1970

b- Reports
- Highway Engineering
- Railway Engineering
- Transportation Engineering
- Airport Engineering
- Transportation problems in urban areas .
- Transportation of materials in industrial centers .
- Transportation of liquids
- Harbour Engineering

c- Public Lectures
- Egyptian Society of Engineers April 1977 .
- Automobile Club, 1977, Cairo .
- Central Traffic Police Headquarters, Ministry of Interior, 1975 - 1978.
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d- Papers

1-"An Automatic Method to collect and Analyse Traffic Congestion Data The Journal of the Engineers Syndicate June 1970 (Ph.D.Paper).

2-"An Electronic System of Traffic Analysis, Armed Forces Scientific Research Bulletin, Vol.VII No.14, 1971. (Ph.D.Paper) .

3-"A Simplified Egyptian Method for Pavement Design, Science Conference, Supreme Council of Sciences, Damascus University, Dec. 1971 .

4-"Noise - Design and Consideration . Discussion The Journal of the Institution of Highway Engineers Dec. 1972 .

5-"Determination of CBR Value from Soil Properties, Armed Forces Scientific Research Bulletin, Vol. VII No. 16, 1972 .

6-"Measurement and Control of Noise Impact on New Roads, Discussion , The Journal of the Institution of Highway Engineers, June 1973 .

7-"Transport Behaviour at High Densities, Transportation Research , Vol. 7, 1973 .

8-"An Approach to an Assessment of the Effects of Policies Relating to Traffic Management Schemes and Land Use Plans in Urban Areas, with Parcticular Reference to "Environmental Areas", Symposium on the environment and transport technoclogy, Laughborough University of Technoclogy, September 1973.

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9-"Traffic Operations and Management in Cairo", Conference on Traffic Problems in Cairo and major Cities of Egypt, Academy of Scientific Research, 1-3 June 1974 .

10-"Design and Safety Aspects for Layout of Low-Cost Roads in Rural Areas", Low-Cost Roads Conference in Kuwait , November 1974 .

11-"Traffic Signs Needs on Urban and Rural Roads in Egypt", Conference, Roads and Bridges Authority, Ministry of Transport, June 1975 .

12-"Design of Bilingual (Arabic/English) Traffic Signs in Egypt", International Road Federation (IRF) Highway Conference, Abidjan, Ivory Coast, October 1976 .

13-"The Urban Road Design for the First Residential City for Workers at Helwan Egypt", IRF Regional Conference for the Middle East and North Africa, Cairo April 1978 .

14-"Environmental Levels of Service for Road Planning and Traffic Management", IRF Regional Conference for the Middle East and North Africa, Cairo, April 1978 .

15-"Transport Phenomena in Cairo", IRF Regional Conference for the Middle East and North Africa, Cairo, April 1978 .

16-"Traffic Accident Patterns in Egypt", IRF Regional Conference for the Middle East and North Africa, Cairo, April 1978 .

17-"A Traffic Model for the Assessment of Noise Capacity Restraint", Egyptian Society of Engineers Vol. XVII, No.2, 1978 .

18-"A Traffic Model for the Assessment of Visual Intrusion Capacity Restraint" Egyptian Society of Engineers Vol. XVII, No.4, 1978 .

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19-"Parking Study in the City Centre of Cairo", Arab Road Association, Cairo Egypt .

20-"A Traffic Model for the Assessment of Pollution Capacity Restraint", Military Technical College (accepted for Publication and under print).

21-"An Approach for Formulting and Developing A Model for Environmental Capacity", Military Technical College (accepted for publication and under print).

Scientific Activities:

- Institution of Highway Engineers, London
- Institute of Transportation Engineers, America
- Society of Egyptian Engineers, Cairo
- Arab Road Association

Appointments :

- Traffic Supreme Council, Ministry of Interior , Cairo .
- Transportation Research Council, Academy of Scientific Research, Cairo .
- Board of Cairo Public Transport, Governorate of Cairo .
- Committee of Area Traffic Control in Greater Cairo, Ministry of Transport .
- Board of Society of Egyptian Engineers.
- Committee of Greater Cairo Public Transport .
- Scientific Consultant of Arab Road Association .
- Senior Research Investigator, Project, Determination of Equivalent Car Units for different Traffic Composition on Road networks, Academy of Scientific Research , Cairo .

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- Cheif of Technical Report Committee IRF Regional Conference , Cairo, April 1978 .

- Resolutions Committee , IRF Regional Conference, Cairo, April 1978 .

- Evaluation Committee for National Transport Study in Egypt, Transport Planning Authority (TPA), Ministry of Transport , Cairo .

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CAIRO 28/11/1978

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